Rice Introduction and Improvement in South Asia

Gurdev S Khush[1]* and DS Brar[2]
[1] Former Principal Plant Breeder, International Rice Research Institute, Manila, Philippines
[2] Plant Breeder, International Rice Research Institute, Manila, Philippines

Rice is the most important food crop and source of calories for four billion Asians. International Rice Research Institute was established in the Philippines in 1960 to address the problems of stagnant rice yield. Rice germplasm was collected from South Asian and other countries through collaborative efforts. This germplasm has been conserved in rice gene bank at IRRI. National Rice Improvement Programmes have also established their own gene banks for conserving the germplasm. Collected germplasm has been evaluated for various morphological and physiological traits, grain quality characteristics and biotic and abiotic stresses. On the basis of this evaluation, donors for rice improvement have been identified and utilized for developing improved rice varieties. These varieties have high yield potential, good grain quality, shorter growth duration, resistance to diseases and insects and tolerance to abiotic stresses. Improved germplasm has been shared with all the rice growing countries and has been widely adapted. As a result, major increases in rice production have occurred. Average yield of rice has almost doubled from 2.1 to 3.9 tons per hectare. The cost of rice production is 20-23 % lower with high yielding varieties and the price of rice is 40-50 % lower in the domestic as well as in the international markets. This is highly beneficial for the poor people who spend 50-60 % of their earnings on food.

Key words: Rice germplasm, Collection, Conservation, Evaluation, Enhancement

Rice is the single most important food crop and a primary food source for half of the world population. About 90% of the rice is grown and consumed in Asia. It provides 35-75% of the calories consumed by 4 billion Asians. There were widespread concerns about the impending food crisis in Asia during 1960s. Rice yields were stagnant and population growth rates were accelerating, owing to declining mortality rates resulting from advancements in modern medicine and health care. International Rice Research Institute (IRRI) was established in 1960 by Rockefeller and Ford Foundations in cooperation with the Government of the Philippines, to apply science to the problems of rice production. Germplasm conservation, evaluation and utilization received top priority since the beginning of institute's research programmes.

Germplasm Collection and Conservation

The need for access to diverse sources of rice germplasm was recognised by IRRI. By systematically contacting national and international agencies in major rice-producing countries, a rice germplasm bank was established at IRRI in 1961. Rice researchers in Asia and officials of U.S. Department of Agriculture (USDA) and Food and Agriculture Organization (FAO) gave enthusiastic support. By the end of 1962, the IRRI varietal collections contained 6,867 accessions from 73 countries. By 1972, the collections increased to 14,600 accessions (Chang, 1972).

In 1970 international conferences on rice germplasm collections were held at IRRI and at Hyderabad, India and led to the start of International Rice Collection and Evaluation Project (IRCEP). The outcome of these conferences was the agreement to coordinate and strengthen national efforts on field collection, evaluation and preservation systematically at an international level. The conference at the Hyderabad meeting recommended:

- Field collections in Myanmar, Cambodia, Sri Lanka, remote areas of India, Indonesia, (especially Kalimantan), East Malaysia, Laos, Vietnam, Nepal and adjacent areas, Pakistan, remote areas of the Philippines and mountainous parts of Thailand.
- Selection of sites and materials for collection on the basis of present availability, genetic diversity and future needs.
- Development of systematic plans for successive stages of testing and evaluation on a national scale and on internationally coordinated basis.
- Provision of medium term seed storage facilities at national centers.
- Storage of duplicate sets of collected materials in international centers to provide maximum security while initial testing underway at the national centers.
- Coordination of field collections, testing operations, pooling and allotting of available funds and exchange of seed and information, guided by a technical

* E-mail: gurdev@khush.org

committee and assisted by an international agency such as IRRI.

- Planning for long-term storage.

A technical committee was organized to coordinate the field and laboratory operations, to develop a training manual and record books to assist national efforts.

During 1970s coordinated efforts were mounted with national programmes to collect germplasm. IRRI hired a germplasm collector who worked with the national programmes in collecting the rice germplasm. Various national programmes established their rice gene banks to conserve the germplasm. Duplicate samples were deposited in IRRI gene bank. By early eighties the number of accessions in IRRI gene bank reached to 49,027. An ambitious germplasm collection programme was undertaken by the Indian Council of Agricultural Research (ICAR) in Northeast India. Germplasm entries designated as ARC (Assam Rice Collection) were a valuable addition to the gene bank at IRRI.

During 1980s and 1990s additions to the IRRI gene bank continued, donated by various countries. In 1994, IRRI launched a project funded by the Swiss Agency for Development and Cooperation involving 14 countries in Asia, Madagascar, several countries in eastern, central and southern Africa and South America with the aim of completing the collection of cultivated and wild rices by the year 2000 (Jackson, 1997). More than 200 accessions of rice were collected from Lao People's Republic. By the end of this project, IRRI germplasm bank had 85,997 accessions. The number of accessions in the International Rice Gene Bank (IRG) from South Asia are given in Table 1.

Table 1. Number of accessions in the International Rice Gene Bank received from different countries of Southeast Asia

Country	No. of entries
Bangladesh	5,800
Bhutan	313
India	15,987
Nepal	2,532
Pakistan	1,107
Sri Lanka	2,122
Total	**27,861**

During 1980s, IRRI mounted a vigorous campaign to collect wild relatives of rice. D.A.Vaughan, an IRRI scientist undertook several missions to collect wild species of *Oryza* in Asia, Africa and Papua New Guinea. Several accessions of the wild species were added to the collection as well as those of *O. schlechteri,* which was known only from herbarium specimens. A new species, *O. rhizomatis* (Vaughan, 1997) was described. IRRI gene bank now contains 3,696 accessions of 21 wild species of *Oryza* besides 1,333 accessions of African cultivated rice *O. glabberrima.*

Germplasm Conservation

Fortunately, *ex situ* conservation of rice seeds is safe and cost effective. Rice seeds can be dried to low moisture content of approximately 6% and stored at varying temperature regimes. At IRRI an active collection for medium term storage and for distribution is maintained at 2°C. Five hundred gram seeds of each accession are stored in sealed laminated aluminum foil packets in 927 m^3 area. For long-term storage, base collection is being kept at –20°C in vacuum sealed aluminum cans with about 60 gram seeds in each can. Seeds are expected to maintain viability for 50-100 years (Khush, 2001).

Germplasm Evaluation

Since the beginning of the institute, the germplasm collection has been systematically characterized for a range of morphological and agronomic traits. Thousands of individual rice accessions have been evaluated for their resistance/ tolerance to wide range of pests, diseases and abiotic stresses and useful donors for disease and insect resistance have been identified (Table 2). Similarly, wild species have been characterized for resistance to diseases and insects, and tolerance to abiotic stresses and useful donors for rice improvement have been identified (Khush and Brar, 2002).

Table 2. Number of *O. sativa* accessions in International Rice Gene Bank evaluated at IRRI for reaction to insect pests and diseases by 1993 (modified from Jackson, 1997)

Stress	No. of accessions screened	% Resistant
Insects		
Brown planthopper biotype 1	44,335	15.40
Brown planthopper biotype 2	10,053	1.90
Brown planthopper biotype 3	13,021	1.80
Green leafhopper	50,137	2.80
Rice whorl maggot	22,949	3.00
White backed planthopper	52,042	1.70
Zigzag leafhopper	2,756	10.10
Rice leafhopper	8,115	0.60
Yellow stemborer	15,656	3.80
Striped stemborer	6,881	0.02
Diseases		
Blast	36,634	26.20
Sheath blight	23,088	9.30
Bacterial blight	49,752	11.10
Rice tungro disease	15,795	3.50

Policy Issues Regarding Germplasm Sharing

In December 1993, the Convention on Biological Diversity (CBD) came into force. Since then concerns have grown over ownership of and access to plant genetic resources. Much of this concern has arisen because of the rapid advances in biotechnology, especially genetic engineering, and widespread belief that germplasm might be misappropriated under various forms of intellectual property protection. Patenting of genes by one or two companies and the ongoing debate in many countries over the patenting of genes and or life forms has exacerbated the problem.

The germplasm collected before the CBD came into force, is not subject to its regulations and this applies to most accessions in the IRG. Even for the germplasm acquired after the CBD came into force, IRG continues to provide accessions freely because the donors of the germplasm have indicated that germplasm exchange is permitted. Under IRRI's policy on Intellectual Property Rights adopted in 1994, no intellectual property protection will be applied to germplasm in the genebank. The international "in trust" status was further enhanced in October 1994 when the IRRI collection was placed under the auspices of the FAO of the United Nations in the International Network of *ex situ* collections. A Material Transfer Agreement is used for the exchange of germplasm from the collection under which recipients must also certify that they will not apply intellectual property rights to the germplasm accessions.

The policy of IRRI on intellectual property rights can be summed up as follows (Jackson, 1997).

The rice genetic resources in the IRG at IRRI are held in trust for world community:

- IRRI follows the principle of unrestricted availability of the rice genetic resources it holds in trust.
- IRRI will not protect the rice genetic resources it holds in trust by any form of intellectual property protection.
- IRRI is opposed to the application of patent legislation to plant genetic resources held in trust.
- The rice genetic resources held in trust by IRRI will be made available on the understanding that the recipient will take no step that restricts their further availability to other interested parties.

Germplasm Enhancement

Major resources have been devoted to develop improved germplasm with high yield potential, superior grain quality, disease and insect resistance and abiotic stress tolerance. Many donors from South Asia have been utilized in the genetic enhancement programme. Major improvement in the genetic yield potential of rice occurred through reduction in plant height resulting from incorporation of a gene for short stature. This led to improvements in harvest index (grain-straw ratio) and in biomass production. The varieties of rice available prior to green revolution were tall and leafy with weak stems and harvest index of 0.3, that is 30% grain and 70% straw. They could produce a total biomass of 10-12 tons. Thus their maximum yield potential was 4 tons per hectare. When nitrogenous fertilizer was applied exceeding 40 kg per hectare, these varieties tillered profusely, lodged early and yielded less than they would with lower fertilizer inputs. The improved varieties on the other hand, have a harvest index of 0.45-0.5. These are lodging resistant due to their short stature, and responsive to fertilizer inputs and their biomass can be increased to about 19 tons per hectare through fertilizer application. Thus their maximum yield potential is 9-9.5 tons per hectare. This improvement in the harvest index was the single most important architectural change in the rice varieties that led to doubling of their yield potential (Khush, 1995).

Several other traits that were equally important in increasing the adaptability and yield stability of new varieties were also improved. For example, most of the traditional varieties of rice grown in the tropics were photoperiod sensitive and took 150-180 days to mature. They were suitable for growing a single crop of rice in monsoonal Asia. New varieties on the other hand, are photoperiod insensitive and can be planted at any time of the year. Moreover, the growth duration has been reduced to 110 days. Much of the early maturing germplasm developed at IRRI inherited this trait from Indian variety TKM6. The availability of these short duration varieties has led to increase cropping intensity. Farmers now grow two crops of rice where only one was grown before or even two crops of rice and another upland crop (Khush, 1987).

In the wet and humid tropics, the rice crop is subject to attack by diseases such as blast, bacterial blight, tungro and grassy stunt viruses. Varietal resistance is the only practical way to control disease of rice in tropics. Several donors for resistance identified by plant pathologists were used in the breeding programme and breeding materials with multiple resistance were developed. Many donors for disease resistance such as

Ram Tulsi (India) for blast, TKM 6 (India) and DZ192 (Bangladesh) for bacterial blight, *O. nivara* (India) for grassy stunt and Adday selection (India) and Habigang DW8 (Bangladesh) for resistance to tungro came from Indian subcontinent.

More than 100 species of important insect pests infest and damage the rice crop. About twenty of these are of major economic importance. Considerable yield losses are caused by different species of stemborers, planthoppers, leafhoppers and gall midge. Excellent sources of resistance to these insects have been identified and rice varieties with multiple resistance have been developed. Most of the sources for insect resistance came from India; TKM6 for striped borer resistance; Mudgo, MTU15, ASD7, Ptb 18 and Co 22 for brown planthopper resistance; Pankhari 203, ASD7, ASD8 and Ptb 8 for green leafhopper resistance; Ptb10, Ptb18, Eswarakora, and ARC1368 for gall midge resistance. Several donors for brown planthopper resistance such as Rathu Heenati and Babawee came from Sri Lanka.

Millions of hectares of land, which is otherwise suitable for growing rice, remain uncultivated because of soil toxicities caused by salt, alkalinity, or acidity. In vast areas, deficiencies of zinc, phosphorus and iron limit rice production. Improved germplasm with moderate levels of tolerance to salinity has been developed at IRRI using donors from India such as Pokkali, Getu and Nona Bokra and some of the lines with salinity tolerance have been released in the Philippines.

Rice varieties differ in physical properties of the grain (size, shape and translucency) and physico-chemical properties of starch. Starch, a polymer of glucose is the major constituent of milled rice. The amount of its linear fraction (amylose), branched fraction (amylopectin) and its gel consistency, determine in large part, the eating quality of rice. The preference in South Asia is for dry cooking (high amylase) rice with long slender and translucent grains. Since most of the donors for disease and insect resistance from India used in breeding programme had high amylose, most of the improved varieties developed at IRRI have both, high amylose and long, slender and translucent grains, which are highly acceptable in Indian subcontinent. There is considerable emphasis for developing improved germplasm with aroma. Basmati rice and Pankhari 203 from India are the main donors for this trait in the breeding programme at IRRI.

Germplasm Exchange

Since the inception of IRRI's rice improvement programme, the germplasm has been freely shared with the national rice improvement programmes. Seeds of donor varieties, early generation breeding materials, fixed elite lines and named varieties are sent to national programme scientists at their request and through international nurseries. Thus the seeds of breeding materials have been sent to 87 countries irrespective of geographical location or ideology. These materials are evaluated for adaptation to local conditions. Some are released as varieties and others are used as parents in rice breeding programmes. More than 300 IRRI bred lines have been released as national varieties in Asia, Africa and Latin America. Those released in Indian subcontinent are listed in Table 3. Since 1975, germplasm has also been exchanged and evaluated through international nurseries conducted by the International Network for Genetic Evaluation of Rice (INGER). These nurseries are composed of IRRI breeding lines, named varieties and donor parents. National programmes are requested to nominate their best entries to these nurseries. These nursery sets are distributed to national programmes upon their request. Various nurseries are composed for international evaluation for yield, resistance to diseases and insects and tolerance to abiotic stresses. They are an excellent means by which germplasm can be exchanged among different national and international programmes. Thus materials developed in one country can be shared and evaluated in another country. For example, varieties released in Brazil, Burkina Faso, China, Myanmar and Vietnam were bred in nine or more other countries. A total of 349 breeding lines selected from INGER nurseries have been released as 525 varieties in 62 countries (Chaudhary *et al.*, 1998).

Impact of Germplasm Improvement

The gradual replacement of traditional varieties of rice by improved ones, together with the associated improvement in farm management practices, has had a dramatic effect on the growth of rice output in Asia. Farmers get 5-7 tons of unmilled rice from high yielding varieties compared with 1-3 tons of unmilled rice from conventional varieties. Farmers have raised average yields of rice by substituting high yielding varieties for traditional varieties. Since 1966 when the first high yielding variety of rice was released, the rice area harvested has increased marginally, from 126 to 152 mha (20%), while the average rice yield has increased from 2.1 to 3.9 tons per hectare

Table 3. IRRI Breeding lines released as varieties in countries of Southeast Asia

IRRI line designation	Name given	Country
IR2053-87-3-1	BR7	Bangladesh
IR2061-214-3-8-2	BR6 (IR28)	Bangladesh
IR2071-199-3-6	BR15 (MOHINI)	Bangladesh
IR272-4-1	MALA	Bangladesh
IR2793-80-1	BR16 (SHAHI BALAM)	Bangladesh
IR33380-7-2-1-3	BRRI-DHAN 34	Bangladesh
IR44595-70-2-2-3	BR26	Bangladesh
IR532-1-176	CHANDINA	Bangladesh
IR532-E576	BRRI-SAIL (IR20)	Bangladesh
IR5-47-2	IR5	Bangladesh
IR54791-19-2-3	BRRI DHAN 36 (BR 36)	Bangladesh
IR578-15-2	BAU 63 (VARASHA)	Bangladesh
IR69690H	BRRI DHAN HYBRID 1	Bangladesh
IR8-288-3	IR8	Bangladesh
IR18348-36-3-3	IR64	Bhutan
IR2071-625-1-252	IR36	Bhutan
IR20913-B-26-2-2-3	IR20913	Bhutan
IR20913-B-60	–	Bhutan
IR61328-1-136-2-1-2-3	BAJO KAAP 2	Bhutan
IR61331-2-148-B	BAJO KAAP 1	Bhutan
IR10781-75-3-2	KHP-2 (KARNATAKA HILL PADDY-2)	India
IR13427-45-2	PY3 (BHARATTHIDASAN)	India
IR13525-43-2-3-1-3-2	IR62	India
IR1561-216-6-2	PRASAD	India
IR1721-14	PAIYUR 1	India
IR17492-18-10-2-2-2	CO 45	India
IR18348-36-3-3	IR64	India
IR1846-284-1	V.L. DHAN	India
IR19661-150-2-2-1	HKR120	India
IR19728-9-3-2	PANT DHAN 6	India
IR2061-213-2-17	IR34	India
IR2061-214-3-8-2	IR28	India
IR2071-586-5-6-3	IR 42 (AU 2)	India
IR2071-625-1-252	IR36, NARENDRA 2	India
IR2153-159-1-4	IR30	India
IR21820-154-3-2-2-3	ADT38	India
IR28224-66-3-2	PR109	India
IR32307-107-3-2-2	IR66	India
IR3941-45-PLP-2B	HIMALAYA 741	India
IR442-2-24	PANI DHAN 1	India
IR442-2-50	–	India
IR442-2-58	PANI DHAN 2	India
IR44595-70-2-2-3	ASD20	India
IR46330	NARENDRA USAR-3 (NDRK 5031)	India
IR5-114-3	PANKAJ	India
IR532-E576	IR20	India
IR57540 (CN10355-61)	Bhudeb	India
IR579-160-2	IR22	India
IR579-48-1	PALMAN 579	India
IR579-97-2-2-1	RAJINDER DHAN 201	India
IR661-1-140-3-2	IR24 (PR103)	India
IR665-79-2	PR 106	India
IR8-288-3	IR8	India
IR9201-30-1-3-1-3	PRABHAT	India
IR9202-25-1-3	CTH3	India
IR9224-117-2-3-3-2	IR50	India
IR930-67-2-2	SITA	India
IR9763-11-2-2-3	PANT DHAN 10	India
IR9884-54-3	–	India
IR2061-628-1-6-4-3	LAXMI	Nepal
IR2071-124-6-4	SABITRI	Nepal
IR2298-PLP-B3-2	HIMALI	Nepal
IR3941-48-PLP-2B	HIMALAYA 741	Nepal
IR3941-4-PLP-2B	KANCHAN	Nepal
IR400-29-9	PARWANIPUR 1	Nepal
IR5-47-2	IR5	Nepal
IR7151-60-3-3	CHAITE 1	Nepal
IR8-288-3	IR8	Nepal
IR8423-156-2-2-1	RADHA 4	Nepal
IR9729-67-3	CHAITE 3	Nepal
IR15323-78-1-3-1	SADA HAYAT	Pakistan
IR2053-261-2-3	DR83	Pakistan
IR28128-45-3-3-2	PAKHAL	Pakistan
IR6-156-2	MEHRAN 69 (IRRI6 or IR6)	Pakistan
IR6-18	SHADAD	Pakistan
IR8-288-3	IR 8 (IRRI-PAK)	Pakistan
IR841-36-2	ABBASI 72	Pakistan
IR9782-44-3-3-3	IR9	Pakistan
IR262-43-8	IR262	Sri Lanka
IR532-1-18	IR532	Sri Lanka

(86%). The total rice production increased from 257 million tons to 600 million tons (133%). The increase in area planted to rice, average yields and total rice production in India, Nepal, Pakistan and Sri Lanka are shown in Figures 1-4. The growth in rice production has outstripped the rise in population, leading to a substantial increase in cereal consumption and caloric intake per capita. For example, during 1965-1990, the daily caloric supply in relation to requirement improved from 81 to 120% in Indonesia, from 86 to 110% in China, from 82 to 99% in the Philippines and from 89 to 94% in India (UNDP 1994).

The increase in per capita availability of rice and a decline in the cost of production per ton of output contributed to a decline in the real price of rice, both in international and domestic markets. The unit cost of production is about 20-30 percent lower for high-yielding varieties than for traditional varieties (Yap, 1991) and the price of rice adjusted for inflation is 40 percent lower

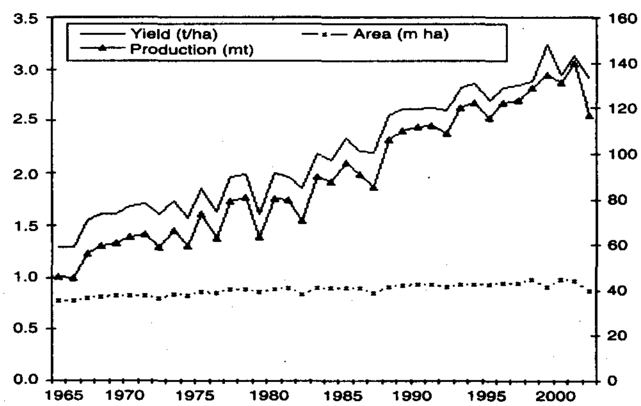


***Fig. 1:** Area, production and yield of rice in India (1965-2002)*

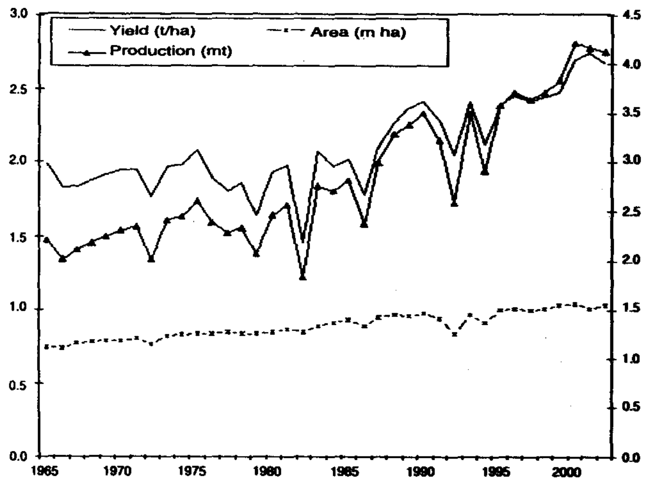


Fig. 2: Area, production and yield of rice in Nepal (1965-2002)

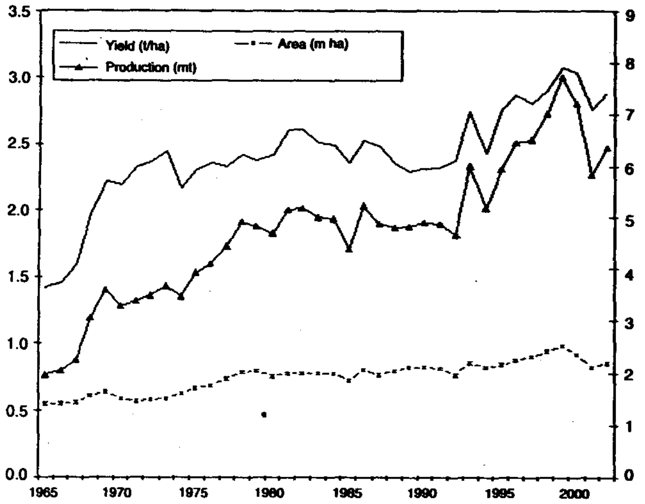


Fig. 3: Area, production and yield of rice in Pakistan (1965-2002)

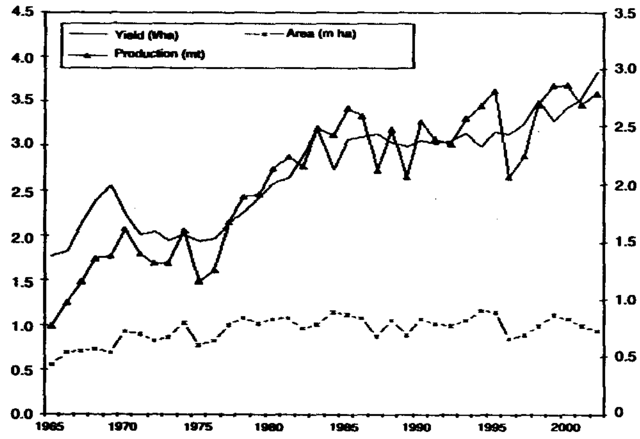


Fig. 4: Area, production and yield of rice in Sri Lanka (1965-2002)

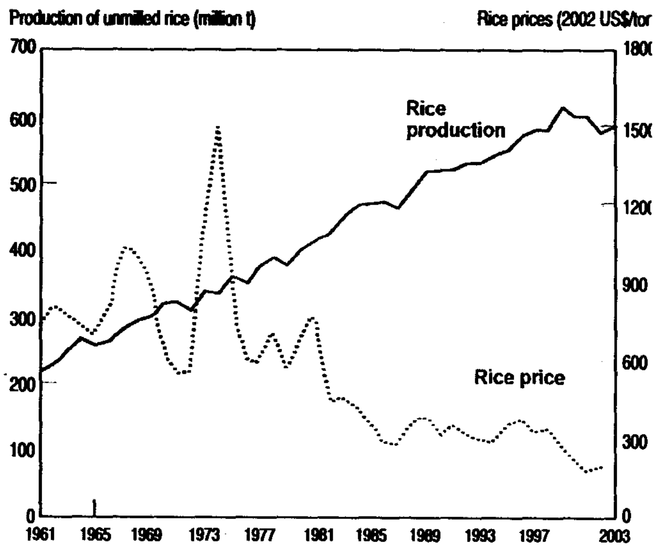


Fig. 5: Trends in world rice production and price adjusted for inflation, 1961-2002

now than in mid 1966 (Fig. 5). The decline in food prices has benefited the urban poor and the rural landless, who are not directly involved in food production but who spend more than half of their income on food grains.

References

Chang TT (1972) International cooperation in conserving and evaluating rice germplasm resources. In: *Rice Breeding. International Rice Research Institute*, Los Baños, Laguna, Philippines. pp. 177-185

Chaudhary RC, D Seshu, K Alluri, F Cuevas-Perez, VC Lopez and GS Khush (1998) INGER derived rice varieties directly released in various countries. International Rice Research Institute, Los Baños, Laguna, Philippines.

Jackson MT (1997) Conservation of rice genetic resources: the role of the international Rice Gene Bank at IRRI. *Plant Mol. Biol.* **35:** 61-67.

Khush GS (1987) Development of rice varieties suitable for double cropping. *Tropical Agriculture Research* Series No. 20, Tropical Agriculture Research Center, Ministry of Agriculture, Forestry and Fisheries, Japan. pp 235-246.

Khush GS (1995) Modern varieties-their real contribution to food supply and equity. *Geo Journal* **35:** 275-284.

Khush GS (2001) Rice Improvement at IRRI: an example of International Collaboration. *Breeding Science* **3:** 281-286.

Khush GS and DS Brar (2002) Rice. Pages 1-41. In: Chopra VL and S Prakash (eds.) *Evolution and Adaptation of Cereal Crops*. Science Publishers Inc. Enfield, NH. USA.

UNDP (United Nations Development Programme) (1994) Human Development Report. Oxford University Press, UK.

Vaughan DA (1997) *The Wild Relatives of Rice*: A genetic resources Handbook. International Rice Research Institute, Los Baños, Laguna, Philippines.

Yap CL (1991) A comparison of the cost of producing rice in selected countries. Food and Agriculture Organization (FAO) economic and social development paper No 101. FAO, Rome.

Plant Introduction: Achievements and Opportunities of Wheat in India

S Rajaram[1], J Shoran[2*], G Ortiz-Ferrara[3] and Gyanendra Singh[4]

[1] *Director, Integrated Gene Management, ICARDA, Syria*

[2] *Project Director (Wheat) Directorate of Wheat Research, Karnal-132001, Haryana, India*

[3] *Principal Scientist (Breeding), CIMMYT-South Asia*

[4] *Senior Scientist (Breeding), Directorate of Wheat Research, Karnal-132001, Haryana, India*

Original landraces of field crops have been introduced and moved across the continents by human beings. These landraces have been used as commercial cultivars and also for the development of improved varieties. The CIMMYT, Mexico successfully utilized the unique wheat germplasm, Norin 10/Brevor for introducing dwarfing genes (Rht1, Rht 2) and 1B/1R segment of chromosome from winter wheat into the background of spring wheat for increasing the yield potential and resistance/tolerance against various biotic and abiotic stresses in modern wheat varieties. Indian wheat scientists could develop large number of improved wheat varieties from wheat germplasm introduced from CIMMTY, Mexico. Some of these varieties like Kalyansona, Sonalika, C-306, WH 147, WL 711, HD 2329, WH 542 and PBW 343 have become very popular among Indian farmers. Similarly, many of Indian wheat varieties have been introduced and grown for commercial cultivation in 15 other countries. The role played by the introduced wheat germplasm from CIMMYT, Mexico in ushering 'Green Revolution' in India has been discussed in the present article. Besides, the future demand of wheat by 2020 and probable ways to increase wheat production in the country to meet our national requirement have also been debated. An increase in average wheat yield from present level of 2,750 kg/ha to 3,624 kg/ha by 2020 has been advocated.

Key words: Wheat, Germplasm, Varieties, Green revolution

The Green Revolution was based on plant introductions, especially improved varieties of rice from the International Rice Research Institute (IRRI), and wheat from the International Maize and Wheat Improvement Center (CIMMYT). The wheat and wheat related species originated in the Middle Eastern region. Indeed, the origin of agriculture is considered to be fertile crescent, between the rivers Tigris and Euphrates, approximately 10,000 years ago.

Modern wheat types such as bread wheat and durum wheat are now grown on all continents except Antarctica on roughly 200 million hectares with an annual production of 590 million metric tons. Through selection and plant breeding, there are now thousands of wheat varieties under cultivation worldwide. There has been continuous movement and introduction of original landraces across the globe, especially in the last 500 years. Since modern plant breeding dates back to 100 years, after the rediscovery of Mendel's law in the late 19th Century, there is an increase in number of improved varieties.

India's modern wheat breeding program is largely based on germplasm introductions from CIMMYT since early 1960's till date. More than 50,000 genotypes of wheat from CIMMYT have been evaluated in India and a set of elite germplasm has been created. Table 1 shows the number of lines and sets of international trials of bread wheat, durum wheat and triticale that have been imported by the Wheat Research Program of India during the last five years (1999-2004). Each year, more than 1,500 elite germplasm wheat entries in the form of nurseries and yield trials have been introduced and evaluated in the country.

Table 1. Important international nurseries and yield trials of bread wheat, durum wheat and triticale received from CIMMYT-Mexico during the last five years (2002-2006)

Nursery/ trial	Total number of lines/sets 2001-02	2002-03	2003-04	2004-05	2005-06
Bread Wheat					
IBWSN	400/8	543/10	372/9	346/8	287/9
ESWYT	50/8	50/9	50/6	50/7	50/8
HTWYT	50/5	50/5	30/5	40/4	–
SAW YT	50/4	50/3	50/4	50/3	50/7
SAWSN	305/4	256/5	189/4	188/4	181/6
WAWSN	40/4	–	–	–	–
IAT	79/4	80/4	80/2	80/1	–
HRWYT	–	50/1	50/2	50/2	50/2
HRWSN	–	333/1	228/1	299/2	116/2
ESW'SN	–	–	150/6	–	–
EGPSN	150/5	150/6	150/7	150/8	150/7
EGPYT	25/5	25/5	25/6	25/5	25/6
Durum Wheat					
IDYN	50/6	50/6	50/5	50/6	50/8
IDSN	290/6	295/6	350/6	370/6	350/8
EDUYT	128/6	128/6	128/8	128/6	128/6
Triticale					
ITSN	250/ 2	150/2	104/2	159/2	100/2
ITYN	50/2	50/2	30/2	40/2	40/2
FWTCI	120/2	140/2	81 /2	–	–

Source: B.S. Tyagi, 2006, Directorate of Wheat Research, Karnal Haryana (India)

* *E-mail: jshoran1948@yahoo.co.in*

CIMMYT-derived wheat germplasm is now core of the Indian Wheat Program. The local germplasm has also played important role in breeding, but its relative importance is minute compared to the exotic germplasm. It can be conclusively said that the introduced germplasm played an important role in shaping the varietal diversity in India. We would like to document some of the major events in wheat germplasm introductions in India, and the impact it has had on national food security.

History of Green Revolution and Wheat Varieties

The CIMMYT based wheat germplasm introductions in 1960's led to the establishment of the modern Indian Wheat Program coordinated by ICAR (Indian Council of Agricultural Research). The two green revolution wheat varieties, Kalyansona and Sonalika, bred in Mexico by Dr. Norman E. Borlaug and his colleagues, played the catalytic role to spark the changes in technology adoption with small farmers in the North Western Region of the Indo Gangetic Plains (IGPs). These varieties, when grown under optimum water and nutrient conditions, produced twice as much as their indigenous counterparts. These wheat varieties were characterized by dwarf stature, input responsiveness, disease resistance and lodging tolerance. Their wide adoption by all types of farmers was popular and they replaced the previously grown wheats in the IGPS. Within 10 years, India experienced a dramatic impact and the country attained self-sufficiency in wheat.

The varieties Kalyansona and Sonalika were a complex blend of genetic materials put together by Mexican and Rockefeller Foundation scientists. Additionally, they had used the shuttle breeding and multilocation testing within Mexico in the process of breeding. The shuttle breeding methodology, practiced by CIMMYT in Mexico, is inherently built in to select genotypes which are generally widely adapted and provide stable performance in the fields. These two varieties were the product of shuttle breeding with unusual breadth of adaptation across the IGPs. Their impact on production was huge, nonetheless, they represented narrow genetic variability considering that there were more than 10 million hectares under wheat cultivation across the North Western and Eastern Plains of the country at that time.

The response to such a situation by ICAR and the Government of India was dynamic. A National Center of Wheat was created at Karnal in the State of Haryana, which also serves as a Coordination Unit for most of the wheat research in India. This Center is an institution of excellence with appropriate funding and undertaking programs and projects based on the needs of the farmers. CIMMYT has remained a partner of ICAR and continues to serve as a reliable provider of selected germplasm suitable for Indian conditions and farmer needs. Through this partnership, a large number of CIMMYT germplasm has been adopted and released for variable Indian conditions (Table 2). Some of these varieties occupy a large acreage in India (Table 3).

Table 2. Wheat varieties released in India as introductions from 1965 to 2002

S.No.	Name of variety	Pedigree	Year of release
1.	Lerma Rajo-64	YAQUI 50-N 10B/ L52/3/2*LR	1965
2.	Sonora-64	YAKTANA 54-N 10B/ /2* Y 54	1965
3.	Chhoti Lerma	LR 64A SIB/HUAR	1967
4.	Kalyansona	PJ SIB/GB 55	1967
5.	Sonalika (RR 21)	MIDA-U/K117A//2*TH/3/FN/4*TH/4/AN/5/YT 54/N 10B//LR/6/B 4946-A 4-18-1/Y 53//3*Y 50	1967
6.	Safed Lerma (S 307)	(YAQUI 50 – N 10 B// L 52/3/3*LR	1968
7.	Lal Bahadur (EA 222-1)	S 54723/RS 31	1970
8.	K 816	CNO SIB//SN 64/KLRE/3/8156	1973
9.	Girija	CJ 60/3/SPO/MTA//MQ/2*RNW	1973
10.	VL Gehun 401	FKN/N 10B	1973
11.	UP 310	KLPE/RAF//LR 64/2*SN 64	1973
12.	UP 319	CNO SIB//SN 64/KLRE/3/8156	1973
13.	HD 4502	PI SIB/2*BY//TC60/3/ZENA TI/B TEL//WLS	1974
14.	IWP 72	FKN/LEE//2*KAL	1974
15.	RAJ-911	PI/ST 464//2*TC 60/3/NACHITSCHEVANICUM(TG)	1974
16.	HS 1138-6-4	PJ SIB/P14/KT54//CNO/NO/3/VEE	1975
17.	WH 147	PJ SIB/P 14//KT 54B/3/C 286/C 273/4/S 339/PV 18	1977
18.	RAJ 1114	SKA/INIA 66	1977
19.	HD- 4530	TPT/MOGHK//4/PI/TML//2*TC 60/3/ZENA TI/BTL//WLS	1979
20.	HP-1102	8156(B)NAD 63	1979

(Contd.)

S.No.	Name of variety	Pedigree	Year of release
21.	Jairaj	YAGULATE(POL)/4/PI/3/ZENA TI/BTL//WLS	1979
22.	HD-2177	SL SIB/NP 852/4/PJ SIB/P 14//KT 54B/3/K 65/5/KAL	1979
23.	WL-410	SN 63/4/36896//CJ 54/P4160E/3/HUAR/5/KAL	1979
24.	UP-115	RIDLEY/NP710/3/PJ SIB/P14//KT54B/4/PJ SIB/GB56// TZPP/NAI60	1979
25.	HP-1209	N 10B/Y53//Y50/3/KT54B/4/PJ	1979
26.	HD-2189	36896/CJ 54//P 4160E/3/SN 63/5/MY54/ N10B// LR64/3/TAC SIB/4/LR64//STP/Y54	1979
27.	HD-2204	BJ66 SIB//NAD63/LR64A/5/SL SIB/NP 852/4/PJ SIB/P14//KT54B/3/K65	1979
28.	IWP-72	FKN/LEE//2*KAL	1979
29.	VL 421	S 64//Y 50E/ G TO	1979
30.	CC 464	BB//CNO/SN 64	1979
31.	GW 40	INIA 66*2/7C	1979
32.	TAWA 267	BB/7C	1979
33.	HD 2177	SL SIB/NP 852/4/PJ SIB/P 14//KT 54B/3/K65/5/KAL	1979
34.	UP 2003	BB/2*7C	1980
35.	HW-517	BB/CC/3/CNO/NO//PI	1981
36.	HS-86	TH/MIDA-U//MCM/E //3/S227/4/S308	1981
37.	HB-208	SPO/MTA//MQ/2*RNW/3/PJ SIB/P14//KT54B	1981
38.	Ajanta	PW 5/Y 53	1981
39.	DWR 216	SKA/TOB	1981
40.	Narmada 215	FGO SIB//VERN(DM)/GLLA SIB	1981
41.	RAJ-1482	NAPO/TOB SIB//8156/3/KAL/BB	1982
42.	DWL-5023	CR/LDS//PLC/GARZA	1982
43.	HI-784	NAPO/TOB SIB//8156/3/KAL/BB	1983
44.	CPAN-1676	BON//CNO/SN 64/3/KAL//BB	1983
45.	HUW 55	PJ SIB/P 14//KT54B/3/HD1982/4/INIA66/5/HD2189	1983
46.	GW-801-3	DG65/C 306//FAO 1061-68R	1983
47.	UP 2121	NAI 60/KAL//UP 301/3/SAM 68	1984
48.	CPAN-1922	ORE.FI 158-FDL/MEXIFEN"S"// TIB 63/COCARAQUE 75	1984(I)
49.	BW-11	KVZ/TI//TITO	1984(I)
50.	GW 89	KAL SIB/LR 64A//SKA	1984
51.	HD-2285	36896//CJ54/P4160E/3/HUAR/4/KAL SIB/5/SL/ HD2160 /7/ SL SIB/NP852/4/PJ SIB /P14// KT54B/3/ K65/5/2*SKA	1985
52.	WL 2265	NAPO/TOB SIB//8156/3/KAL/BB	1985
53.	WH-291	SHERA/3/N 10 B/K 68//BB	1985
54.	DWR-39	LR 64/2*SN 64//S 308	1985
55.	PBW-34	AA SIB/FGO SIB	1985
56.	HUW-206	KVZ / BUHO // KAL/BB	1985
57.	J-405	CNO/INIA 66//BB/3/CNO//PI/GLL	1985
58.	VW-120	(INIA-CNO / INIA-BB) Y 50E-KAL^3	1985
59.	GW 120	INIA 66/CNO//INIA 66/BB/3/Y 50E/3*KAL	1985
60.	CPAN 1796	NAPO/TOB SIB// 8156/3/KAL/BB	1985
61.	MACS 1967	GULAB/5/BYE*2/TCTE//4*TC 60/3/BYE*2/TC 60/STW 63/4/ AA SIB/CIT SIB	1986
62.	PBW 65	USA 255/K 816/3/S 738/C 306//KAL	1987
63.	HI 977	GLL/AUSTII61.157//CNO/NO/3/Y50E/3*KAL	1988
64.	HD 2270	SL SIB/NP 852/4/PJ SIB/P 14//KT 54B/3/K 65/ 5 /CNO SIB/3/ C273// NP 875/PI SIB/ 60 CB/CNO SIB// BB/4/NAI 60 SIB*2//TT/SN 64/3/- LR 64/SN 64	1988
65.	HS 240	AU//KAL/BB/3/WOP/4/PVN	1989
66.	HS 207	KVZ/BUHO//KAL/BB	1989
67.	HI 1077	GLL/AUSTII 61.157//CNO/NO/3/KAL/BB	1989
68.	GW 503	TOB SIB/NAPO//CC/INIA 66 SIB/3/ CNO/NO/4/ CTFN/CNO SIB/3/JAR SIB//MENG/8156	1990
69.	MACS 2496	VEERY # 5	1991
70.	HS 277	KVZ/CGN	1991
71.	WH 542	JUP/BJY SIB//URES	1992
72.	HS 295	CQT/AZ//IAS 55/ALDML SIB/3/ALDML SIB/ NAFN/4/ PJN SIB/PEL 1276.69	1992
73.	CPAN 3004	GLL/AUSTII 61-157//CNO/NO/3/VEE	1992
74.	HPW 42	VEE/3/PVN SIB/CNO SIB//JAR/ORZ SIB	1992
75.	HP 1633	TH*6/TF//6*SKA	1992
76.	AKW 1071	VEE/3/FLN/ACC//ANA	1992
77.	WH-533	VEERY #5	1992
78.	DWR 162	KVZ/ BUHO// KAL/ BB	1993
79.	HI 8381	JO 69 SIB/AA SIB//FGO SIB	1993
80.	DWR 195	SHI#4414/CROW'S	1994
81.	WH 896	STIL 'S'/YAV'S'/PEN 'S'	1994

(Contd.)

S.No.	Name of variety	Pedigree	Year of release
82.	HP 1731	LIRA//PARULA/TONICHI	1994
83.	VL 719	VEE#5"S"	1994
84.	AKW 1071	VEE "S"/FLN-ACC/ANA	1994
85.	PBW 343	ND/ VG 9144//KAL /BB/3 YACO "S" /4/VEE#5 "S"	1995
86.	PDW 233	YAV'S'/TEN 'S'	1996
87.	MACS 2694	MEXICALI/ RAJ 1555//MACS 2130 E4707-6-6-7-2-BK	1996
88.	NIAW 34	CNO 79/PRL "S"	1996
89.	PBW 373	ND/VG 1944//KAL//BB/3/YACO 'S'/4/VEE 'S'	1996
90.	HP 1744	CIANO/PARULA/CHILARO/GARUD	1997
91.	HP 1761	RL 6010/6* INIA//3*KAUZ	1997
92.	VL 738	NS 12.07/LIRA "S"//VEE "S"	1997
93.	K 9465	B 1153/CB 85=[(CHD 2402/CPAN 1830)]/VEE 'S'	1998
94.	NW 1012	PARANA#2//JUP/BJY "S"/3/VEE#5.5/JUN"S"	1998
95.	NW 1014	HANS "S"CM 33682-L-1Y-1Y-1M-3Y-100 B 503 Y-500B-OY	1998
96.	PBW 396	CNO 67/MFD/MON 'S'/3/SERI	2000
97.	HD 2733	ATTILA/3/TUI/CARC//CHEN/CHTO/4/ATTILA	2001
98.	NIAW 301	SERI 82/3/MRS/JUP//HORK 'S'	2001
99.	WH 912	HUI 'S'/YAV'S'//FULI 'S'/ALTER 84	2001
100.	NW 1076	OPTA/KILL	2001
101.	HPW 184	ATTILA	2001
102.	NW 2036	BOW/CROW//BUC/PVN	2002
103.	HS 420	LAJ 3302 // CMH 73 A-497/3*CNO 97	2002
104.	HS 375	BB/GH/CJ 71/3 T.AEST//KAL/BB	2002
105.	MP 4010	ANGOSTURA-88(CM 50123-3M-Y-2M-1Y-2M-2Y-OM-OMR/S)	2002

Table 3. Leading wheat cultivars in India

Cultivar	Purpose
Kalyansona	High yield and disease resistance
Sonalika	High yield and disease resistance
C 306	Drought tolerance and chapati quality
WH 147	High yield
WL 711	High yield and disease resistance
UP 2003	High yield
HD 2329	High yield and disease resistance
WH 542	High yield and disease resistance
PBW 343*	High yield and disease resistance

* Presently continuing as the most predominant wheat variety in India

India's Wheat Research Program has also contributed to increasing wheat production in other parts of the world. Many of these varieties have also been released in other countries in the developing world (Table 4).

Table 4. Indian wheat varieties released in other countries of the world

Variety	Indian synonym	Country	Year
Annapurna 2	CPAN 1796	Nepal	1988
Arz	HD 1931 Sib	Pakistan	1976
Bajoka 1	HD 2380	Bhutan	1992
Balkh 66	HD 2322	Afghanistan	1987
Balaca	Pratap	Bangladesh	1981
Bloudan	HD 2172	Syria	1981
Janak	Janak	Nepal	1975
HD 1220	HD 1220	Algeria	1982
Manywa White	NP 4	Myanmar	–
Mukta	Mukta	Sudan	1978
NP 798	NP 798	China	1964
Pusa 4	NP 4	Australia	1916
Pusa 12	NP 12	Argentina	1916
Sonalika	Sonalika	Ethiopia	1970
Safed Lerma	Safed Lerma	Oman	1978
Kalyansona	Kalyansona	Mongolia	1974
WL 711	WL 711	Pakistan	1978
Debeira	HD 2172	Sudan	1983
UP 262	UP 262	Nepal	–

Source: Vision 2020: Perspective Plan, DWR-Karnal, India, 1997.

Story of PBW 343

On Indian wheat scene especially in the IGPs, there has been a dominance of 1 to 2 varieties, which have occupied millions of hectares. We mentioned the widespread cultivation of Kalyansona and Sonalika in the early years after their introduction. In the mid eighties (1985), the variety HD 2329 bred at IARI-New Delhi, was released. In subsequent years, this variety replaced the previously grown varieties in North Western Plains Zone (NWPZ). Ten years later, PBW 343, a line called "Attila" in Mexico, was released by Punjab Agricultural University (PAU) in 1995. PBW 343 is a complex blend of pedigree ND/VG9144//KAL/BB/3/YACO 'S'/4/Vee #5. Part of its pedigree ND/VG9144 is a line from Oregon State University, USA. Nord Deprez (ND) line is from France. This complex pedigree resulted in the advanced line Attila, which after 3 years of further experimentation and testing, became PBW 343. This variety is now grown in about 7 million hectares in India, and represents a yield potential gain of 5 quintal/ha over the most popular variety HD 2329. It is now released nationally and is now also grown in some areas of the eastern states like Uttar Pradesh including Uttaranchal and Bihar. Due to widespread adoption of this variety, there could be an evolution of new pathotypes, especially yellow rust, that can make it highly susceptible and out of production. Nonetheless, its widespread adoption and high yield potential has provided good benefits to all kinds of farmers. It is estimated that additional benefits to Indian farming community have been in the range of at least 500 million dollars per year due to this variety alone.

Paramount Germplasm

In the entire history of wheat breeding, breeders worldwide have struggled with the issue of combining ability. Within this framework of combining ability, there are certain germplasm, which play greater role in transmitting genes than others. The story of Norin 10/ Brevor in transmission of Rht1 and Rht2 genes are well known. The variety Veery's role in modern wheat breeding is not very well documented, but its contribution in transmission of 1B/1R segment is great. The component 1B/1R has positive effects on drought tolerance, yield potential, Phosphorus efficiency, but negative effect on quality. PBW 343 is a descendent of Veery # 5 and perhaps would be a paramount germplasm in the future wheat breeding to capture stability and yield potential.

In our opinion, an ideal plant-breeding program would be that which allows conscious accumulation of most useful genes into one package. The more the number of genes in the package, the better is the varietal performance. To achieve such a balance, a measured process of introduction of genes into crossing system has to be allowed and selected accordingly. A complex random crossing system brings together many unwanted genes, and such technique, though widely appreciated in the academia, is not the best approach.

Future Wheat Scenario in India

India's wheat production statistics are very impressive. The overall yield has increased from 9.1 quintal/ha in 1965 to 27.5 q/ha in 2003. The area under wheat cultivation doubled from 1965 to 2003, however, the total production increased by 6 times within the same period (Table 5).

India now enjoys self-sufficiency in wheat, but the projected statistics for 2020 are not that encouraging (Table 6). In 2020, the national average yield should be increased to 3,383 kg/ha compared to 2,552 kg/ha in 1997 or 2,750 kg/ha in 2003. This is an increase of 635 kg/ha in the next 15 to 17 years or 42 kg/ha/year until the year

Table 5. Area, production and productivity of wheat in India (1965-2006)

Year	Area (Million Hectares)	Production (Million Tons)	Yield (q/Ha)
1965	13.4	12.3	9.1
1970	16.6	20.1	12.1
1975	18.0	24.1	13.3
1980	22.2	31.8	14.3
1985	23.6	44.1	18.7
1990	23.5	49.8	21.2
1995	25.7	65.8	25.6
2000	27.5	76.4	27.8
2005	26.5	72.0	27.1
2006	26.5	69.0	26.0

2020. According to IFPRI (International Food Policy Research Institute) projection, India would still have to import 6,731,000 tons of wheat in 2020, which may cost about 1 billion dollars at current international price. To avert this situation, the average national yield has to be increased at the level of 3,624 kg/ha in 2020 rather than 3,383 kg/ha. This is translated into an increase of 58 kg/ha/year until 2020. Optimistically speaking this is possible. However, there is a need for a cohesive science policy environment in India, suitable production incentives to farmers, and priorities for funding to regions where wheat productivity is still lagging behind. In future wheat yield gains are likely to be made in the Eastern Gangetic Plains (EGPs) and Central Zone (CZ) rather than in the North Western Zone, inspite of the yield gaps still existing in each wheat growing zone.

Table 6. Wheat production statistics for India from 1997 to 2020

	Year	
	1997	2020
Area (000 ha)	25,902	27,776
Yield (Kg/ha)	2,552	3,383
Production (000 MT)	66,105	93,955
Demand (000 MT)	66,857	100,686
Food (000 MT)	58,465	87,629
Feed (000 MT)	789	1,606
Net Trade (000 MT)	– 761	– 6,731

Source: IFPRI, Impact Global Food Production

Based on the results obtained from the Front Line Demonstrations (FLD) being conducted during 1998-99 to 2002-03, a wide yield gap has been found in each wheat-growing zone (Table 7). These results suggest that there is enough scope to increase the wheat production from the available area under wheat cultivation. If this yield gap could be narrowed down through the adoption of new production technologies, an additional wheat production to the tune of 24.7 million metric tones could be produced without further increasing the wheat area

Table 7. Yield gaps in different regional zones in India (1998 to 2003)

Zone	FLDs mean yield (q/ha)	Regional mean yield (q/ha)	Yield gap (q/ha)	Area (million ha) under wheat 2002-03	Additional attainable production (1000 tonnes)
NHZ	26.87	18.90	7.97	0.7	558
NEPZ	37.52	25.18	12.34	8.5	10,489
NWPZ	49.79	41.55	8.24	10.7	8,817
CZ	37.09	28.00	9.09	3.8	3,454
PZ	36.37	37.00	9.36	1.5	1,404
Total					24,722

NHZ – North Hill Zone; NEPZ – North East Plains Zone; NWPZ – North Western Plains Zone; CZ – Central Zone; PZ – Plateau Zone

in the country. Out of the projected 24.7 million metric tones, the major share will be received from the Northeastern parts comprising the eastern States of U.P., Bihar, West Bengal, Jharkhand, Orissa and Assam. About 8.8 million metric tons will have to be produced in the NWPZ and the rest by the CZ.

Future wheat research in the Eastern Gangetic Plains and Central Zones can be prioritized as follows: maximizing yield potential and yield stability, removing disease susceptibility constraints, stabilizing high temperatures, drought and salinity tolerance through better adapted genotypes and improving water use efficiency (WUE).

To achieve maximum efficiency for these traits, a combination of both conventional breeding and biotechnological interventions would be required. We would still need germplasm either from within or from outside India. Perhaps the inside genetic resources have been tried, with little effects on yield and stability or other traits. One outside genetic resource that comes to our attention is the exploitation of *Aegilops squarrossa* derivatives especially for high temperatures and drought tolerance.

NWPZ is to stabilize wheat production, to watch out the onset of rust epidemics in this region because of high uniformity of varieties grown in this area. The region would benefit with further breakthrough in yield potential, most probably through long spike program. The India Wheat Research Program needs to watch out the evolution in rust pathotypes through monitoring within the country, and indeed, all the countries, which influence the epidemiological impact in India. Such countries could be those situated in Middle East, Central Asia, Nile Valley and East Africa.

Maize Breeding in India – Retrospective Analysis and Prospects

BS Dhillon* and NS Malhi
Punjab Agricultural University, Ludhiana-141004, Punjab, India

Maize is one of the three most important food grain crops in the world. It is utilized as human food, livestock and poultry feed, industrial raw material and as fodder. In India, it occupies third position among food grains with respect to production and productivity, and ranks fifth for the area under cultivation.

The All-India Coordinated Maize Improvement Project, the first multi-centre, multi-disciplinary project of unique nature, was established in 1957. The project has made outstanding contributions not only in maize improvement but also in the development of similar research projects in other crops/disciplines. The project focused on hybrid breeding and released eight hybrids during 1961 to 1964. However, due to less than expected impact of these hybrids and the problems faced in their seed production, the breeding strategy was reassessed, and composite breeding was prioritized. A first set of composites (six) was released in 1967. Up to 1972, 21 cultivars were released which generally possessed late maturing. During 1970s the breeding programme was again assessed and reoriented towards early maturity. Further, intra-population improvement was undertaken on a vast scale to develop composites particularly early maturing. Consequently, hybrid breeding was discontinued with the exception of a few research centers. During 1980s emphasis was shifted back to hybrid breeding with a focus on the single crosses. Apparently there have been sharp turns in the breeding strategies and priorities.

Indian maize breeding programme has a very strong linkage with the International Maize and Wheat Improvement Center (CIMMYT), Mexico, and CIMMYT's maize germplasm has been extensively used by the Indian programme. CIMMYT has not only liberally supplied germplasm but has also significantly contributed in the development of human resources and has, thereby, markedly influenced breeding strategies and objectives of the Indian programme. To exploit the emerging opportunities, maize breeding needs to be focussed on specific adaptation, for example, development of input responsive hybrids (specifically single crosses) for favourable environments, and early maturing hybrids and composites possessing tolerance to stresses like low nutrient supply and extreme moisture and temperature regimes for other environments. The cultivars must possess high yield, stability of performance, multiple resistance/tolerance to biotic/abiotic stresses and appropriate maturity. Breeding efforts in special maize types (high oil, quality protein, pop, sweet, baby, specialized starch) and more specifically in winter maize and in fodder maize need to be strengthened and streamlined. Last but not least, there is an urgent need to upgrade the research in maize biotechnology in the areas like development of transgenics for biotic and abiotic stresses, marker assisted selection and prediction of hybrid performance; and integrate the same with maize breeding.

Key words: Maize, Hybrid breeding, Population improvement, Germplasm utilization, Biotechnology

Maize is one the three most important foodgrain crops in the world, the others being rice and wheat. It is utilized as human food, livestock and poultry feed, raw material for a large number of industrial products and as fodder. It is a staple food in 22 countries, two-thirds of the produce is consumed as feed, and a very large number (>3500) products/by-products can be derived from it. In India, maize ranks fifth with respect to the area under cultivation and third for production as well as productivity. There has been an impressive growth in maize production and productivity in India. The production increased from 1.73 to 11.1 million tonnes and productivity from 547 to 1920 kg/ha during 1950-51 to 2002-03. But the production in the years to come is not expected to be sufficient to meet the growing demand for maize for various uses, particularly with the expansion of dairy, piggery, poultry and maize-based industries.

Maize is a cross-pollinated crop. Its populations comprise freely interbreeding individuals, and are heterozygous and heterogeneous. The species is, therefore, adapted to heterozygosity, which is an essential feature of maize cultivars. The cultivars may be open-pollinated (OP) population or hybrid. Hybrid cultivars have the advantage of higher performance and uniformity, whereas the populations are expected to have wider adaptation. Further, the seed production of OP cultivars is easier and less costly. Before the advent of hybrids all maize acreage was cultivated with heterozygous and heterogeneous populations (races, landraces, farmers' varieties or their improved versions).

The exploitation of hybrid vigour or heterosis in maize through the use of hybrid cultivars is one of the major achievements in plant breeding. Beal (1880) was the first to propose commercial cultivation of inter-varietal hybrids. However, the exploitation of hybrid

* *E-mail: dhillonbaldevsingh@gmail.com*

vigour had to wait for the pioneering studies by Shull, East and Jones. Shull (1909) gave the 'pureline method of corn breeding', which involved the development of inbred lines and commercial single cross (inbred x inbred) hybrids. However, there was no good response as inbred lines were weak and there were problems in commercial seed production of single crosses. Jones (1918) suggested the commercial cultivation of double cross (single cross x single cross) hybrids, and their commercial use began in 1922. The adoption of hybrid maize was initially slow, but starting in the mid-1930s, the area planted to hybrids began to increase rapidly and after15 years, 95 percent of the maize acreage in the US Corn Belt was under hybrids (Duvick, 1999).

Among various types of hybrids, single crosses have the highest performance potential and are the most uniform. The maize breeders, particularly in North America continued their efforts to develop vigorous inbred lines so as to make seed production of single-cross and other simple hybrids economically viable. The cultivation of single crosses started in late 1950s and early 60's, and at present almost entire area in the USA is covered by single crosses. The productivity has increased from 1.5 t/ha in 1930 to 8t/ha by the beginning of 21st century. Similar success was obtained in Europe, where also initially double crosses and other complex hybrids were adopted and then these were replaced by single and other simple crosses.

In India, the maize improvement work was earlier largely confined to the State Departments of Agriculture. During 1940s and early 50s, the work basically involved isolated efforts on mass selection in local varieties in Punjab, Uttar Pradesh, Bengal and Central Provinces. These varieties were collected, evaluated and the seeds of promising ones were multiplied and distributed to the farmers. The cultivars that were released included KT 41 in Uttar Pradesh, Basi in Rajasthan, Pusa Yellow in Bihar and Farm Sumeri in Gujarat (Singh *et al.*, 1996). These showed only marginal improvement because of narrow intrapopulation genetic diversity and inefficient selection procedure.

Realizing the success of hybrids in developed world, isolated efforts were made in India also after the Second World War by various state departments to introduce commercial maize hybrids developed in the USA, Australia and other countries. In 1948, the Indian Council of Agricultural Research in collaboration with the state departments extensively evaluated introduced hybrids at the maize research stations at Delhi, Naraingarh (Punjab) and Almora (Uttaranchal). The evaluation of introduced hybrids was continued in early 1950s. A few hybrids from USA like US 13, Dixie 18, Texas 26, NC 27 and Illinois 1656 showed marked superiority ranging (30 to 50%) over local varieties. These were, however, not accepted by the farmers due to their unattractive (dent) grain type and late maturity. These hybrids also had problems in seed production because their parental lines were not adapted to the prevalent environment. The lines were late maturing, susceptible to pests and even failed to produce pollen. Above all, at that time, there was no seed industry which was vital for the success of hybrid cultivars.

At some stations inbreeding was carried out in the indigenous populations to derive inbred lines and develop hybrids. In Punjab, a scheme on hybrid maize was started in 1955. Four orange flints, double cross hybrids, with all parental lines derived from indigenous germplasm, were developed in Punjab. These included Punjab Hybrid 1 [(Pb68-66 x Pb72-103) x (NW12-580 x Kash2-597)] that was released in 1956. But it did not become popular due to seed production problems. A three-way hybrid was also developed at Arbhavi, Karnataka.

Coordinated Maize Improvement Project

In 1957, the All India Coordinated Maize Improvement Project (AICMIP) was established which is a landmark in maize improvement research in India. The establishment of this project greatly organised and strengthened the maize research and development in the country. The project facilitated better planning, coordination and monitoring of research activities; and in rapid generation of more precise data on the performance and stability of experimental hybrids or composites through simultaneous testing at a number of locations and, thereby, also reducing the time required for evaluation. Later on the disciplines of agronomy, pathology and entomology were added and multi-disciplinary teams devoted to maize improvement started working at many centers in the country. Maize improvement research since 1957 can be discussed under three phases.

Phase I: Hybrid Breeding

With the establishment of the coordinated project, a large number of germplasm including inbred lines were introduced from USA and Caribbean region and many locals were collected; and large-scale inbreeding was initiated in the promising introduced and indigenous germplasm. The inbred lines were crossed with varietal testers to produce top-crosses (inbreds x OP populations) which were evaluated in multilocation trials along with indigenous and exotic checks. As a result 28 inbred lines were identified and used in hybrid breeding. The first set of hybrids was released in 1961. These were Ganga 1, Ganga 101, Deccan and Ranjit, and all these were double crosses (Table 1).

For economical seed production, a short-term approach of developing non-conventional hybrids, namely double top-crosses (single cross x non-inbred parent) was adopted. As a result, in 1963, two double top-cross hybrids (Hi-starch, Ganga Safed 2) were released. The parents of these hybrids included CM202, which later on was used as a parent of other commercial hybrids;

Table 1. Maize Hybrids developed and released in India since the inception of All India Coordinated Maize Improvement Project

S. No.	Hybrid	Year of release	Area of adaptation*	Centre**
1.	Ganga 1	1961	Northern Plains	DMR
2.	Ganga 101	1961	Northern Plains	DMR
3.	Ranjit	1961	Southern Raj. and Central India	DMR
4.	Deccan	1961	Kar. and A.P.	Hyderabad
5.	VL 54	1962	Himalayan region	Almora
6.	Ganga Safed 2	1963	Across the country except hilly areas and Kar.	DMR
7.	Hi-starch (R)	1963	Bihar & U.P.	DMR
8.	Ganga 3	1964	Northern plains	DMR
9.	Him 123	1964	Himalayan region	DMR
10.	Ganga 5	1968	Northern plains and Peninsular India	DMR
11.	Ganga 4	1971	M.P., U.P. and Bihar	Pantnagar
12.	Ganga 7	1971	U.P.	Pantnagar
13.	Deccan 101	1975	Peninsular India	Hyderabad
14.	Ganga 9	1979	Himalayan region, U.P. and Bihar	DMR
15.	Him 128	1979	H.P. and U.P.	DMR
16.	Sangam	1981	Pb.	Ludhiana
17.	DHM 103	1982	Across the country	Hyderabad
18.	VL 41	1986	High elevation areas of H.P. and U.P.	Almora
19.	Sartaj	1988	Across the country	Ludhiana
20.	DHM 1 (R)	1988	Across the country	Dharwad
21.	VL 42	1988	U.P. hills, Himalayan region and Peninsular India	Almora
22.	Ganga 11	1988	Across the country except hilly areas	DMR
23.	DHM 105 (R)	1990	Across the country except hilly areas	Hyderabad
24.	Trishulata	1991	Across the country except hilly areas	Hyderabad
25.	DHM 107	1992	Across the country	Hyderabad
26.	CoH 2	1993	T.N.	Coimbatore
27.	DHM 109	1994	Across the country	Hyderabad
28.	Rajendra Makka 1 (R)	1994	Bihar, Orissa and W.B.	Dholi
29.	Paras	1995	Pb.	Ludhiana
30.	Rajendra Makka 2	1995	Bihar, Orissa and W.B.	Dholi
31.	DHM 1	1996	Kar.	Dharwad
32.	CoH 3 (R)	1996	T.N.	Coimbatore
33.	Him 129	1997	Himalayan region, Raj., Guj., and M.P.	Almora
34.	Pusa Hybrid 1	1997	Peninsular India, Raj., Guj., and M.P.	Delhi (IARI)
35.	Pusa Hybrid 2	1997	Peninsular India, Raj., Guj., and M.P.	Delhi (IARI)
36.	Parkash	1998	Across the country except hilly areas	Ludhiana
37.	Vivek Hybrid 4	1998	Raj., Guj., and M.P.	Almora
38.	Pusa Hybrid 3	2000	A.P., Mah., Kar. and T.N.	Delhi (IARI)
39.	JH 3459	2000	Pb., Har., Delhi and U.P.	Ludhiana
40.	Vivek Hybrid 9	2000	Uttaranchal, J&K, H.P., North East Hill region, Hills of W.B., A.P., Kar., Mah. and T.N.	Almora
41.	HHM 1	2000	Har.	Karnal
42.	HHM 2	2000	Har.	Karnal
43.	DHM 2	2001	Kar.	Dharwad
44.	Vivek Hybrid 5	2001	Uttaranchal, H.P., North East region and J & K	Almora
45.	Shaktiman 1	2001	U.P.	Dholi
46.	Sheetal	2002	Pb.	Ludhiana
47.	Shaktiman 2	2002	Bihar	Dholi
48.	Buland	2002	Delhi, Har., Pb., Western U.P.	Ludhiana

* Raj.=Rajasthan, Kar. =Karnataka; A.P.=Andhra Pradesh; U.P.=Uttar Pradesh; M.P.= Madhya Pradesh; H.P.=Himachal Pradesh; T.N.=Tamil Nadu; Mah.=Maharashtra; Pb.=Punjab; Har.=Haryana; J&K = Jammu and Kashmir; W.B.= West Bengal; Guj.=Gujarat.

** DMR=Directorate of Maize Research, New Delhi; IARI=Indian Agricultural Research Institute, New Delhi and CM104 and CM105, which later on showed durable resistance against leaf blights (Sharma and Payak, 1990). Among indigenous collections the most important example is Rudrapur local (CM600), the male parent of hybrid Ganga Safed 2. Inbreeding in indigenous collections showed these to be poor source germplasm for inbreeding.

The National Seeds Corporation was established in 1963 to facilitate hybrid maize seed production. Yet problems were faced in seed production (poor performance of inbred lines and lack of seed industry) and hybrid maize did not become popular on the expected scale. Other reasons were extremely low frequency of good inbred lines and lack of financial resources and infrastructure for hybrid breeding. This resulted in the reorientation of the programme with greater emphasis on composite breeding.

Phase II: Composite Breeding

The shift towards composite breeding has been due to various limitations associated with hybrid breeding and seed production as discussed above, and equally important due to the expectation of wide adaptation of composites and their seed by farmers. In 1967, six composites (Amber, Jawahar, Kisan, Vijay, Vikram, Sona) were released in the country (Table 2). On the whole the performance of these composites was encouraging. Composite Vijay became popular not only in India but also in adjoining countries. It was released in Pakistan under its experimental name J1 and in Nepal as Rampur Yellow. It is still grown as a fodder crop in some states. However, these composites could not cover large area. The major limitation was their long duration. About 85% of the crop was rainfed where early maturing locals were under cultivation. Realising this, the development of early maturing composites got prioritized in 1970s, and Makki Safed 1 (an improved local) was released in 1973, and Ageti 76, Tarun and others later on. So far, 85 composites have been released for general cultivation in different agro-climates in the country (Table 2). These covered substantial area in the country. The important ones are Vijay, Kisan, Ageti 76, Tarun, Parbhat, Navjot Arun, Type41, Shweta, Navin, Pusa Comp 1, Parvati, Azad Uttam, Mahi Kanchan, Megha, Mahi Dhawal and Devaki. Navjot has been commanding the largest breeder seed indent for more than a decade. During 1970s and 80s, large scale intra-population improvement was undertaken to develop better composites as discussed later. In this era of composite breeding and population improvement, certain centers including Punjab Agricultural University (PAU), Ludhiana, ANG Ranga Agricultural University (ANGRAU), Hyderabad and Vivekananda Parvatiya Krishi Anusandhan Shala, Almora, continued their hybrid breeding programmes in an isolated manner.

Phase III: Single Cross Hybrid Breeding

In view of the experiences with hybrids at world level and that of composites in India, and the emergence of private sector, national breeding programme was again reoriented in late 1980s with a focus on single cross and other simple hybrids. First three-way hybrid, Trishulata, was released for general cultivation in 1991 and first single cross, Paras, in 1995. These were followed by release of other single cross hybrids like Pusa Early Hybrid Makka 1 and 2, Parkash, Sheetal and Buland. In this endeavor, development and formation and improvement of heterotic pools got emphasis as discussed later.

Since 1961, 33 open-pedigree hybrids (18 double crosses, 9 double top-crosses, 4 three-way crosses, 2 varietal crosses) have been released for general cultivation (Table 1). The hybrids that played a role in increasing the maize productivity in the country include Ganga Safed 2, Hi-starch, Ganga 5, Sartaj, Ganga 11, Deccan 103 and Deccan 105. The number of cultivars released decade-wise since 1957 are given in Table 3.

Special Breeding Programmes

Breeding Maize for Winter Season

The cultivation of maize in winter season started in 1960s in some pockets in South India (Singh, 1974). Over time it has covered an area of about 0.65 million ha in different states – about 0.35 million ha in Bihar, about 0.10 million ha in Andhra Pradesh and about 0.05 and 0.07 million ha in each of Tamil Nadu and Karnataka. Maize during winter season yields higher than the traditional monsoon season particularly in Bihar and Andhra Pradesh.

It is generally believed that maize can be cultivated during winter season if it is frost free and temperature does not fall below 13°C. The climate of the above mentioned states generally qualifies the above defined climatic requirements. In North-western plains, however, the average temperature sometimes falls below 10°C and the minimum temperature may even be sub-zero; and there is frequent frost incidence in the months of December and January. The germination is delayed and it may be very low if seed quality is poor. The plant growth is

Table 2. Maize Composites released in India since the inception of All-India Coordinated Maize Improvement Project (Directorate of Maize Research since 1994)

S.No.	Hybrid	Year of release	Area of adaptation*	Centre**
(1)	(2)	(3)	(4)	(5)
1.	Amber	1967	Himalayan Hills and Peninsular India	Hyderabad
2.	Vijay	1967	Across the country except Kar.	Ludhiana
3.	Sona	1967	Across the country except Kar.	DMR
4.	Jawahar	1967	Indogangetic plains and Peninsular India	DMR
5.	Kisan	1967	Indogangetic plains	DMR
6.	Vikram	1967	Indogangetic plains	DMR
7.	Protina	1971	Throughout India	DMR
8.	Rattan	1971	Throughout India	Ludhiana
9.	Shakti	1971	Throughout India	DMR
10.	Makki Safed 1	1973	Pb.	Ludhiana
11.	Ageti 76	1976	Pb.	Ludhiana
12.	Moti	1982	Throughout country except Kar. & T.N.	Udaipur
13.	KT 41	1978	Raj State release	DMR
14.	C 1	1978	U.P.	Srinagar
15.	C 2	1978	J & K	Srinagar
16.	C 3	1978	J & K	Srinagar
17.	Mandsar	1978	J & K	Srinagar
18.	Trikuta	1978	J & K	Srinagar
19.	Nishat	1978	J & K	Srinagar
20.	Tarun	1978, 1982	U.P. & Indogangetic Plains	Pantnagar
21.	VL Makka 16	1980	U.P. Hills	Almora
22.	L 4	1980	H.P.	Bajoura
23.	Partap	1980	Pb.	Ludhiana
24.	Shweta	1980	U.P.	Pantnagar
25.	Manjari	1980	Mah.	Kolhapur
26.	V L Amber	1981	U.P.	Almora
27.	Chandan Makka 1	1982	M.P.	Chhindwara
28.	Chandan Safed 2	1982	M.P.	Chhindwara
29.	Makka			
30.	Navin	1982	U.P.	Pantnagar
31.	Amber popcorn	1982	A.P.	Hyderabad
32.	Lakshmi	1982	Pb.	Dholi
33.	Navjot	1982, 1988	Across the country	Ludhiana
34.	Partap 1	1983	Pb., Har.	Ludhiana
35.	African Tall	1983	Across the country for fodder	Rahuri
36.	Hunius	1983	J&K, H.P., U.P., Guj., Mah., Sikkim, Kar.	DMR
37.	Diara 3	1984	East & Central U.P.	DMR
38.	D 765	1984	Across the country except. Pb. Har., Sikkim & Kar.	Pantnagar
39.	Farm Sameri	1985	Guj.	Godhra
40.	Suwan	1985	Bihar	Dholi
41.	NLD	1985	Sikkim, W.B. NE region except Assam	DMR
42.	Kanchan	1986	U.P.	Pantnagar
43.	Early Composite	1986	H.P.	
44.	Hemant	1986	Bihar	Dholi
45.	Co 1	1986	Tamil Nadu	Coimbatore
46.	Renuka	1986	Kar.	Dharwad
47.	MCU 508	1987	U.P.	DMR
48.	Arun	1987	Pb., Har., U.P., Raj., & Bihar	N. Delhi (IARI)
49.	Kiran	1988	Across the country	Ludhiana
50.	Parbhat	1988	Pb. U.P., Bihar, M.P., Guj., Mah., Kar., T.N.	Ludhiana
51.	Pusa Composite 1	1988	M.P. and Guj.	N. Delhi (IARI)
52.	Pusa Composite 2	1988	Indo-Gangetic Plain	N. Delhi (IARI)
53.	Parvati	1988	H.P.	Bajoura
54.	Harsha	1988		Dharwad
55.	VL 88	1988	Uttaranchal	Almora
56.	Dhawal	1988	U.P., Bihar, A.P., T.N., Mah., Orissa, Kar. Guj., Pb., Raj.	DMR
57.	Surya	1988	U.P.	Pantnagar
58.	J-1006	1989	Pb. (For fodder)	Ludhiana
59.	Prabha	1990	Kar.	Dharwad

Contd.

(1)	(2)	(3)	(4)	(5)
60.	Madhuri	1990	A.P.	Hyderabad
61.	Varun	1990	H.P., A.P., Mah.	Hyderabad
62.	Azad Uttam	1991	Raj.	Kanpur
63.	Kesari	1992	Pb.	Ludhiana
64.	Mahi Kanchan	1992	Raj., Guj., M.P., Pb., A.P. and Kar.	Udaipur
65.	Panchganga	1993	Mah.	DMR
66.	C-6	1994	J&K	Srinagar
67.	C-8	1994	J&K	Srinagar
68.	Punjab Sathi 1	1994	Punjab	Ludhiana
69.	Gujarat Makka 1	1994	Guj.	Godhra
70.	Megha	1994	Pb., Har., Raj., U.P., Bihar, W.B., Orissa, M.P., Guj	Ludhiana
71.	Gujarat Makka 2	1995	Guj.	Godhara
72.	Pearl Popcorn	1995	Pb.	Ludhiana
73.	Mahi Dhawan	1995	Raj.	Udaipur
74.	Birsa Makkai	1995	Jharkhand	Ranchi
75.	C 14	1995	J&K	Srinagar
76.	Devaki	1995	Bihar	Dholi
77.	Jawahar Makka 8	1996	M.P.	Chhindwara
78.	Shakti 1	1997	Throughout India	DMR
79.	Gujarat Makka 4	2000	Guj.	Godhra
80.	Aravali Makka 1	2000	Raj.	Udaipur
81.	Amar	2000	A.P., T.N., Mah., Kar. and Guj., Raj & M.P.	Pantnagar
82.	NAC 6004	2001	Kar.	Nagenhalli
83.	Narmada Moti	2002	U.P., Pb., Har., Mah., Kar., Kerala, T.N., Raj., Guj., & M.P.	Banswara
84.	Jawahar Makka 216	2003	M.P.	Jabalpur
85.	Gujarat Makka 6	2003	Guj.	Godhra

* Raj.=Rajasthan, Kar. =Karnataka; A.P.=Andhra Pradesh; U.P.=Uttar Pradesh; M.P.= Madhya Pradesh; H.P.=Himachal Pradesh; T.N.=Tamil Nadu; Mah.=Maharashtra; Pb.=Punjab; Har.=Haryana; J&K = Jammu and Kashmir; W.B.= West Bengal; Guj.=Gujarat.
** DMR=Directorate of Maize Research, New Delhi; IARI=Indian Agricultural Research Institute, New Delhi

Table 3. Number of hybrids and composites of maize released in India during different periods

Period	Hybrids (no.)	Composites (no.)
1957 – 1966	9	0
1967 – 1976	4	11
1977 – 1986	5	34
1987 – 1996	14	31
1997 – 2003	16	10

slowed and there is yellowing, graying and drying of leaves (non-freezing injury) due to low temperature and mild frost, and burning of leaves (freezing injury) when there is severe frost incidence (Khehra and Dhillon, 1984). Low temperature at flowering restricts the pollen dehiscence resulting in poor or no seed set, and extreme low temperature even leads to an abnormal development of tassel. Under such environments, the cultivars should have a high level of tolerance to low temperature/frost. Further, crop production technology, particularly the method of sowing and the schedule of input (nutrient, irrigation) application, has to be such that the plant is not exposed to stress at the critical stages of growth and development, such as flowering and pollination, and is able to withstand stress. Intensive studies were carried out on the development of cold tolerant cultivars and agronomic practices for their production at PAU. Field and laboratory methods were developed to screen germplasm for cold tolerance (Khehra *et al.*, 1987; Dhillon *et al.*, 1988); and germplasm evaluation for cold tolerance under field conditions has been undertaken on an extensive scale. These efforts resulted in the development and release of cold tolerant cultivars, namely Partap and Partap 1, and their production technologies for cultivation of winter maize in Punjab in 1983, and these were later adopted in Haryana. Partap was identified to be promising among the available germplasm and intra-population improvement in it for cold tolerance, grain yield and other traits resulted in the development of Partap 1 (Dhillon *et al.*, 1984). Two heterotic pools, discussed later, were synthesized and improved for cold tolerance, grain yield and other traits; and used to derive inbred lines using which two cold tolerant hybrids, namely Sheetal and Buland, have been developed.

Breeding Speciality Maize

Special types of maize include quality protein maize (QPM), popcorn, sweet corn, baby corn, specialized starch (waxy, amylo) types and high oil maize.

Quality Protein Maize: The nutritional quality of maize is poor mainly due to high proportion of zein (prolamin) protein fraction in the endosperm that has low contents of lysine and tryptophan, two essential amino acids, and imbalanced ratio of leucine to isoleucine contents. However, the discovery of association of recessive opaque-2 (*o2*) gene with improved lysine and tryptophan contents and leucine to isoleucine ratio by Mertz *et al.* (1964), opened up new vistas in maize quality improvement. Opaque-2 maize has, however, soft grain and many other undesirable traits. Three *o2* composites (Shakti, Rattan, Protina) were released for general cultivation in 1971. But, these had low yield, soft endosperm, unattractive grain type and susceptibility to stored grain pests. Breeding efforts were continued at New Delhi to develop QPM, that carries *o2* gene along with genetic modifier genes for hard endosperm. As a result, Shakti 1, a hard endosperm version of Shakti, improved for grain appearance, yield and other agronomic traits, was released in 1997. Recently, the work on QPM has been strengthened with the introduction and utilization of QPM inbred lines developed at the International Maize and Wheat Improvement Center (CIMMYT), Mexico; and two hybrids, Shaktiman 1 and Shaktiman 2, have been released during 2001 and 2002, respectively, using these lines. Many other mutants have also been reported for improved amino acid pattern but these have received a little attention in maize breeding.

Popcorn: Popcorn is an extreme hard endosperm type flint maize with small kernel having high expansion volume on popping, and it is used as a snack food. Amber Popcorn, VL Amber Popcorn and Pearl Popcorn are the released composites.

Sweet Corn: It has high sugar content in kernel. In comparison to 3% in normal maize, 20% of dry matter in sweet corn is sugar. Sweet corn is eaten in the immature stage, and is harvested at about 70% moisture in kernels. Kernels are high in sugar when they are eaten on the cob, or are canned or frozen. Madhuri and Priya sweet corn composites have been released for general cultivation.

Baby Corn: Baby corn is the young ear of maize at or before silk emergence and is consumed as a vegetable, salad, in soup and some other preparations. Early maturity, prolificacy, yellow cob colour and regular arrangement of kernel-rows are some desirable traits. Also relevant is quality of stalk which is used as green fodder after the cobs are picked up. Though, no cultivar has been developed specifically as a baby corn, early maturing hybrids, namely Parkash, Vivek 4 and 5, Pusa 1 and 2 are being cultivated as baby corn.

Specialized Starch Type Maize: Normal maize starch has 78% amylopectin and 22% amylose. A recessive gene, *waxy* (*wx*), results in the starch that has 100% amylopectin and waxy appearance of the kernel. Waxy maize is grown to supply raw material for specialty products of the wet milling starch industry and the separation cost of amylose and amylopectin is avoided. Waxy experimental hybrids are under evaluation. Amylo-maize has *amylose extender* (*ae*) gene which doubles the amylose content in the kernel's starch and possesses normal kernel appearance. It is used in preparation of cellophane, films, fibres, plastics, food and other products.

High Oil Maize: Maize oil has high proportion of unsaturated fatty acids and is an excellent cooking medium for human beings. It is also a source of high energy cattle feed. Some work on breeding for high maize oil has been initiated and germplasm with 6-7% oil content in the kernel have been identified.

Breeding for Resistance to Pests

Maize has number of serious diseases, such as stalk rots, leaf blights and downy mildews, and insect-pests like stem borers. To breed for resistance, germplasm and breeding materials need to be continuously evaluated for their reaction to pests. To accomplish it, many hotspot locations among the available coordinated research centers were identified and used. These include Pantnagar for stalk rots and brown stripe downy mildew, Ludhiana for maydis leaf blight and post-flowering stalk rots, Gurdaspur for brown stripe downy mildew and banded leaf and sheath blight, Delhi for maydis leaf blight and banded leaf and sheath blight, Udaipur for sorghum downy mildew. In addition certain centers were specifically created in hot spots to work on disease resistance, namely Dhaula Kuan for stalk rots and brown stripe downy mildew, Mandya for sorghum downy mildew and Nagenhalli for turcicum leaf blight. The Project developed excellent stem borer (*Chilo partellus*) rearing laboratories at Delhi and Ludhiana, and a large germplasm are evaluated every year under artificial infestation conditions.

Population Improvement

Population improvement involves recurrent selection, that is, selection generation after generation with recombination of the selects. It aims at gradually increasing the frequency of favorable alleles in the population and at the same time maintaining genetic variability. It may be carried out for intra-population or inter-population improvement. Intra-population improvement is carried out in a population to accumulate genes in a manner that the mean of improved population is maximized. Inter-population improvement involves two populations and accumulates genes to maximize the mean of inter-population cross between their improved versions and the inbred lines derived from them.

Intra-population Improvement and Cultivar Development

An extensive intra-population improvement programme was initiated at the national level during 1974 to enhance the performance of a number of elite populations representing different maturity groups and adaptation to agro-ecologies. These populations include Vijay, Makki Safed 1, Ageti 76, Navjot, Kiran, Partap, Parbhat, J663, D1, D743, BVI, Manjri, Diara, Hunius, L4, H3, Safaida, J1 Arr2, B21, B23, Pool 7, Tarun, Naveen, Surya, Kisan, Super 1 & 2. In the project, five broad based gene pools (both in yellow and white grain colour), AB yellow, AB white, BC yellow, CD yellow and CD white representing a wide array of maturity levels germplasm were constituted and subjected to population improvement. In almost all cases, modified full-sib (FS) family selection method was followed in which recombination of selected families and generation of new families were carried out simultaneously and one cycle of selection was completed in a year (Lonnquist, 1964, Compton and Lonnquist, 1982). These studies generally resulted in 2-3% gain in grain yield per cycle of selection. However, the experiences at P AU showed that intra-population improvement accompanied by introgression of new germplasm was more rewarding than the elite populations without germplasm introgression as generally conducted by various centres of AICMIP, when the objective is to improve the populations for direct use as commercial cultivars. Intra-population improvement in released composites resulted in the development of only a limited number commercial cultivars, namely Partap 1, Diara 3 and MCU 508.

Inter-population Improvement and Development of Heterotic Pools

Initially inter-population improvement did not get much attention because of its complexity and large resource requirement, and above all, emphasis on composite breeding. Yet a reciprocal recurrent selection programme was undertaken in J1 (Vijay) and Cuba 11J. In view of the international experience in hybrid maize breeding, a number pairs of heterotic pools were later developed. The PAU developed three pairs of heterotic pools to cater to the needs of different agro-climates (Dhillon *et al.*, 1986). These are Makki Safed and Tuxpeno pools and Indigenous and Semi-exotic pools adapted to the monsoon season, and Ludhiana Lancaster and Ludhiana Stiff Stalk adapted to the winter season. Makki Safed and Tuxpeno pools have high yield potential and long duration. These were developed using Makki Safed 1-DR (an improved local) and Tuxpeno PBL (an adapted version of Tuxpeno Planta Baja C7) as testers. Indigenous and Semi-exotic pools have short duration and stress tolerance. The testers used to develop these pools were JS2 (composite constituted from elite locals collected from rainfed areas in Punjab) and CM124 x CM125 (male parent of double cross hybrid Sartaj). Semi-exotic pool has two sub pools, namely Semi-exotic pool A and Semi-exotic pool B, on the basis of type of germplasm used. For the development of Ludhiana Lancaster and Ludhiana Stiff Stalk, CM202 x Mo17-# and B73 x B79-# were used as testers. To facilitate the germplasm from one pool to another, efforts were made to assign Lancaster related materials to Makki Safed pool, Semi-exotic pool A and Ludhiana Lancaster pool; and Stiff Stalk related materials to Tuxpeno pool, Semi-exotic pool B and Ludhiana Stiff Stalk pool.

Modified reciprocal recurrent selection, discussed later, was carried out to enhance heterosis between the opposite pools, while at the same time paying due attention to performance of pools per se and variability within them (Dhillon *et al.*, 1997). New germplasm was introgressed keeping in view the above objectives and to rectify specific defects. The overall objective was to develop heterotic pools which are genetically diverse, highly heterotic, have good performance per se and acceptable inbreeding tolerance; so as to promote the derivation of vigorous and heterotic inbred lines and high performance hybrids.

The important germplasm which have been used to develop various pools or has been introgressed into the pools are: Makki Safed pool - indigenous germplasm (Makki Safed 1-DR, J617, J6663), indigenously developed materials using exotic germplasm (Vijay, Ageti 76, Partap, Navjot, Tarun, Arun, CM202) and US Corn Belt lines (Mo17, FR13A, FR619, FR670, FR Va26, H96, H101); Tuxpeno pool - Tuxpeno Planta Baja, CM123, CM206, Suwan 1 and B73; Indigenous pool - locals and related germplasm; Semi-exotic pool A - Makki Safed pool, Ageti 76, Tarun, Mo17 and FR13A; Semi-exotic pool B - B73, B79, Tuxpeno pool, CIMMYT

Populations 24, 26, 31 and 36; Ludhiana Lancaster pool - Partap and Lancaster germplasm (CM 111, CM202, CM205, Mo17, FR13A, B57, H98, H99, H101, A670, FRVa26); and Ludhiana Stiff Stalk pool - Suwan 1 and Stiff Stalk germplasm (B73, B79, B84, FR632, H100, BS13, MSP!). In case of populations, inbred lines derived from them were tested in combination with the tester, and selected ones used for the synthesis of pools or introgression into them. Commercial hybrids like Paras, Parkash, JH3459, Sheetal and Buland have been developed using the inbred lines derived from these heterotic pools.

The AICMIP developed eight pairs of complementary heterotic pools in various maturity groups (Singh, 1995). These include XI(Y), X2(Y); XI(W), X2(W), in each maturity group. In full season maturity the testers used were CM111 and CM202 for yellow (Y) and CM300 and CM400 for white (W) grained pools. Two early maturing pools [Pool 1 (tester: Pop. 31), Pool 2 (tester: Tarun)] have recently been developed by GB Pant University of Agriculture and Technology, Pantnagar, and VPKAS. Two pairs were developed by Indian Agricultural Research Institute, New Delhi (A62 x AD609, A61 x MDR1).

Collaboration with CIMMYT

Indian maize breeding programme has a very strong linkage with CIMMYT since the latter was established in 1960s. The CIMMYT liberally supplied germplasm which has been extensively used in the Indian breeding programme. Further, there has been a free flow of scientific ideas and strong support in human resource development and capacity building. The AICMIP has been a very active partner in CIMMYT's international progeny, experimental variety and elite experimental variety testing programme. In addition to these, AICMIP is operating some specific projects in collaboration with CIMMYT on breeding for resistance/tolerance to Asian maize stem borers and resistance to downy mildews and post- flowering stalk rots. Indian maize programme has not only been greatly benefited by the materials generated at CIMMYT, but its breeding strategies and objectives (composite breeding and population improvement in 1970s and hybrid breeding in 1980s) have also been influenced by the CIMMYT.

Advances in Breeding Methodology

New scheme of population improvement programme having higher genetic gain per unit time as compared to those already available, and an approach to efficiently sample foundation plant for inbreeding have been proposed. Further genetic stocks for haploidy induction have been developed. These are briefly discussed below:

Selfed Plant Mass Selection

Selfed plant mass (SPM) selection, proposed by Dhillon (1991a), involves selfing of plants in a random mating population and subjecting the resultant S1 population to modified mass selection of Gardener (1961). One cycle of SPM requires one (off) season for selfing the plants and another (test) season for evaluation and recombination and it can be completed in a year if an off-season nursery is available. The relative efficiency of SPM selections vs. mass selection has been examined by Dhillon (1991a). The SPM selection generally has higher expected genetic gain per cycle, when mean degree of dominance varied between no dominance to complete dominance and gene frequency from 0.1 to 0.7, than mass selection. Three cycles of SPM selection were carried out in an experimental composite, J1413, and 2.4% gain per cycle was obtained for grain yield (Table 4).

Table 4. Selfed plant mass selection in J1413

Population	Grain yield (Kg/ha)	Days to silk	Plant height (cm)
J1413C3	3963 (7.3%)*	56.6	173
J1413C0	3695	56.3	171

*Gain due to selection

Modified S1 Selection

There are three types of families, namely half-sib (HS), FS sib (FS) and selfed (S); and among these, S families have the largest variability. But a cycle of selection based on S families generally requires more seasons than those based on HS and FS families. One cycle of S1 (one generation selfed) family selection requires three seasons for (i) development of families, (ii) evaluation of families, and (iii) recombination of selected families. In modified S1 (MS1) selection, the evaluation and recombination phases are accomplished together (Dhillon and Khehra, 1989). The evaluation experiment in one environment is grown in an isolated evaluation-cum-recombination block (Lonnquist, 1964) in which S1 families are inter-planted with balanced male (BM) composite developed by mixing an equal number of seeds of all S1 families under evaluation. The S1 families are detasseled and are, thus, allowed to pollinate with the pollen of BM composite. Selection is conducted among and within S1 families.

One cycle of MS1 selection is completed in two seasons, one (off) season to develop S1 families and another (test) season to evaluate and recombine S1s; and in one year if an off-season nursery is available. The expected genetic advance of MS1 selection vs. other methods of intra-population improvement (for assumed heritability estimates relevant to breeding programmes) showed the superiority of MS1 selection over others. Sekhon *et al.* (1999) conducted two cycles of MS1 selection in Composite Kesri and obtained 3.2% grain in grain yield.

Two-stage Recurrent Selection

Dhillon (1991b) proposed alternate evaluation of S1 and HS families to take advantage of the fact that recombination of selected families generates HS families. One cycle of the proposed selection method requires four seasons. It was shown that alternate evaluation of HS and S1 families has higher expected genetic gain than other methods of intra-population improvement. Various other options involving different types of families (S1, S2, HS, FS) and individuals were also considered. Dhillon *et al.* (1993) discussed two-stage recurrent selection to breed for resistance to insect-pests. Kaur (1996) carried out two-stage recurrent selection in Composite Parbhat. She conducted two cycles in 2 years and each cycle included HS selection and MS1 selection. She reported 12.9% gain per cycle of HS/MS1 selection.

Modified Half-sib Reciprocal Recurrent Selection

Comstock *et al.* (1949) proposed reciprocal recurrent (RR) selection for inter-population improvement of two heterotic populations. The method involves development of inter-population top-crosses (HS families, tester – opposite population) and S1s, evaluation of top-crosses, and within population recombination of S1s selected on the basis of top-cross performance. In modified HSRR (MHSRR) selection (Dhillon *et al.*, 1997), the evaluation of intra-population HS and S1 families is incorporated into RR selection. It involves: (i) development of S1s in each population (test season), (ii) development of inter-population top-crosses (S1s x opposite population) and possible mild selection in S1s (off-season), (iii) evaluation of top-crosses (test season), and (iv) within population recombination of S1s selected on the basis of top-cross performance aided by performance per se, that generates HS families within each population (off-season). The HS families are evaluated in the next (test) season, and in selected HSs, S1s are developed for second cycle of selection. Thus, intra-population improvement is incorporated in inter-population improvement in MHSRR selection. It aims at the concentration of genes for enhanced heterosis and performance per se; and is an appropriate method to develop source populations for the derivation of heterotic and vigorous inbred lines. The method was proposed for Hico breeding (Hico being an inter-population cross having high heterosis in F1 and least inbreeding depression in subsequent generations raised through random mating) to partially exploit heterosis in the absence of well developed seed industry, and is still relevant in less developed regions/countries. Two cycles of MHSRR selection (without germplasm introgression) were practiced in MS1-DR and Tux PBL and (MS1-DR x Tux PBL) C2 Syn2 and Syn3 were evaluated. In Syn 3 grain yield declined 8.7% but Syn 3 was on a par with the composite check. It indicated the possibility of hico breeding.

Comprehensive Recurrent Selection

Recurrent selection may have one or more of the following objectives: (i) improvement of random mating generation of the population for the development of germplasm and OP cultivars, (ii) improvement of selfed generation of the population enabling development of productive inbred lines, and (iii) improvement of the combining ability to develop high performance hybrids. Comprehensive recurrent selection offers opportunities to select for all three objectives (Dhillon, 1998). The various steps are: (i) development of HS families in the first (off) season, (ii) evaluation of HS families and development of S1 families in HS families in the second (test) season, (iii) development of test-crosses (TCs) in an isolated crossing block in third (off) season and also mild selection among S1 families, (iv) evaluation of TCs and their S1 parents in separate trials and selection among TCs and S1s in the fourth (test) season, and (v) recombination of S1 families selected on the basis of TC and S1 performance, thereby, generating HS families for evaluation in the next cycle of selection. The selfs in selected S1 families may be used for inbred lines development. Comprehensive recurrent selection is a multi-stage recurrent selection based on the evaluation of inbred (S1) and outbred (HS) families within a population and crosses (TCs) with an appropriate tester (for example – related or unrelated), and represents a synthesis of intra-population and inter-population improvement. Dhillon (1998) compared comprehensive recurrent selection with other methods and showed it to generally have higher expected genetic gain.

Unit Selection

Singh and Singh (1968) and Singh *et al.* (1982) proposed unit selection and its modifications. They considered a sub-population derived from six plants as a unit. In unit selection three female plants are pollinated with bulk pollen of three selected male plants. The resulting units are evaluated as experimental varieties and also used to develop second cycle units. This method has been used in a number of populations, which led to the development of some composite cultivars including MCU 326 and MCU 508.

Other Modifications in Population Improvement Methods

Two dual purpose designs that permit the conduct of selection as well estimation of additive and dominance components of genetic variance, have been proposed. These are combined HS-FS selection (Dhillon *et al.*, 1984), partial diallel matings in modified FS selection (Dhillon *et al.*, 1987). Many suggestions have also been given to enhance the genetic gain due to recurrent selection methods based on evaluation-cum-recombination block (Vasal *et al.*, 1997).

Selection of Foundation Plants for Inbreeding

Dhillon *et al.* (1994) proposed to sample the foundation plants for inbreeding, as half-sibs rather than S1s, and then initiate inbreeding. This helps in better sampling and identification of foundation plants.

Production of Homozygous Lines through Haploidy

The production of homozygous diploid lines through doubling the chromosome number of haploids is a quicker approach than the conventional approach of selfing and selection for 5-6 generations or more. This requires efficient method to produce and identify haploids and then chromosome doubling through colchicine treatment. Sarkar *et al.* (1994) developed haploidy inducer lines (using Coe Stock 6) yielding haploid frequency as high as 5%. They also incorporated suitable genetic markers (seed marker) in the inducer stocks to identify haploids.

Relative Expected Genetic Response for Intra-population Improvement

Expected Response to Selection

Hallauer (1992) worked out expected response to different methods of population recurrent selection for intrapopulation improvement in Iowa Stiff Stalk Synthetic of maize. His results alongwith additional computations are presented in Table 5. SPM selection showed higher expected response than modified mass selection when a year had two seasons, but modified mass selection seemed to be better when there is only one season per year. Among family-based methods, S_1 selection showed markedly higher expected gain per cycle than other methods. The MS_1 selection closely followed by MFS selection had higher expected response per year than other methods when the year was assumed to have two seasons. On the other hand, expected response due to MER selection was higher when only one season per year was available. The AR selection showed higher expected response than other methods under both situations: HS-S_1 and MER-S_1 selection methods being better when a year had two seasons and HS-MS_1 selection being better when a year had only one season.

Impact of Improved Cultivars on Productivity

The impact of a crop improvement programme depends upon the adoption of improved varieties and is expressed as productivity enhancement. The data on average yield, area under high yielding varieties (HYV), and area under irrigation (from TE 1961-62 to TE 2001-02, decade wise) are presented in Table 6. The productivity around the time

Table 5. Expected response to different methods of intrapopulation recurrent selection for grain yield in Iowa Stiff Stalk Synthetic of maize

Selection Methods	Expected response (g/plant)*		
	Per cycle	Per year**	
		Two seasons	One season
Modified mass	3.5	3.5	3.5
Selfed plant mass	5.1	5.1	2.6
Mod. Ear-to-row (MER)	7.8	7.8	7.8
Standard Half-sib (HS)	8.2	8.2	4.1
FS	10.8	5.4	3.6
Mod. FS	10.8	10.8	5.4
S1	17.5	8.8	5.8
Mod. S1 (MS1)	11.2	11.2	5.6
AR: HS - S1	25.7	12.9	6.4
AR: MER - S1	25.3	12.7	6.3
AR: HS - MS1	19.4	9.7	9.7

* Estimates of components of variance used to predict response were reported by Silva and Hallauer (1975): $V_A = 169$, $V_D = 193$, $V_{AE} = 92$, $V_{DE} = 75$, $V_E = 185$, $V_E = 1301$. Selection intensity was assumed to be 10% (k=1.75). Three environments each with two replications were assumed for family evaluation and selection. Equal allele frequency (p = q = 0.5) was assumed for the methods based n the evaluation of selfed populations and selfed progenies.

** A year is considered to have two crop seasons (one for evaluation and another for raising off-season breeding nursery) and a year has only one season.

Table 6. Mean yield, area under high yielding varieties (HYV) and area under irrigation in India

Year	Yield (kg/ha)	Area under HYV (%)	Area under irrigation (%)
TE 1961-62	940	–	10.7
TE 1971-72	1049	8.6	16.2
TE 1981-82	1100	30.1	19.3
TE 1991-92	1509	46.2	22.2
TE 2001-02	1896	58.0	21.7

of release of first set of the hybrids was 940 kg/ha (TE 1960-61) which doubled to 1896 kg/ha during TE 2001-02. The impact of improved varieties is evident as the area under HYV during the same period increased from 8.6 to 58.0%. Of course, other inputs also contributed to the productivity increase. For example, the area under irrigation rose from 10.7 to 21.7%.

In comparison to maize, the impact of HYV of wheat and rice on productivity and production has been far greater. The progress in maize is still very significant when analyzed in the following context:

1. In both wheat and rice, new plant types which have dwarf stature, lodging resistance and input responsiveness were developed. But in maize no such advancement could be made (deployment of dwarfing gene did not favorably affect grain yield). Even in the absence of such a path-breaking research in plant type of maize, there has been steady improvement in grain yield.
2. Wheat and rice improvement programmes in India in comparison to that of maize, got distinctly greater support from the international agricultural research system. There are many direct releases in India, of wheat and rice materials developed at CIMMYT and International Rice Research Institute, Manila, respectively. In maize, however, the only direct releases of CIMMYT's maize materials are Laxmi, Hemant, Dhawal, NLD, Kanchan, Panch Ganga and Devaki, and these also did not occupy large area.
3. Seed supply in maize is critical factor and it continues to be a limiting one even at present. In hybrid maize it has to be continuous, as fresh seed is needed for every planting. Even in case of composite cultivars of maize, more frequent seed replacement is needed than that in pure line cultivars of wheat and rice. In composites, there may be outcrossing disturbing the genetic structure and adversely affecting the performance and phenotypic appeal.
4. Most importantly, the national food security needs and policy favoured wheat and rice. Subsidy on inputs (fertilizer, water, electricity) has benefited rice more than maize (Table 7). Both rice and wheat have minimum support price, assured procurement and are included in public distribution of foodgrains. In 1980, there was price parity of maize and paddy but presently maize price is about 80% of rice (Table 8).

Table 7. Maize and rice area under irrigation and High Yielding Varieties (HYV)

Year	Rice	Maize
Irrigated Area 1995-99	51.0	22.0
Area under HYV (%) 1995-98	74.9	58.6

Table 8. Minimum support price of maize and rice since 1976-77

	MSP (Rs/q)	
Year	Rice	Maize
1976-77	74	74
1982-88	122	118
1991-92	230	210
1996-97	380 (414)*	320 (332)
1998-99	440 (495)	390 (427)
1999-2000	490 (562)	415 (461)

* Increase in MSP (over 1976-77)

In spite of all these factors the productivity increase in maize has been at least as good as that in rice (Table 9).

Maize Improvement Programme – An Analysis

The AICMIP, a multi-centre and multi-disciplinary project, was the first of its kind in India. Besides the development of improved varieties that have played a significant role in increasing maize production and productivity, the project gave a short-term approach of developing non-conventional (double top-crosses), concept of composite breeding, new methods of intra- and inter-population improvement with higher expected response to selection. The AICMIP was also instrumental in laying the foundation of seed industry with the establishment of National Seeds Corporation. Above all the project has served as a model of coordinated efforts leading to the establishment of a large number of similar projects in crop improvement research as well as in other areas like long-term fertilizer application, rodent control and pesticide residue. But an analysis of the achievements, objective and approaches, indicates that the programme may have suffered on following accounts.

Table 9. Increase in productivity of maize and rice since 1951

Year	Rice			Maize		
	Mean yield (kg/ha)	% increase in productivity over		Mean yield (kg/ha)	% increase in productivity over	
		1951-56	1976-81		1951-56	1976-81
1951-56	815	–	–	741	–	–
1956-61	914	12	–	856	15	–
1961-66	986	21	–	992	33	–
1966-71	1033	27	–	1066	44	–
1971-76	1128	38	–	1022	38	–
1976-81	1227	51	–	1065	43	–
1981-86	1393	71	14	1252	68	17
1986-91	1622	99	32	1371	85	29
1991-96	1829	123	48	1539	107	44
1996-01	1920	136	56	1772	139	66
2001-02	2066	153	68	1918	159	80

Consistency in Breeding Programme

There have been very sharp turns in the breeding approach. The hybrid breeding was taken up with the establishment of the AICMIP in 1957. Eight hybrids were developed and released since 1961 to 1964. Considering that lower than expected progress in the area under hybrid maize is due to seed production problems, composite breeding got prioritized. Six composites were released in 1967, but again the acceptance of HYV was not as much as expected. Up to 1972, 21 cultivars were released and all these were of at least 95-day maturity with some exceptions (national releases like Ganga 1, Ganga 3, Vikram in comparison to about 80 to 85 days maturity of most of the locals under cultivation. Expecting the longer duration of HYV to be the main factor limiting their popularity, the breeding programme was reoriented during 1970s towards early maturity. Further, intra-population improvement was undertaken on a vast scale. There is no disagreement on the importance of early maturing composite cultivars and their population improvement but whole emphasis shifted to these. Consequently, hybrid breeding was discontinued except at some centers where it was practised on a small scale. Again a similar shift took place in late 1980s when emphasis was shifted to hybrid breeding particularly single crosses at the cost of other options.

It was, however, not appreciated that outstanding cultivars, namely Hybrid Ganga Safed 2, Hybrid Hi-Starch, Hybrid Ganga 5 and Composite Vijay, were developed during 1960s. These performed very well in farmers' fields and continued to be under cultivation over a long period. The success of four of 16 cultivars (three of 10 hybrids and one of six composites) released during 1960s was not a poor performance. Evidently, an in-depth analysis was not carried out that resulted in sudden turns in the breeding programmes rather than a balanced approach. An emphasis on the development of hybrids and composites having full season maturity to create an initial impact in favourable agro-ecologies was a sound approach. But neither ignoring the development of early maturing cultivars over a long period (1960s) nor diverting almost all resources to composite breeding and population improvement (1970s) are understandable. The same is true of the present overwhelming emphasis on single cross hybrid breeding.

Population Improvement and Germplasm Introgression

As discussed earlier an extensive intrapopulation improvement was undertaken in elite composites without any germplasm introgression, whereas the experiences at PAU indicated intrapopulation improvement accompanied by germplasm introgression has been more successful in cultivar development.

Emphasis on Wide Adaptation

Maize is cultivated in India under very diverse conditions including many stresses. Probably there has been greater than required emphasis on breeding for wide adaptation under favourable conditions

Utilization of Indigenous Germplasm

Variability in the indigenous germplasm, though, limited in comparison to that in the center of diversity, is of special significance as this germplasm has evolved in balance with the prevalent agro-climatic/factors including biotic and abiotic stresses, cropping patterns and needs of the farmers. This is highlighted by the fact that locals continued to be cultivated over a large area indicating that they possess certain traits that enable them perform well on the farmers' fields. Further, Ganga Safed 2 had Rudrapur Local as male parent. But the importance of local germplasm was not appreciated and its utilization, practically ignored.

Breeding Programmes of Different Centres

All the centres of the AICMIP did not work seriously and efficiently. Some centres simply conducted the evaluation trials. These did not have any worthwhile breeding programme and did not develop any commercial cultivar. An analysis is presented in Table 10.

Utilization of Non-inbred Parents of Hybrids

Hybrids Ganga Safed 2, Hi-Starch and Ganga 5 were all double topcrosses, their male parents being Rudrapur Local (CM600), Jellicourse (CM601) and Antigua Gr.I (CM500), respectively. The natural course should have been to derive inbred parents or at least develop non-inbred parents (populations/synthetics or HS/FS families) with narrow-genetic base or early generation inbred lines. Some work was carried out on the development of inbred lines but it was not successful. Perhaps, more intensive efforts were needed. In case of severe inbreeding depression (as in case of locals because of their narrow genetic base), options of recycling of early generation inbred lines or the development narrow-genetic base non-inbred parents might have been examined. It may be added that inbreeding in Suwan 1 (CM501), the male parent of double top-cross, Ganga 11, has been carried out successfully.

Table 10. Number of cultivars released at national and/or state level that have been developed by different centres

Centre	Hybrids	Composites	National+State=Total[1]
a) Centre that developed cultivar released at national and state level			
Delhi - DMR	9	11(10)	19+1 = 20
1. Delhi - IARI	3	3	6+0 = 6
2. Ludhiana	7(4)	14(8)	12+9 = 21
3. Hyderabad	8	5(2)	11+2 = 13
4. Almora	7	3	7+3 = 10
5. Pantnagar	2(1)	7(3)	4+5 = 9
6. Dholi[2]	4(2)	4	2+6 = 8
7. Udaipur	0	4(1)	3+1 = 4
8. Kohlapur	0	3(1)	2+1 = 3
b) Centre that developed cultivar released at state level only			
1. Srinagar	0	9	0+9
2. Godhra	0	6	0+6
3. Chhindwara	0	5	0+5
4. Dharwad	2	2	0+4
5. Coimbatore[3]	2	1	0+3
6. Kullu	0	3	0+3
7. Karnal[3]	2	0	0+2
8. Kanpur	0	2	0+2
9. Nagenhalli	0	1	0+1
10.Ranchi	0	1	0+1

[1] Releases at national/zonal level or over states + state level = total
[2] Two hybrids and two composites are direct introductions
[3] Are/were not centres of AICMIP

Recording and Utilization of Data

There are certain limitations in data recording and utilization which need to be corrected. Grain yield is computed assuming 80% shelling and is adjusted for grain moisture (15%). But there is wide variation in shelling percentage (Dhillon *et al.*, 1994) which is ignored. Further, the method used to estimate grain moisture is prone to sampling and technical fluctuations.

The data are sometimes interpreted very strictly, such as the differences in days to silk of the experimental entry vs. check cultivar, even though, it is well appreciated that this trait is appreciably influenced by environment; and there is variability for post-silking days to maturity and days to silk is not a fool proof indicator of days to mature (Mittal *et al.*, 1997).

Pollination Technique

Silks are cut to carry out control pollination. But pollinating without silk cutting has certain advantages (Dhillon, 1998) and this needs to be adopted.

Hybrid vs. Composite Breeding

Hybrid and composite breeding and cultivars have certain advantages and limitations as discussed earlier. Hybrid cultivars have higher performance potential and better phenotypic appeal. However, composite cultivars are expected to be more widely adapted and stable. These also have an advantage in simpler seed production and their maintenance by the farmers; whereas, farmer cannot maintain hybrid cultivars and fresh F1 hybrid seed is required for every planting. In composite breeding, the breeder selects the promising materials and recombines them, thereby, generating a number of new genotypes. Thus, breeder does not have a full control over the materials that he is handling. This affects breeder's skill, interest and criticality (he can not identify all the genotypes in the population). In comparison to composite breeding, hybrid breeding is complex, resource and technology intensive, and has long gestation period. But the breeder has the control and knowledge over the process. On the whole both types of cultivars have a place in the agriculture in developing countries.

Maize Improvement Programme – Objectives and Approaches

Maize is a C4 plant, has wide adaptation (monsoon, winter and spring/summer seasons) and has diverse breeding options. The demand for maize is bound to increase due to consumption for human food, livestock and poultry feed and as industrial raw material. Maize has an added importance as it is an important candidate to replace rice in rice-wheat cropping system. This system is the most popular one and it, specifically rice, has adversely affected soil heath and quality and quantity of water particularly in North-West India; and there is an urgent need for diversification. Maize requires less water than rice and has less adverse effects on soil and water resources.

Objectives

To exploit the emerging opportunities, maize breeding needs to be more focused on the following objectives:

Breeding for Specific Adaptation: Earlier there has been emphasis on wide adaptation. Though, there has been good success, but it is easier to breed for high yield in combination with specific adaptation rather than wide adaptation. Further, this will enhance on-farm diversity. The breeding programmes need to emphasize the development of cultivars as follows:

Input Responsive, High Yielding Hybrids: To get a quantum jump, it is imperative to develop input responsive hybrids for cultivation under optimum growing conditions. Irrigated areas in monsoon season and winter season provide such maize production conditions. While breeding cultivars for these areas, the emphasis should be on the development of high yielding, input responsive hybrids, preferably single crosses, of as long duration as much permitted by the prevalent cropping systems. For intensive cropping system under irrigated conditions, the duration of the hybrids has to be shorter as per requirement of the crop rotations. Efforts should be made to exploit the positive correlation between grain yield and crop duration. In winter maize breeding programme, there seem to be greater chances of exploiting temperate germplasm. Further, tolerance to low temperature is an important trait.

Stress Tolerant, Short Duration Cultivars: Maize is cultivated under different stresses; and cultivars (composites and hybrids) with stress tolerance, good and stable yield and generally short duration are needed for cultivation under the stressed conditions.

Drought and Low N Stresses: During monsoon season, about 80 per cent of maize area is under rainfed cultivation where the crop faces many stresses; drought and low N being the main stresses. In addition to stress tolerance and short duration, other important traits while breeding for drought tolerance, include short anthesis-silking interval, prolificacy, stay green, increased number of kernels, reduced tassel size and plant height. The evaluation and selection under high plant density has been effective in reducing anthesis-silking interval and barrenness, and increasing harvest index.

Water Logging: It is another important stress encountered during monsoon season. Genetic variability has been observed for various agronomic traits under water-logged conditions. Brace root development and root porosity are the important traits for avoiding damage due to water logging. 'Saracura' a population developed in Brazil having tolerance to water logging need to be studied for adaptation to Indian conditions and use in the breeding programmes.

High Temperature Stress: Maize is cultivated during spring/summer season on a limited scale. This season is characterized by high temperature (>40°C) that results in tassel blast, pollen desiccation and ovule abortion. *Sathi* germplasm (about 70 days to mature) possesses heat tolerance and that need to be exploited in breeding cultivars for this season.

Breeding Fodder Maize: Maize is an important fodder crop, but this has not received due attention. Only two composites of fodder maize, African Tall and J1006, have been released. Of these, African Tall has higher fodder yield but is low grain yielder. A strengthening of the programme on fodder maize breeding with due importance to fodder yield, nutritional quality and seed yield is called for. There are greater chances of utilizing tropical germplasm in fodder maize breeding. Further, closer and effective collaboration is required between the scientists working on maize and fodder crop projects to develop fodder maize cultivars, preferably composites.

Breeding Speciality Maize: Quality protein maize has special significance for us in view of maize being staple food of a large population including tribal and poor; and it has recently been focused again. It may be more rewarding if the development of single crosses for cultivation during winter season is prioritized. Other specialty maize namely baby corn, popcorn, sweet corn, waxy and amylo-maize possess high market value. Uniformity of their produce is preferred for processing. Therefore, the emphasis has to be on hybrid breeding. However, not much effort has been made to breed cultivars, hybrids or even composites, of these special maize types.

Breeding for Intercropping Systems: Maize is cultivated in some intercropping systems. The experiments conducted in other crops do not indicate any need for separate breeding programmes for mono- and intercropping systems. But there is a need to generate such information in maize. Some important traits while breeding cultivars for intercropping are short plant height, narrow and erect leaves and small tassel.

Breeding for Multiple Resistance to Biotic Stresses: To realize yield potential, incorporation of resistance to the diseases and insect pests prevalent in the given season and region, is very important. With the intensification of agriculture, stalk rots, downy mildews, leaf blights and stem borers, which cause considerable economic losses, are becoming more serious. It is important to pay more attention to develop genetic stocks possessing multiple resistance and combine resistance with other desirable traits in improved varieties.

Development of Seed Production Technology: Seed production technology did not get much attention in the past. In fact seed production of hybrids was taken for granted. The importance of research on seed production technology has increased with single cross hybrid breeding. Inbred lines need to be evaluated under different agronomic treatments so as to develop a complete seed production-protection technology package.

Approaches: To achieve these objectives, the approaches that need to be strengthened/followed are:

Development and Improvement of Heterotic Pools: The synthesis and improvement of heterotic pools greatly facilitate hybrid cultivar development. The pools should be diverse, heterotic and have high mean performance, inbreeding tolerance and within-population genetic variability. To accomplish this, diverse germplasm need to be evaluated for these parameters and put together in two or more pools keeping in view pedigree and geographic diversity; and subjected to population improvement accompanied by germplasm introgression.

Integration of the Population Improvement with Hybrid Breeding: This integration is very important but has been lacking. Population improvement methods that involve the evaluation of crossbred and selfed families should be preferred so that inbred lines and hybrids are continuously obtained as a spin off (Dhillon *et al.*, 1997; Dhillon, 1998).

In the development and improvement of pools and integration of population improvement and hybrid breeding, choice of base populations, selection method and selection criteria are all important.

Development of Vigorous Inbred Lines: The importance of vigorous lines has increased with single cross hybrid breeding. To accomplish it, greater emphasis has to be laid on the improvement of performance per se and inbreeding tolerance of base germplasm and selection for performance per se of inbred progenies during inbreeding.

Development of Seed and Pollen Parents of Hybrids: With the development of the breeding programme, it would be desirable to concentrate the alleles controlling the traits associated with seed parent (high number of kernels, bold kernel, small tassel) on one side, and those with pollen parent (profuse pollen production) on the other side in the heterotic pools or sub-pools and during second cycle inbred line development.

Breeding Non-inbred Parents of Parents: Some very successful hybrids have non-inbred parent. Such parents may particularly be relevant in the development of short duration, stress tolerant hybrids. The experiences indicate that it is difficult to develop early maturing inbred lines that are vigorous and stress tolerant. The use of non-inbred parent as a female parent may be a stopgap arrangement till vigorous early maturing inbred lines become available.

Exploitation of Temperate Germplasm: Tropical maize yields lower than temperate maize in spite of producing higher biomass. Important traits of temperate germplasm include high harvest index (about 50% in comparison to 30-35% in tropical maize), relatively light canopy and erect leaves, input responsiveness, and adaptation to high plant density. Temperate maize germplasm, however, generally performs poorly under tropical conditions due to early maturity and susceptibility to diseases and insect-pests. Though, some efforts have been made to use temperate maize germplasm (Khehra *et al.*, 1986a; 1986b) but these efforts need great strengthening. More germplasm should be introduced and evaluated; and the promising ones hybridized with tropical inbred and non-inbred germplasm for introgression and second cycle breeding.

Application of Multiple Selection Criteria: Though much progress has been made in computer technology, its application in our breeding programme is below desired level. Experimental entries (hybrids or composites) are many times promoted/rejected on the basis of a single trait like grain yield or days to silk, even following arbitrary cut offs. Multi-trait selection criteria need to developed and applied to promote/reject experimental entries. Further, there should be flexibility for the promotion of experimental varieties. An outstanding experimental entry may be directly promoted from Initial Varietal Trial to Advance Varietal Trial-II Year.

Due Importance to Target Environment: The important states for maize cultivation are Rajasthan, Uttar Pradesh, Madhya Pradesh, Karnataka, Gujarat, Bihar, Andhra Pradesh, Jammu & Kashmir and Himachal Pradesh. All these states jointly account for 79% area and 86% of the national maize production during 1997-02 and the first four states are particularly important. The allocation of resources, besides administrative considerations, should be in accordance with the maize area, uniqueness of agro-ecology and output; so that materials are developed and evaluated in target environments.

Breeder-farmer Interaction and Farmers' Field Evaluation: There has been intensive discussion on farmer participatory plant breeding/participatory varietal selection in recent years. Suggestions have been made to the extent of involving farmers in the selection of parents for hybridization and in the evaluation and selection in segregating generations. While these suggestions seem quite exaggerated, there is always a scope for improvement of the system.

There is no gainsaying that the breeder, to be successful, must know the farmers' field conditions and their needs. The breeder must interact with farmers and frequently visit the farmers' field and arrange farmers' visits to the experiment station. Further, materials must be evaluated under the conditions prevalent at the farmers' fields. For the release of cultivars at state level, elite experimental entry (ies) (generally one), identified in research station trials, is evaluated in farmers' field trials for 1-2 years by. To collect more data on the performance of experimental entries in the target environment and enhance the farmers participation, these trials should be conducted as early as possible (may be after 2-year evaluation at experiment station) and with as many experimental entries as possible; and farmers view should get due importance. For varietal releases at the national and zonal levels, pre-release farmers' field trials (then known as minikit trials) used to be conducted. But the experiences were not encouraging. The data were received very late and that were not very reliable either; and these trials had to be discontinued. Thus, the national/zonal releases should be followed by aggressive demonstrations.

Germplasm Evaluation under Stresses: Generally the experimentation is carried out under uniform and favourable conditions to maximize genetic expression and minimize non-genetic effects so as to enhance heritability and genetic advance through selection. This has led to criticism of the Indian crop improvement programme that the evaluation is done under favourable conditions. But it is mostly unfounded. Germplasm/ breeding materials/ experimental entries are being evaluated under stresses. Of course stresses are prioritized on the basis of resources and technologies available and expected genetic returns. Maize breeding materials have been continuously evaluated for reaction to leaf blights, stalk rots and downy mildew under artificial inoculation or in hot spots and for *Chilo* under artificial infestation. These efforts need to be expanded and the required facilities developed. Further, evaluation under high plant density has proved very successful, and this needs to be incorporated in the evaluation protocol.

Liberal Varietal Release: There is an unrealistic expectation that each and every released variety should be successful. It is very difficult, if not impossible, in case of all field-based technologies as cannot be thoroughly evaluated under all field conditions including stresses. There should be reasonable testing and liberal release of cultivars so as to give wider choice to the farmers.

Integrating Biotechnology with Maize Improvement: Very rapid advances are being made in biotechnology and its application in plant breeding. Biotechnology has quickened the pace of plant breeding and made it precise. Some of the important areas of research are the development of transgenics for resistance/tolerance to insect-pests, diseases and abiotic stresses, marker assisted selection and prediction of hybrid performance based on molecular diversity among parents. We, on the whole, are not keeping pace with the advances in biotechnology. To take advantage of these developments and to work in a synergistic manner, plant biotechnologists need to initially work in close collaboration with maize improvement teams, and they should ultimately be absorbed in the team. This needs immediate attention.

In addition to recording and consideration of data on some important traits and use of appropriate pollination technique is important.

Streamlining the Working of Coordinated-Project Centres

The project has delivered well and has served as a model of coordinated efforts not only in crops but also in other areas. But some lethargy and complacency has crept at certain centres which carry out only routine varietal testing and do not produce any significant breeding materials. The Directorate of Maize Research and eight centers have developed cultivars and 10 others have developed cultivars for their state only (Table 10). The remaining centers have not developed even one cultivar.

The research in various disciplines needs to be toned up and facilities strengthened particularly with reference to basic research, breeding for resistance/tolerance to abiotic and biotic stresses and upgradation of nutritional quality. Also there is an urgent need to promote collaborative efforts of maize breeding units, probably by putting various scientists (maize breeder, agronomist, plant pathologist, entomologist) under one administrative control as is the case at some centres. These teams need to interact closely with plant biotechnologists (as discussed above) and plant physiologists.

The project should have a dynamic system of location of centers depending on the area under maize cultivation and uniqueness of the agro-ecology, so as to facilitate due importance to target environments. There is also a need to strengthen zonal/regional testing. Some of the zones have only 3-4 centres which are not enough to generate adequate data. Above all, the need is for dedicated, consistent and persistent efforts.

References

Beal JF (1980) Report of the professor of botany and horticulture. Michigan Board Agric. Lansing, USA, pp 287-88.

Compton WA and JH Lonnquist (1982) A multiplicative selection index applied to four cycles of full-sib recurrent selection in maize. *Crop Sci.* **22:** 981-983.

Comstock RE, HF Robinson and RH Harvey (1949) A breeding procedure designed to make maximum use of both general and specific combining ability. *Agron J.* **41:** 360-367.

Dhillon BS (1991a) Recurrent mass selection based on selfed-plant evaluation in allogamous species. *Crop Sci.* **31:** 1075-1077.

Dhillon BS (1991b) Alternate recurrent selection of S1 and half-sib families for intrapopulation improvement. *Maydica* **36:** 45-48.

Dhillon BS (1998) Recurrent selection for combining ability and performance per se of crossbred and selfed families. *Maydica* **43:** 155-160.

Dhillon BS (1998) Shoot-cutting is not necessary for control-pollination in maize. *Indian J. Genet.* **58:** 383-384.

Dhillon BS and AS Khehra (1989) Modified S1 selection in maize improvement. *Crop Sci.* **29:** 226-228.

Dhillon BS, UK Bansal and WR Kapoor (1994) Variability for shelling in maize. *Crop Improv.* **21:** 87-88.

Dhillon BS, WR Kapoor and VV Malhotra (1984) 'Partap-1' and 'Partap': Cold tolerant composites of maize. *Prog. Fmg.* **21(2):** 5-6.

Dhillon BS, AS Khehra and VK Saxena (1984) Combined half-sib full-sib selection and estimation of genetic parameters. *Crop Improv.* **11:** 88-91.

Dhillon BS, AS Khehra and M Singh (1987) Modified full-sib selection and estimation of genetic parameters. *Theor. Appl. Genet.* **73:** 672-674.

Dhillon BS, NS Malhi and VK Saxena (1997) Development and improvement of heterotic pools in maize. The Genetics and Exploitation of Heterosis in Crops–An International Symposium. p. 74-75. CIMMYT, Mexico.

Dhillon BS, NS Malhi, VK Saxena and AS Khehra (1986) Hico breeding in maize. p. 279-285. In: B Napompeth and S Subhadrabandhu (eds.) *New Frontiers in Breeding Researches*, Kasetsart Univ., Bangkok, Thailand.

Dhillon BS, RK Sharma, VV Malhotra and AS Khehra (1988) Evaluation of maize germplasm for tolerance to low temperature stress under field and laboratory conditions. *J. Agron. Crop. Sci.* **160:** 89-93.

Dhillon BS, SK Vasal, G Srinivasan and J Crossa (1994) Improving the sampling and identification of foundation plants for inbred line development by integrating half-sib family selection with inbreeding. *Cereal Res. Commun.* **22:** 321-325.

Duvick DN (1999) Heterosis: feeding people and protecting natural resources. In: JG Coors, S Pandey (eds) Genetics and exploitation of heterosis in crops. *Am. Soc. Agron*, Madison, Wisconsin, USA. pp 19-29.

Gardner CO (1961) An evaluation of effects of mass selection and seed irradiation with thermal neutrons on yield of corn. *Crop Sci.* **1:** 241-245.

Hallauer AR (1992) Recurrent selection in maize. *Plant Breed Rev.* **19:** 115-179.

Jones DF (1918) The effects of inbreeding and crossbreeding upon development *Conn. Agric. Exp. Stn. Bull.* **207**: 5-100.

Kaur G (1996) Selection based on alternate evaluation of selfed and HS Families in an open pollinated population of maize. Unpublished PhD. Thesis, Punjab Agricultural University, Ludhiana.

Khehra AS and BS Dhillon (1984) Breeding maize for cultivation in winter. *Tech. Bulletin*, Punjab Agricultural University, Ludhiana. p. 49.

Khehra AS, BS Dhillon, NS Malhi, VK Saxena, VV Malhotra, SK Dey, SS Pal and WR Kapoor (1986a) Systematic introgression of the Corn Belt germplasm of maize. In: B Napompeth and S Subhandrabandhu (ed) *New Frontiers in Breeding Researches*. p. 291-302. Kasetsart Univ., Bangkok, Thailand.

Khehra AS, BS Dhillon, VK Saxena, WR Kapoor, VV Malhotra, SS Pal, SK Dey and NS Malhi (1986b) Breeding maize for adaptation in winter season. In: B Napompeth and S Subhandrabandhu (ed) *New Frontiers in Breeding Researches*. p. 319-330. Kasetsart Univ., Bangkok, Thailand.

Khehra AS, RK Sharma and BS Dhillon (1987) Laboratory studies on freezing injury in maize. *Indian J. Agric. Sci.* **57:** 176-178.

Lonnquist JH (1964) Modification of the ear to row procedure for the improvement of maize population. *Crop Sci.* **4:** 227-228.

Mertz ET, LS Bates and OE Nelson (1964) Mutant gene that changes protein composition and increase lysine content of maize endosperm. *Science* **145:** 279-280.

Mittal UK, BS Dhillon and VK Saxena (1997) Evaluation of maturity in maize. *Crop Improv.* **24:** 135-136.

Sarkar KR, A Pandey, P Gauyen, JK Madan, R Kumar and JK Sachan (1994) Stablization of higher haploid inducer lines. *Maize Genet. Coop News Lett.* **68:** 64-64.

Sekhon RS, BS Dhillon, VK Saxena and MS Grewal (1999) Modified S1 recurrent selection in a maize composite. *Maydica* **44:** 175-177.

Sharma RC and MM Payak (1990) Durable resistance to two leaf blights in two maize inbred lines. *Theor. Appl. Genet.* **80**: 542-544.

Shull GH (1909) A pure line method of corn breeding. *Amer. Breeders Assoc. Rep.* **5:** 51-59.

Singh J (1974) Extend maize cultivation to *rabi* for higher yields. *Indian Fmg.* **24:** 23-26.

Singh J and NN Singh (1968) In: Unit Selection (ed) Inter-Asian Maize Improvement of. Pakistan, 65-67.

Singh, J, NN Singh, SB Singh, NP Gupta and I Singh (1982) Unit selection. In: - (ed) *Advances in Cytogenetics and Crop Improvement*. Kalyani Publ., New Delhi.

Singh NN (1995) Hybrid maize research and development in India. p.37-44. In: M Rai and S Mauria (eds) *Hybrid Research and Development*. Indian Society of Seed Technology. Indian Agricultural Research Institute, New Delhi, India.

Vasal SK, BS Dhillon and S Pandey (1997) Recurrent selection methods based on evaluation-cum-recombination block. *Plant Breed. Rev.* **14:** 139-163.

Role of Plant Introductions in Varietal Development of Pulses in India

Masood Ali*, Sanjeev Gupta, BB Singh and Shiv Kumar
Indian Institute of Pulses Research, Kanpur-208024, Uttar Pradesh, India

Plant introduction is the oldest and simplest method of crop improvement, as well as an effective means to overcome the narrow genetic diversity observed in certain parts of the world. Genetic base of pulse varieties is narrow and needs immediate corrective measures by involving unadapted germplasm accessions, exotics and wild relatives in breeding programme. Over a period of time, several promising exotics of pulses were introduced in India from different countries. A total of 8 exotics of chickpea, two of pigeonpea, eleven of mungbean, one of lentil, five of fieldpea and four of Rajmash have contributed in the development of 52 cultivars of different pulse crops released in India. Rate of infusion of new exotics in pulse breeding programme has been slow. Several exotic accessions with useful traits are yet to be exploited in breeding programmes. Access to unique and potential valuable germplasm is key to sustained pulse improvement programme. The present paper describes the analysis of genetic base of the released cultivars, status of utilization of exotics, target traits for introduction, availability of useful exotic germplasm and possible approaches and strategies for their utilization in pulse improvement programme.

Key words: Pulses, Introduction, Varietal development, Genetic base, Released cultivars

In India more than a dozen pulse crops are grown on 22-24 million ha area with an annual production of 13-15 million tonnes. The major pulse crops grown in the country are chickpea (*Cicer arietinum* L.), pigeonpea (*Cajanus cajan* Millsp.), lentil (*Lens culinaris* L.), mungbean (*Vigna radiata* L. Wilczek) and urdbean (*Vigna mungo* L. Hepper). India holds the first position in area as well as production of these crops. As compared to cereals, most of these pulses still await significant breakthrough in terms of production and productivity. Productivity of pulses is still regarded as below the acceptable levels. In resource rich regions, these are not able to compete with cereals and cash crops as most of the pulses are not responsive to higher inputs. The reasons for low productivity are attributable to narrow genetic base, poor plant type, vulnerability to abiotic and biotic stresses and their cultivation in marginal and harsh environments. Over a period of time, a large number of improved cultivars have been developed in pulse crops. Notwithstanding the number of cultivars released, there has been limited improvement in productivity of pulses in almost all the environments. For example, yield of lentil, urdbean and mungbean have remained on plateau for the last ten years, while chickpea and pigeonpea observed marginal increase in yield during the period. Genetic diversity is limited both within production system and breeding programmes.This indicates that immediate steps should be taken up for broadening the genetic base of pulse crops either through exploitation of exotics or wild relatives, as most of the present day cultivars of different pulse crops are very closely related.

Genetic Base of Released Cultivars

Due to concerted breeding efforts, a total of 442 varieties of different pulse crops were released for cultivation in India. Of them, 126 varieties in chickpea, 100 in pigeonpea, 72 in urdbean, 100 in mungbean, and 37 in lentil were developed through different breeding methods. About 230 varieties were developed through hybridization following pedigree selection. Pedigree analysis of these varieties revealed narrow genetic base in most of the pulse crops (Table 1).

Pedigrees of 86 chickpea cultivars that have been released through hybridization were traced back to 95 ancestors. The top ten ancestors contributed more than 35 % to the genetic base of the released varieties. Most frequently used ancestors were Pb 7,IP 58, F8, Rabat and S 26 (Kumar *et al.*, 2004).

Coefficient of parentage were worked out by Gupta *et al.* (2004) to quantify the ancestral contributions to 99 cultivars of mungbean and identify the ancestor genotypes which contributed the most to cultivated germplasm. From the analyses it is evident that these varieties could be traced back to 74 ancestors. The ancestor genotypes T1, T49, T2, BR2, G65 and Madhira were those which contributed the most to the current mungbean germplasm. T1 alone contributed as high as 17 % of the genetic base of the released cultivars (Gupta *et al.*, 2004).

* E-mail: mali@iipr.ernet.in

Table 1. Genetic base of varieties of pulse crops released in India

Crop	Number of varieties developed	Number of varieties developed through hybridization	Number of ancestors used	Relative contribution of top 10 ancestors (%)	Name of top five ancestors
Chickpea	126	86	95	35	Pb 7*, IP 58, F 8, Rabat, S 26
Pigeonpea	100	47	57	48	T1*, T 190, P 4768, Sangareddy selection, Brazil 1-1
Lentil	35	14	22	30	L 9-12*, T 8, LG 171, JLS 2, JLS 1
Mungbean	99	50	74	79	T1*, T 49, BR2, G 65, Madhira
Urdbean	72	33	26	69	T 9*, D-6-7, G 31, Netiminumu

* Appearance of most frequent ancestor

The pedigrees of 35 lentil varieties released in the country were traced back to 22 ancestors. Out of these, the top ten ancestors contributed 30 % to the genetic base of the released varieties. L 9-12 is the most frequently used parent followed by K 8, LG 171, JLS 2 and JLS 1.

In pigeonpea, 57 ancestors were used to develop 47 varieties through hybridization. The top ten ancestors contributed 48 % to the genetic base of the released varieties. Ancestors T 1 and T 190 appeared in 34% varieties. Other ancestors used very frequently were P 4768, Sangareddy selection and Brazil 1-1.

Pedigree analyses were performed by Gupta *et al.*, 2003 to quantify the ancestral contributions to 72 urdbean cultivars released in India so far. From the analyses it was evident that these varieties could be traced back to 26 ancestors. Five ancestors, T9, D-6-7, G31, Netiminumu and AB-1-33 together contributed 50% to the total genetic base. T9 alone contributed as high as 31 % of the genetic base of the released cultivars (Gupta *et al.*, 2003).

Extensive and repetitive use of superior genotypes with common ancestry explained why the genetic base of the released varieties is narrow and the integration of unadapted germplasm, exotics and wild relatives is of paramount importance for broadening the genetic base of pulse crops.

Successful Introductions and their Utilization

Plant Introductions have been important to meet the varietal needs for a growing situation and overcoming the narrow genetic diversity observed in a region. A total of 31 exotics have contributed in the development of 45 cultivars of different pulse crops released in India. Of them, 8 of chickpea, two of pigeonpea, five of fieldpea, 11 of mungbean, one of lentil and four of *Rajmash* have contributed significantly in pulse improvement programme (Table 2).

Table 2. Utilization of exotic germplasm in varietal development of pulses in India

Crop/Accession	Country of origin	Varieties
Munbean		
China Moong	China	Shining Moong 1, Sunaina, RMG 62, Jalgaon 781
NM 9473	Pakistan/ AVRDC	Pusa 9531
NM 92	Pakistan/ AVRDC	Pusa Vishal
NM 94	Pakistan/ AVRDC	SML 668
V 2164	AVRDC,Taiwan	SML 134
V 3484	AVRDC,Taiwan	Pusa 101, WGG 2
VC 1137-213	AVRDC,Taiwan	Pusa 105
CES 44	Phillipines	AAU 34
MG 50-10	Phillipines	Co 5, Co 6
VC 6368	AVRDC,Taiwan	Pant Mung 2
Rajmash		
EC 94453	Bulgaria	Uday
ET 8447	Columbia	Amber
EC 400431	Columbia	Utkarsh
EC 400418	Columbia	Arun
Fieldpea		
L 116	Sweden	Hans
EC 33866	Russia	Harbhajan
EC 109196	–	Aparna (HFP 4)
EC 109185	–	Uttara, Sapna
Afilaknund	–	HUP 2
Lentil		
Precoz	Argentina	NDL 1, DPL 58
Pigeonpea		
PI 2817-2	Zimbawe	Hy 3C
Brazil 1-1	Brazil	Mukta, Sharad, Pusa Ageti
Chickpea		
Cyprus Local	Cyprus	Pragati
Rabat	Jordon	L 550, L 144
Ceylon 2	Sri Lanka	Phule G 12
ICC 3935	Egypt	BG 391
E 100Y	Greece	Gaurav, Dharwad Pragati
FLIP 88-120	Syria	BG 1053
P 9847	Russia	BG 261, BG 244
P 9263	Russia	BG 267

Chickpea variety, Pragati, was the outcome of the direct introduction of Cyprus local. Besides, 16 cultivars of chickpea released in India have been developed through utilization of exotic germplasm as an immediate parent in their pedigrees. Some of these varieties are Pusa 261, Pusa 244, Pusa 267, C 104, L 550, L 144, BG 1003, BG

1053, Phule G12, BG 391, Gaurav and BGD 72. Rabat, an exotic *Kabuli* variety, in combination with S 26 and Pb 7 led to the development of *kabuli* varieties L 144 and L 550, respectively. In two different cross combinations, the *Ascochyta* blight resistant line from Greece, E 100Y led to the development of Gaurav and Dharwad Pragati. The Russian accession, P 9847 in different combinations led to the development of tall *desi* variety BG 261. This exotic was also involved in a three way cross to develop a variety BG 244. Another Russian accession P 9263 was also involved in a three way cross and led to the development of a *kabuli* variety BG 267.

Pigeonpea cultivar, Hy 3C was a secondary selection from exotic line PI 2817-2. Another exotic line Brazil 1-1 has been used as a source of earliness in pigeonpea, which, in combination with NPWR 15, NP 41 and NP 69, has led to the development of early maturing varieties Mukta, Sharad and Pusa Ageti.

Promising exotics were extensively utilized in the development of at least seventeen popular cultivars in mungbean. Pusa Vishal, a selection from AVRDC accession NM 92, released for NWPZ has become most popular because of its large seed (6 g/100 seed weight). SML 668, a promising cultivar of mungbean for summer/ spring cultivation is also a direct selection of exotic line NM 94. Selections made from exotic material introduced from China and Iran have led to the development of Shining Moong 1 and PS 16, respectively. These selections were widely used in crossing programme and subsequently few superior cultivars such as KM 1, Sunaina and RMG 62 were released. An accession from AVRDC, V3484 contributed shining coat character in development of Pusa 101 and WGG 2.

Introduction of an early, rust resistant *macrosperma* line, Precoz, from Argentina has accelerated *microsperma* x *macrosperma* crosses in lentil resulting in the development of NDL 1 and DPL 58.

In fieldpea, an exotic accession EC109196 in a cross combination led to the develoment of a dwarf, leafless and powdery mildew resistant cultivar, HFP 4. HUP 2, a tall cultivar is the product of three way cross involving an exotic Afiakund. An old pea variety, Hans was a mutant of L116, an exotic accession from Sweden, and Harbhajan was a selection from exotic line, EC33866. Exotic pea accessions for useful traits viz., resistant to *Pea mosaic virus* (EC271572), resistant to powdery mildew (EC322745 and EC381853), tolerant to drought (EC389374) are yet to be exploited in pea improvement programme.

Rajmash (*Phaseolus vulgaris* L.) is relatively a recent introduction in the country. It was believed to have originated in the America and domesticated in Mexico, Peru and Columbia. The primary gene pool is well represented in collections of CIAT and Columbia. *Rajmash* cultivar, Uday was selected from exotic germplasm, EC 94453 introduced from Bulgaria, while Amber, Utkarsh and Arun were selected from Columbian accessions, ET8447, EC400431 and EC400418, respectively.

Traits for Introduction

In pulses, traits other than high yield had little importance. With the development of production systems in which the pulses are grown, other traits are now becoming more important. For introduction, normally those traits are considered for which sufficient variability is not present in the indigenous material. However, for rapid breeding advancements, the exotics with useful traits like disease and insect-pest resistance, drought and cold tolerance, low neurotoxins and high protein content are important and these should be introduced for further utilization. In different pulse crops, the preferred traits for introduction are mentioned in Table 3.

Chickpea

The chickpea has two main types, the *Desi* type with small, brown and angular seeds, and the *Kabuli* type with large, beige seeds with ram-head shape. Wilt is a serious problem wherever chickpea is grown. Different pathogenic races of *Fusarium oxysporum* f.sp. *ciceri* were recognized by Dolar (1995) and Singh and Jimenez-Diaz (1996). Ascochyta blight is a serious problem in

Table 3. Preferred traits for introductions in pulse crop

Crop	Preferred traits
Chickpea	Short duration, Bold seed, High temperature tolerance at maturity (> 25^0C), Cold tolerance (< 5^0C), Salinity tolerance, Resistance against Wilt and Ascochyta blight
Pigeonpea	Short duration, Cytoplasmic Male Sterility (CMS) source, Resistance against Wilt and Phytophthora Stem Blight
Mungbean	Short duration, Bold seed (> 6g), Photo-thermo insensitivity, Bruchids resistance, Pre-harvest sprouting tolerance, Resistance against Powdery mildew and *Cercospora* Leaf Spot
Lentil	Bold seed, Resistance against Rust and Vascular Wilt
Fieldpea	Dwarfness, Afila types, Short duration (<100 days), Resistance against Powdery mildew
Rajmash	Cold tolerance (< 5^0C), *Bean common mosaic virus* (BCMV) resistance

comparatively cooler environments. Race specific resistant sources are needed for pyramiding the genes and thereby insulating the crop against the particular disease. Drought is one of the major abiotic stresses as the crop is mostly grown on residual moisture in *rabi* seasons. The crop experiences low temperature of 0-5°C for about 15-20 days in North Plain Zone of the country. Prevalence of such a low temperature at early flowering stage causes flower abortion, leading to 15-30% yield loss. Accessions which can retain flowers and set pods under these conditions are needed for their utilization in breeding programme. Introductions from Russia (e.g. K1189) have shown cold tolerance. Similarly, prevalence of temperature above 30°C especially during the reproductive stage can also cause severe stress in Southern region. Efforts are needed to identify tolerant sources for high temperature. Tolerant sources for salinity/ alkalinity are also needed as the crop also suffers from these stresses. Bold seeded types are becoming popular among farmers. The proportion of bold seeded varieties have gone upto 41% during last decade showing the promise that the genetic manipulation for seed size can be made successfully. Therefore, infusions of new sources for seed size both for *desi* and *kabuli* types are urgently needed. Availability of short duration varieties has made it possible to shift the sowing of chickpea from October to November and December making rice–chickpea rotation a reality in northern zone. Similarly, the early maturing varieties have been the main catalyst behind the expansion of the crop in southern and central zones. Since the trait is occupying importance in production systems, the new sources for short duration types (maturing < 120 days) should be made available for their utilization in breeding programmes.

Pigeonpea

Pigeonpea is the second most important pulse crop of the country. Among biotic stresses, wilt, stem blight and sterility mosaic are major challenges to its production. Sources of durable resistance to these diseases are needed for improvement programmes. Short duration maturity allows great flexibility in its planting. Development of early maturing cultivars has made pigeonpea–wheat rotation a great success in northern states. New sources of short duration types hold promise in further advancement of breeding efforts. Sources of cytoplasmic male sterility (CMS) are important for exploitation of heterosis in pigeonpea. So far, the CMS sources could be available from wild species only. However, promising CMS sources, wherever available, need to be introduced to accelerate hybrid pigeonpea programme in the country.

Fieldpea

Some minor characters seemed to be of interest and were used in breeding but the main targets were, naturally, yield and stiffness. Analysis of crosses with exotic material was not very informative. The only approach was for phenotypic selection and the first character addressed was stem length. Unfortunately a lot of germplasm are very tall and selecting shorter types gave no major step forward in desired characters. Afila, a natural mutant observed in early 50's has been found responsible for transformation of leaflet into tendrils. This type has some obvious advantages and therefore regarded as a major breakthrough in changing plant type of fieldpea. Aparna (HFP 4), Uttara (HFP 8909) and Sapna are such successful cultivars developed using Afila mutant gene *'af'*. These cultivars were developed using exotic accessions. Several germplasm carrying 'ramosus' gene has been identified having branching ability at several levels of plant (Beveridge *et al.*, 1990) and these need to be utilized in breeding programme identified a flowering gene *'lfa'* which determines the level of first flowering node. This trait is useful for modulation of earliness. Short duration pea cultivars maturing in less than 100 days may be important as these can ensure intercropping of mungbean and urdbean in spring planted sugarcane. Sources of powdery mildew and rust resistance are important to sustain fieldpea breeding programme. Resistance to *Erysiphe pisi* was first observed in an accession carrying *'er1'* and *'er2'* genes in Peru.Since than several sources have been reported in the literature. It is necessary to exploit exotic germplasm, carrying such useful traits. To make a major step forward in yield, stiffness, plant type, earliness etc., it is necessary to continue exploiting exotic germplasm.

Lentil

In lentil, an exotic Precoz has been used in breeding programme to develop bold seeded cultivars in the country. Extra bold types are preferred in cultivation mainly for export purposes. New exotics need to be introduced to achieve this objective. Among biotic stresses, rust and vascular wilt are major fungal diseases. Several other important traits such as biomass yield, pod shedding etc., could not be addressed in breeding programmes because of non-availability of appropriate sources.

Mungbean

Development of short duration varieties of mungbean brought the era of short duration pulses in different cropping systems. Since the crop has occupied a place in different cropping systems, it often faces major challenges from biotic and abiotic stresses. Reliable and durable sources of powdery mildew and cercospora leaf spot are not available to the breeding programmes. Bold seed size (>5 g) is the most preferred trait for introductions. Besides, bruchid resistance and pre-harvest tolerance are two major traits, for which new sources need to be introduced.

Rajmash

Rajmash is a successful example where exotics played an important role with useful traits. An exotic from Bulgaria, EC 94453, led to the development of cultivar 'Uday' (PDR 14) which has made cultivation of *rajmash* possible in plains during *rabi* season. Since the crop has been introduced in new nitches, it is becomming prone to many biotic and abiotic stresses. *Bean common mosaic virus* resistance and cold tolerance are two major traits, for which the potential sources are needed. However, for attractive seed colour and size, sufficient variability is available in existing collections from CIAT, Columbia.

Future Needs

Breeding efforts with introduced germplasm tend to increase genetic diversity. Germplasm introgression in virtually all areas has increased, and selection programmes with increased levels of exotic germplasm are expected to continue in the future. This exchange of germplasm and breeding efforts has generated different germplasm sources available to breeders for development of cultivars. Introduction of exotic germplasm will increase the genetic base of pulse crops, but lower productivity will not be acceptable in any breeding programme. The increased genetic variability will have to contribute positively to breeding programmes. Hence, careful introgression and selection will be necessary to develop germplasm sources to meet desired standards for productivity, maturity, quality and resistance to biotic and abiotic stresses. The need for plant introduction is continuous, since new diseases and new niches are continually appearing. This makes it imperative that breeders be constantly supplied with useful germplasm and that reservoirs of basic plant material be maintained in gene banks.

Germplasm Enhancement

Integrating some exotics into adapted germplasm has advantages over selecting with in the exotic material for adapted types. This requires patience and long- term selection and breeding. Most of the exotics sometimes are difficult to use in conventional breeding programmes. Thus, except as a last resort, breeders tend to avoid using this germplasm. The major reasons for limited use of exotics may include: adverse photoperiod response masks desirable traits, linkages between favourable and unfavourable genes in exotic adapted populations cannot readily be broken and no current basis exists for choosing the best exotics. Germplasm enhacement is referred as the act of transferring useful genes from exotic or wild types into more adapted backgrounds. Rick (1984) used the terms " prebreeding" or " developmental breeding" to describe the same activity, but enhancement has become more commonly used term among breeders. Enhancement implies the use of any tool available to plant breeders. The precise technique used will depend upon the mating system of the material and intended results. The progress made in the past few years in molecular biology makes biotechnology a promising way to integrate specific genes from related as well as nonrelated species into adapted material.

Introgression Library

For advanced backcross QTL methodology, it is necessary to have an introgression library of useful traits in different pulse crops. Efforts are also needed to find new interesting alleles. With the haplotype breeding, it is necessary to investigate new tools to introduce valuable alleles from exotic germplasm.

Trait Specific Introductions

Over 60,000 accessions of pulse crops were introduced by National Bureau of Plant Genetic Resources, New Delhi from more than 56 countries under strict quarantine measures. However, most of the introduced materials were in the form of international screening nurseries and yield trials. Such introductions have little impact in breeding programmes as the efforts were directed only for screening and evaluation. For effective utilization, an emphasis has to be given on the introductions with useful gene(s). Different accessions with useful traits are available in literature and these should be introduced for utilization and gene introgression (Table 4).

Informal Introductions

There is a legitimate need to introduce new germplasm

Table 4. Source of germplasm with useful traits

Crop/Trait	Accessions	Source	Reference
Chickpea			
Fusarium wilt (race 0,1,5)	ILC 9784	ICARDA	Singh and Jimenez-Diaz, 1996
Fusarium wilt (race 0,1)	ILC 9785, -9786, FLIP 86-93C, FLIP 87-38C	ICARDA	Singh and Jimenez-Diaz, 1996
Resistance to Ascochyta Blight	ILC 72, ILC 191, ILC 3279, ILC 3856	ICARDA	
Resistance to Dry root rot	ICC 2867, ICC 9023, ICC 1003	ICRISAT	
Cold tolerance	FLIP 87-38C, FLIP 86-93C	ICARDA	Singh and Jimenez-Diaz, 1996
	ILC 8262, ILC 8617, FLIP 8-82C	ICARDA	
Combined resistance to Ascochyta Blight and wilt and Cold Tolerance	FLIP 91-178C, FLIP 93-53C, FLIP- 93-98C	ICARDA	Singh *et al.*, 1997
Resistance to Ascochyta blight and cold tolerance	ILC 72, ILC 3279, ILC 482, ILC 2956	ICARDA	Singh *et al.*, 1989
Drought tolerance	FLIP 87-59C	ICARDA	Singh *et al.*, 1996
	ICC 4958, ICC 5680, IC 10448	ICRISAT	
Pod borer resistance	ICCV 7	ICRISAT	Singh *et al.*, 1997
Bruchids resistance	(*Cicer echinospermum*) ILWC 39, ILWC 181	ICARDA	Singh *et al.*, 1997
Pigeonpea			
Resistance to Fusarium wilt	ICP 9145	ICRISAT	Reddy *et al.*,1995
	ICP 8959, ICP 8863, ICP 9120	ICRISAT	
High Protein	ICPL 87162	ICRISAT	Reddy *et al.*, 1997
Waterlogging tolerance	ICPL 227	ICRISAT	Chauhan, 1987
Resistance to sterility mosaic	ICP 7035, ICP 886	ICRISAT	Reddy *et al.*, 1995
Resistance to Phytophthora Stem Blight	ICPL 84023	ICRISAT	Reddy, *et al.*, 1991
Fieldpea			
Resistant to pea mosaic virus	EC 271572	France	NBPGR, 2000
Resistant to Powdery Mildew	EC 322745, EC 381853	Canada	NBPGR, 2000
Tolerance to drought	EC 389374	Syria	NBPGR, 2000
Lentil			
Cold Tolerance	ILL 323, ILL 465, ILL 857, ILL 975	ICARDA	ICARDA, 2000
Resistant to Bean Leaf Roll Virus	ILL 74, ILL 85, ILL 213	ICARDA	ICARDA, 2002
Resistant to Necrotic Yellow virus	ILL 6816, ILL 213	ICARDA	ICARDA, 2003
Resistant to wilt	ILL 6994, ILL 7201	ICARDA	ICARDA, 1999
Mungbean			
Photo-thermo Insensitivity	V 1400, V 1944, V 3726	AVRDC	AVRDC, 2003
Bruchids resistance	VM 2011, VM 2164, V 2802, TC 1966	AVRDC	AVRDC, 2004
Flood Tolerance	V 1968, V 2984, V 3092	AVRDC	AVRDC, 2000
Maruca resistance	V 2109, V 4270, V 2106	AVRDC	
Resistance to Cercospora Leaf Spot	V 2773, V 4718, V 5000, V 1137A, V 1560D, VC 2720A	AVRDC	AVRDC, 2003

into plant breeding programmes for specific traits preferred by the consumers or to reduce the vulnerability of the crop to diseases. There are certain cases of informal introductions for specific traits and subsequently brought into a large scale cultivation. For example, Mahrashtra farmers are growing extra bold seeded Kabuli type 'Mexican Gold' brought from other countries. These materials might have found place either through informal trade or bulk import for grain purposes. Such movement of material is at risk because of quarantine reasons. To avoid pathogen transfer, germplasm movement must be based on a safe strategy. Therefore, any such introductions should only be permitted with the concurrence of official plant quarantine service.

References

Baranger A, G Aubert, Arnau, AL Laine, G Deniot, J Potier, C Weinachtet, J Lallamad and J Bustin (2004) Genetic diversity in *Pisum sativum* using protein and PCR used markers. *Theor. Appl. Genet.* **108:** 1309-1321.

Beveridge CA, JJ Ross and IC Murfet (1990) Branching in pea: action of genes Rms 3 and Rms 4. *Plant Physiol.* **110:** 859-865.

Dolar FS (1995) Evaluation of some chickpea cultivars for resistance to *Ascochyta rabie* (Pass.) Labr. *Fusarium oxysporum* and *F. solani* in Turkey. *J. Turkish Phytopathol.* **24:**15-22.

Gupta Sanjeev, Shiv Kumar and BB Singh (2004) Relative genetic contribution of Indian mungbean (*Vigna radiata* (L.) Wilczek) cultivars based on coefficient of parentage analysis. *Indian J. Genet.* **64(4):** 299-302.

Gupta Sanjeev and Shiv Kumar (2003) Pedigree analysis of urdbean varieties released in India. *Indian J. Pulses Res.* **18(2):** 153-155.

Kumar Shiv, Sanjeev Gupta, Suresh Chandra and BB Singh (2004) How wide is the genetic base of Pulse crops? In: *Pulses in new perspective* (eds. Masood Ali, BB Singh, Shiv Kumar and Vishwa Dhar). Indian Society of Pulses Research and Development, IIPR, Kanpur, India. pp. 211-221.

Reddy MV, VK Sheila, AK Murthy and N Padma (1995) Mechanism of resistant to *Aceria cajani* in pigeonpea. *Intern. J. Tropical Diseases* **13:** 51-57.

Reddy MV, YL Nene, TN Raju, VK Shiela, N Sarkar and P Ramanadan (1991) Pigeonpea lines with field resistance to Phytophthora blight. *Intern. Pigeonpea News Letter* **13:** 20-22.

Reddy LJ, KB Saxena, KC Jain, Umaid Singh, JM Green, D Sharma, DG Faris, AN Rao, RV Kumar and YL Nene (1997) Registration of high protein pigeonpea elite germplasm, ICPL 87162. *Crop Sci.* **37:** 294.

Reddy MV, YL Nene, TN Raju, J LKannaiyan, P Remanandan, MH Mangesha and KS Amin (1995) Registration of pigeonpea germplasm line resistant to Fusarium wilt. *Crop Sci.* **35:** 1231.

Singh Onkar, SC Sethi, SS Lateef and CLL Gowda (1997) Registration of Pod borer resistant ICCV 7 chickpea germplasm line. *Crop Sci.* **37:** 295.

Singh KB, S Weigand and MC Saxena (1997) Registration of ILWC 39 and ILWC 181 *Cicer echinospermum*, resiatant to *Callosobruchus chinensis*. *Crop Sci.* **37:** 634.

Singh KB and MV Reddy (1989) Ascochyta blight and cold toerant chickpea. *Crop Sci.* **29:** 657-659.

Singh KB, M Omar, MC Saxena and C Johansen (1996) Registration of FLIP 87-59C, a drought tolerant chickpea germplasm line. *Crop Sci.* **36:** 472.

Singh KB and RM Jimenez-Diaz (1996) Registration of six *Fusarium* wilt resistant chickpea germplasm lines. *Crop Sci.* **36:** 817.

Singh KB, RS Malhotra and MC Saxena (1997) Chickpea germplasm lines resistant to Ascochyta blight, Fusarium wilt and cold tolerance. *Crop Sci.* **39:** 1817.

Plant Introductions in Soybean – Achievements and Opportunities

S Prakash Tiwari

Deputy Director General (Education & Crop Science), Krishi Anusandhan Bhawan-II, Indian Council of Agricultural Research, New Delhi-110012, India

Soybean presently covers about 8 million hectares in the country and significantly contributes towards agrarian economy and farm-prosperity. Although soybean has originated in China, the north-eastern region of the Indian sub-continent has a degree of endemic variability. The earlier soybean introductions have been owing to propinquity of these areas with China. Early varieties like Punjab White/ Punjab-1 and a host of strains grouped under Bhat/ Bhatmash / Kalitur are also part of this endemic variability. These have saved the Indian soybean variability from the founder-effect as, later, most of the yellow-seeded varieties and strains of soybean in India have been introduced via USA. Several important genes such as those for resistance to yellow mosaic virus and other diseases, nutritional characteristics, photoinsensitivity, long-juvenility etc. have been introduced in India, mainly from USA followed by Taiwan, Brazil and other countries. Of late, a sizable number of black-seeded soybean varieties of Indian provenance have been repatriated from USDA, USA. The introductions particularly for specific genes of interest have helped in bringing about a renaissance of this ancient crop of northern India into a commercial crop of the country. Opportunities exist to further have directed-introduction for several traits and genes of interest which were hitherto unimportant but are presently assuming significance such as those for food and nutritional quality, lack of anti-nutritional factors etc.

Key words : Soybean, Introduction, Evaluation, Crop improvement

Owing to a consortium approach under the Technology Mission on oilseeds, which was set up in May 1986, a breakthrough in oilseed production could be achieved which was christened as "Yellow Revolution". The present oilseed production is about 26 million tonnes. Out of nine oilseed crops of India, the major contributors towards this revolution were rapeseed-mustard and soybean. We have to (i) defend the gains made, (ii) extend the gains to potential areas yet uncovered, and (iii) make new gains on sustainable basis.

Soybean (*Glycine max.* (L.) Merrill) is the most important oilseed crop in the world, accounting for more than 50% of oilseeds produced and about 30% of the total supply of all vegetable oils. It is unique crop having both high quality protein (43%) and oil (20%) content. It also helps in improving soil fertility through nitrogen fixation. The protein from soybean is equivalent to that of meat, milk products and eggs in quality. Among the leguminous crops, soybean is a relatively higher yielder and farmers get better returns. It is one of the most popular source of protein in the world. It is used for making diversified products with a wide range of uses. Besides being a source of vegetable oil, soybean is moving towards being utilised as a functional food.

Soybean is the unique oilseed crop in view of its contribution to agrarian economy and farm-prosperity. The research and developmental efforts in soybean have yielded not only outputs but also outcome; socio-economic uplift of Malwa farmers in Madhya Pradesh is an example of it (Badal *et al.*, 2000). It has established itself as one of the most important oilseed crops of India along with groundnut and rapeseed-mustard. The estimates show that soybean presently covers an area of about 8 million hectares with a production of over 8 million tonnes and a productivity of about 1.1 tonne per hectare.

The crop is concentrated in the central Indian niche predominantly in Madhya Pradesh, Maharashtra and Rajasthan states around a latitude range of about 16 to 26° N and longitude range of about 73° to 84° E wherein Indore, the epicentre of soybean renaissance is situated at 22° 44 N and 75° 50 E. Some area is beyond this range also and it is feasible to grow soybean in most parts of the country. Soybean is generally grown as a rainy season crop under rainfed situation. Soybean, particularly in its early years of spread, largely occupied the rainy season fallow land. This resulted in an enhancement in the cropping intensity and an increase in the unit area profitability from the land use. Soybean also replaced some less remunerative crops like sorghum and minor millets. In western Madhya Pradesh, Maharashtra and Karnataka, some area under cotton is also being replaced by soybean.

Origin, Evolution and Domestication

Soybean is native to eastern Asia particularly Korea and China border. The first record of its cultivation

E-mail: sptiwari@icar.org.in

dates back to 2838 B.C. in China (Morse, 1947). This is based on the occurrence of the *Glycine ussuriensis* which is considered as a progenitor of the cultivated soybean *Glycine max*. Cytogenetic evidence suggests that *G. max* and *G. ussuriensis* are the same species. Thus, *Glycine soja* Sieb & Zucc. is the probable progenitor of cultivated soybean. The eastern half of North China is believed to be the primary centre and Manchuria, the secondary centre of origin of soybean.

Some of the early workers as Nagata (1959, 1960) consider China proper to be the homeland whereas others suggested eastern Asia to be the centre of origin of soybean. Nagata thinks that soybean was introduced into Korea and later disseminated to Japan. According to Hymowitz (1970), *G. ussuriensis* grows wild in Korea, Taiwan, Japan, North East China and adjacent areas of USSR. He further suggested North East China as the area where soybean was first domesticated around 11th century B.C. Chang Ruzhen (1989) discussed different hypothesis suggesting centre of origin and largely accepted that lower and middle Yellow River valley is the main centre of origin of soybean.

Global Spread and Introductions of Soybean

The available evidences suggest dissemination of cultivated form of soybean from North China to Korea and then to Japan, sometime between 200 B.C. and 3rd Century A.D. (Nagata, 1959, 1960). Another route of dissemination could have been from North China to Southern Japan (Morse, 1950). Morse (1950) presented a comprehensive review of the history of soybean production and suggested that soybean seeds were sent to Paris by missionaries around 1740. Its cultivation in England was done as early as 1790 (Alton, 1842). According to Brooks (1966), soybean was known in Europe in the 17th Century as an exotic plant from orient. However, it was not until 1712 when the Western world finally recognized soybean as a food plant. Its cultivation in Europe started since 1875.

In the USA, mention of soybean in literature dates back to 1804 but its commercial production picked up only in 1930s. Afterwards, the Perry expedition to Japan in 1854 brought two soybean varieties viz. 'Japan pea' or 'Japan beans'. However, at the end of the Nineteenth century a systematic introduction of soybean started in the USA from Asian countries. Today it has occupied such a position that there is no other crop plant in the USA that has found such a diversified utilization as the soybean. During the World War I and II soybean was recognized as most essential in the manufacture of various food and industrial products. Likewise, in Germany, during the II World War soybean flour was used in making of ration for the soldiers (Burns, 1941).

Today, United States, Brazil, Argentina, China and India are the major soybean growing countries accounting for 90% of the soybean production and area.

Indian Soybean Introduced in USA : Quid Pro quo?

While in the later part of the history, most of the soybean varieties and germplasm has been introduced in India from and via USA, it is interesting to note that in the early times, and even later the Indian soybean material went to USA. It is documented that at the beginning of the twentieth century, there were perhaps eight soybean cultivars growing in the USA. It will be interesting to know that during the first two decades, new soybean accessions were introduced from India and China, into the USA by USDA plant explorers Charles V. Piper and Frank N. Meyer, respectively (cf. Hymowitz and Bernard, 1991). Owing to seed viability and germinability problems, these introductions could not be kept well in USA. Later in sixties, USA soybean varieties and lines started to be introduced largely from USA and to some extent from Taiwan to India.

Some indigenous material from India is well documented. For example, the USDA Germplasm Collection Inventory (1989) records that USA introduced 258 accessions from India during the years 1945 to 1985. Further, it also records "to have imported 54 PI numbers i.e. serially from 374.154 to 374.207 collected from central India (Table 1) which were all black-seeded and belonged to the maturity groups VIII and Xth.

Introduction of Soybean in India

In India, soybean has been grown for a considerable length of time on the borders of North West Frontier provinces and in Mirpurkhas in Sindh and in Nepal. In those days it has been used as forage and as a food crop. It appears that soybean was introduced into the country from north-eastern India and Himalayan regions, especially from where the area that is contiguous to or near China. The advent and renaissance'of soybean in India has been depicted by Tiwari *et al.* (1999). The soybean renaissance resulting in phenomenal growth of soybean in India started with the use of indigenous black soybean variety 'Kalitur' as a vehicle of this revolution. The black soybean, ruled 'for several years thereafter. Yellow-seeded introductions helped later in consolidation of early gains made through this black indigenous variety. 'Kalitur' was and is still

Table 1. Indian soybean strains in the USA germplasm collections (1945-1985)

Year	PI No.	No. of strains	Source
1948	163.308, 165.524-165.583, 165.896-166.105, 166.437-166.439	17	Almora, Kulu, Garhwal regions of Uttar Pradesh (U.P.)
1949	174.852, 174.856-174.868, 175.174-175.176, 175. 179-175.199, 179.935, 180.051-180.052, 180.444, 183.929-183.930	42	Kumaon, Tehri Garhwal, Dogra regions of U.P., Khasia (Assam) and Punjab
1951	194.771-194.773, 198.078	2	Punjab and U.P.
1957	239.484	1	Vidarbha
1959	255.734, 256.376	2	Punjab no. 1 (New Delhi)
1965	307.597, 307.836-307.900	61	IARI (New Delhi), JNKVV (Jabalpur)
1967	319.525-319.533, 323.550-323.581	39	Almora, Nainital (U.P.)
1969	346.298-346.312	10	IARI (New Delhi)
1972	374.154-374.207	54	Mhow, Ujjain, Dewas, Simrol, Indore, Nagpur (Central India)
1978	428.691-428.692	2	Imphal (Meghalaya)
1981	462.312	1	Ankur from Pant Nagar (U.P)
1982	468.373-468.375	2	Imphal (Meghlaya)
1984	486.327-486.335	6	Jabalpur, Ranchi,Pune
1985	497.952- 497.970	19	Pusa (Bihar), Jammu and Kashmir, Sikkim
	Total	**258**	

Source: Bernard et al. (1989) The USDA Germplasm Collection Inventory, Volume 2, P. 190

recognised for its high seed longevity, tolerance to a degree of water-logging, general resilience to changes in weather etc. The Indian varieties of today represent different groups based on their breeding history. There are soybean varieties that are land races or selections from them and have been known since long. These are:

(a) A pool of black-seeded indigenous varieties/stocks such as 'Bhat'/Bhatmash' which represent the habitat of northern region but are also cultivated in scattered pockets of central India under names such as 'Kalitur' and 'Kala Hulga'.

(b) Yellow-seeded pool of northern Tehri-Garhwal region presently represented by the variety 'JS 2', and

(c) A pool of indigenous varieties with yellow-coloured small seeds such as those represented by 'Type 49'. These varieties, in their original form, have been cultivated in small pockets since long. Plant breeders have either identified them through trials or practised simple selection on them. The variety 'Punjab 1' (a maturity group VII variety later entered as PI 198.078 in the year 1951 and further as PI 255.734 in the year 1959), although representing a selection from the exotic 'Nanking' variety, is also known to have been adopted quite early by the farmers. Old reports from Central India clearly state that 'Punjab White', a promising 'desi' type (country or indigenous types having long history of cultivation), was being grown in small plots in several states (IPI, 1934).

Around 75% of the accessions in the Indian collections maintained at the NRCS, Indore are exotic (Table 2). USA, the Philippines and Taiwan were the major donor countries. Of the total germplasm accessions available in India, NRCS is the largest holder and also the National Active Germplasm Site (NAGS) for soybean. Other major centres holding soybean germplasm are JNKVV, Jabalpur, IARI, New Delhi and GBPUAT, Pantnagar (Table 3).

Table 2. Source of Indian soybean accessions maintained at NRCS (ICAR), Indore

Country	No. of collections
India	1,014
USA	1,474
Taiwan	610
Philippines	365
Argentina	90
Japan	14
Australia	20
Myanmar	10
Nigeria	43
Brazil	16
Srilanka	5
Others	294
Total	**3,955**

Table 3. Soybean collections in India

Institute/SAU	Total no. of germplasm collections
National Research Centre on Soybean, Indore	3,954
Jawaharlal Nehru Krishi Viswavidyalaya, Jabalpur	1,364
ARI, MACS, Pune	609
Jawaharlal Nehru Krishi Viswavidyalaya, Sehore	180
Indian Agricultural Research Institute, New Delhi	1,200
Govind Ballabh Pant University of Agriculture and Technology, Pantnagar	978
Panjab Agricultural University, Ludiana	795
Marathwada Agricultural University, Parbhani	674
University of Agricultural Sciences, Dharwad	374
Total	**10,128**

Recently collected data shows, that the above trend of introduction is broadly being maintained and USA and Taiwan remain to continue as the two major donors (Table 4).

At the NBPGR (ICAR), Akola centre also, majority of the accessions are exotic. The prominent donor countries are USA (582 accessions), Argentina (190 accessions), Germany (152 accessions), Australia (109 accessions), Taiwan (71accessions), Hungary (58 accessions) and USSR (45 accessions) (Table 5). Exotic material from other countries was also obtained. From the bordering Nepal, 24 accessions were obtained. Surprisingly, not much material was directly obtained from China. It came to India through USA. However, the USA material itself was obtained largely from three major countries viz. South Korea, Japan and China (Bernard *et al.,* 1989).

Table 4. Introduction of soybean (mainly *Glycine max*) germplasm during 1994-2006

Year	No. of acc.	Source/countries
1994-95	90	China, Russia, Taiwan, USA
1995-96	154	Indonesia, Japan, Philippines, Taiwan
1996-97	651	Australia, Brazil, Korea, Russia, Taiwan, USA
1997	62	North Korea, Russia, Taiwan, USA
1998	199	Mexico, Taiwan, USA
1998	10	Taiwan
1999	421	Canada, Taiwan, USA
2000	1,235	Nigeria, Taiwan, USA
2001	1,753	Australia, Japan, Taiwan, USA
2002	169	USA
2003	378	Nigeria, Taiwan, USA
2004	81	Myanmar, Brazil, Sri Lanka, USA
2005	34	Taiwan
2006	281	Sri Lanka, Taiwan, Thailand, USA
Total	**5,518**	

Of late, introductions of soybean have become trait-specific. Some people prefer to call this as "directed introduction". Recent introductions of soybean in India are listed in Table 5 and the specific trait characteristics of these are mentioned in Table 6.

At NRCS, Indore, there are 36 collections of wild relatives of soybean representing eleven wild species of the sub-genus *Glycine* and one accession of *G. soja* of the sub-genus *soja (Table 7)*. These species are *G. tabacina, G. falcate, G. arenaria, G. latrobeana, G. tomentella, G. arygyrea, G. cyrtoloba, G. canscens, G. latifolia, G. clandestine* and *G. microphylla*. These have been obtained mainly from USA and AVRDC, Taiwan.

Table 5. Sources of exotic soybean accessions in India (NBPGR, Akola Centre)

Country	Frequency	Country	Frequency
Argentina	190	Morocco	4
Australia	109	Nepal	24
Brazil	16	Nigeria	22
Canada	7	P. New Guinea	3
Sri Lanka	2	Philippines	3
China	16	Rhodesia	3
Fiji	4	Romania	10
Germany	152	S. Africa	2
Ghana	8	Taiwan	71
Hungary	58	Thailand	6
Indonesia	3	Trinidad	1
Israel	1	UK	1
Italy	36	USA	582
Japan	35	USSR	45
Korea	2	Yugoslavia	1

Evaluation of Introduced Germplasm in Soybean

For a successful variety development program utilization of possible diversity available in germplasm is primary need. Evaluation of exotic germplasm, in particular, is necessary to widen the genetic base by facilitating the identification and eventual incorporation of the desired traits lacking in the existing varieties. Use of exotic germplasm along with indigenous ones often results in the increased genetic variability for desired selection. Khalaf *et al.* (1984) reported that there was greater variability for yield in populations where exotic genotypes contributed to the crosses. In this concern, the three way or multiple crosses are found suitable. A greater number of suitable lines may be identified from such crosses. Evaluation of exotic germplasm in India has resulted in identification of donor sources (Table 8) several of which have been used in breeding for crop improvement.

In India, there are about 3,094 soybean accessions in the long-term storage for base collection at gene bank at NBPGR, New Delhi. About, 3,250 accessions are at NRCS, Indore; 3,000 at NBPGR Centre, Akola; 809 at Pune; 636 at Pantnagar; 650, at Bangalore; 592 at Coimbatore; 287 at Sehore and 286 at Jabalpur (Tiwari, 2001b). Despite this it is very less compared to USA collections. Several accessions are not duplicated at different centres and therefore, are not in use in breeding programmes extensively.

Tiwari (2001 b,c) and Karmakar (2001) reviewed the soybean improvement programme in India and found that the genetic base of Indian released varieties is narrow

Table 6. Characteristics of soybean germplasm introduced during 1994-2006

EC Number	No. of Acc.	Countries	Characteristics
EC 426727-744	18	Taiwan	Grain and vegetable type
EC 439597-622	26	Taiwan	Rust resistant, insect resistant and early maturing lines
EC 434782-812	31	USA	Transgenic
EC 468377-629	253	USA	Lines resistant to root knot nematode, drought, heat, soybean moasic virus, multiple foliar disease, downy mildew
EC 473111-138	28	Taiwan	Rust resistant and wild perennial lines
EC 473265-288	24	Taiwan	Vegetable types and rust resistant lines
EC 478225	1	USA	Resistant to soybean cyst-nematode
EC 483041-61	21	USA	Lines resistant to foliar feeding insects, rust/and stem canker, having high protein, genetic male sterility, low trypsin inhibitor,
EC 497964	1	USA	High yielding, mid-maturity with indeterminate habit, high protein content
EC 528619-629	1	USA	High yielding and widely adapted
EC 537946	11	Taiwan	Rust resistant lines
EC 537947	1	USA	High yielding, resistant to shattering, lodging and root knot nematode
EC 538792-800	1	USA	High yielding, resistant to soybean cyst and root knot nematode
EC 538801-804, 538806	9	USA	Rust resistant lines
EC 538810	6	USA	Rust differential lines
EC 538805,538811, 558812 EC 538815, 558807-538809,	3	USA	Drought tolerant lines
EC 538813-14, 538816	7	USA	Insect resistant lines
EC 538817-818	2	USA	Concentric black over brown seed coat
EC 538820-821	2	USA	Saddle patterns on seed coat
EC 538822-823, 538830	3	USA	Drought and heat resistant
EC 538824	1	USA	Low lipoxygenase
EC 538825-829	5	USA	Resistant to root knot nematode
EC 538831-833	3	USA	5.5% linolenic acid
EC 538834	1	USA	Resistant to soybean scab
EC 538835-841	7	USA	Resistant to soybean cyst nematode
EC 539008	1	USA	Resistant to phytophtora rot, races 3 and 14 of soybean cyst nematode
EC 559539-271	33	Taiwan	Vegetable Type
EC 559572	1	Taiwan	Rust tolerant vegetable type
EC 592181-212	32	Taiwan	Late/early maturity, whitefly and downy mildew resistant
EC 592211-219	9	Taiwan	High oil content
EC 5986966	1	USA	Early, resistant to stem canker and soybean mosaic virus
EC 586967	1	USA	High yield, shattering resistant, resistant to stem canker, soybean cyst nematode, sudden death syndrome and frog eye leaf spot
Total	**533**		

*EC =Exotic Collection

Table 7. List of wild species of soybean introduction

S. No.	Crop	EC number	Source coutries
1	*Glycine argyrea*	EC 468551	USA
2	*G. canescens*	EC 56371-73, 468421-22	Taiwan, USA
3	*G. centennial*	EC 1468570	USA
4	*G. clandestinea*	EC 456369-70, 468426-33	Taiwan, USA
5	*G. cyrtoloba*	EC 468423-24	USA
6	*G. latifolia*	EC 56379, 468418-420	USA
7	*G. microphylla*	EC 468425	USA
8	*G. soja*	EC 456384-86, 473120-137	Taiwan, USA
9	*G. soja clandestine*	EC 468426-433, 473138	USA
10	*G. tabacina*	EC 456380-8, 1, 468375-416	Taiwan, USA
11	*G. tomentella*	EC 56382-83, 468453-54	Taiwan, USA
12	*G. falcate*	EC 456374-75	Taiwan, USA
14	*G. javanica*	EC 56376-78	USA

and the trend of hybridization is elite x elite germplasm lines. Therefore, there is a need for broadening the genetic base for soybean varieties. Verma *et al.* (1995) have evaluated the genetic resources at NBPGR and reported several donors for different characters. Lal *et al.* (2001) evaluated the germplasm for rust resistance and Pushpendra and Sidhu (2001) reported some sources of resistance for disease-insect complex. The original Indian accession Kalitur has played a key role for revolution in Indian soybeans. This black seeded variety is still used as a donor for multiple characters such as high seed number per plant, better seed longevity and higher germination percentage, wide adaptability and resistance to water lodging. Evaluation of soybean germplasm has been done at Agharkar Research Institute

Table 8. Important characteristics of soybean and the donor sources, including introductions and their derivatives, for use in breeding programme

Characters	Donor varieties/lines
Early maturity	EC 4478(61DAS) EC 34116, EC 39171, EC 95284, EC 39237 (All 69 DAS), EC 7849, EC 28177, EC 32526, EC 34066, (All 70 DAS)
High yield	JS335, Hardee, Bragg, Carroll, MACS 13, MACS-124, MACS 450, NRC-37, MAIS 2, TS 98-21, PK 472, Pusa 16, JS 80-21
Seed longevity	Type 49, Kalitur, Punjab 1, JS 80-21, NRC 1
High seed germination	Kalitur, MACS 111, MACS 450, Type 49.
Pod shattering resistance	Bragg, PK 416, NRC 7, Pusa 22, VLS 1, Himso 1520, Nathan, JS 71-05, MACS 124
Resistance to insect pests	*Glycine soja* (for Bihar hairy caterpillar, girdle beetle, etc.) PI 171451, PL 227687 and PI 229358, L592 (for girdle beetle)
Resistance to diseases	
Yellow mosaic virus	*Glycina soja*, UPSM 534, PK 416
Bacterial pustules	Bragg, Hardee, PK 564, PK 416
Aerial blight	PK 472, JAVA 16, Kalitur
Rust	PI 200492, PI 462312, PI 230970, PI 459025, Ankur, PK 1029
Early maturity	Monetta, Shelby, Punjab-1, JS 71-05, PK 327, MACS 330
High oil content (more than 21%)	PK 416, Lee (non-nodulating), MACS 58, MACS 942, MACS 943, MACS 944, MACS 945, MACS 948, MACS 957, MACS 959 and MACS 961
Low linolenic acid	A 16 and A17
lodging resistance	PK 262, JS 71-05, PK 472, MACS 13
Enhanced efficiency and Promiscuity for nodulation	Carroll, JS 335, MACS 124, MACS 450, Pusa 16
Higher insertion of first pod	PK 416, MACS 58 and JS 80-21
Suitability for food uses	Hardee, Punjab 1, PK 472, PI 408251, PI 86023, 'Wase Natsu' (PI 417458), 'I-Higo-Wase' (PI 205085), Himso 1563, Kunitz

(Pune), NBPGR Regional Station (Akola) and National Research Centre for Soybean (Indore). The data have been presented in the form of catalogues. Important breeding objectives for soybean and their sources for use in breeding programme have been given in the Table 8.

The performance of newly bred lines depends upon how much diverse the parents were. Genetically diverse parents are likely to produce high heterotic and desirable segregates. The concept of Mahalanobis D^2 analysis for measuring divergence between populations has been applied by several workers. Murthy and Arunachalam (1966) stated that the genetic drift and selection in different environments could cause greater diversity among genotypes than their geographical distribution. Joshi (1979) reported that genetic diversity involving genetically diverse parents in crossing would be advantageous as it would provide an opportunity for bringing together gene constellations of divergent origin. Raut *et al.* (1998) evaluated the germplasm lines for seed oil content and reported 21 lines having more than 21.5% oil content. Chauhan and Singh (1982) studied the segregating populations and explained that there was greater variability in the populations of the medium to high divergent parents. Raut *et al.* (1984) studied genetic divergence in soybean and grouped variable genotypes into 12 clusters irrespective of geographical distribution or origin. They suggested that EC2586, EC077, PLSO-24-A and IC10037 were most divergent. After evaluation of 41 Indian cultivars for 10 yield components, Karmakar *et al.* (1998) have observed that there was maximum diversity between JS71-05 and T-49 and the crosses between JS-2 and Monetta were identified as good possible combinations for earliness. Thus the diversity analysis of the present germplasm lines is important for design of the future breeding strategies to get higher genetic gain. Tiwari (2001) have put forward some strategies as, i) assessment of genetic base through pedigree and other analyses, ii) introduction should be extensively initiated, iii) consolidation of national germplasm collection to different research stations, iv) evaluation of core collection for various qualitative and quantitative characters, and v) pre-breeding and germplasm enhancement using cultivars as well as wild relatives and land races.

Broadening the Genetic Base

Results of pedigree analysis and diversity analysis in soybean have indicated narrow genetic base of cultivated varieties. Studies in major soybean growing countries like USA (Delannay *et al.*, 1983; Manjarrez-Sandoval, *et al.*, 1997; Kisha *et al.*, 1998; Thompson and Nelson, 1998), Brazil (Hiromoto and Vello, 1986; Vello *et al.* 1988), India (Karmakar and Bhatnagar, 1996) and China (Gai, 1999) have indicated that up to now breeders have used only a small part of available genetic resources and the soybean varieties have a very narrow genetic base. Germplasm enhancement and pre-breeding is needed. There is a need to strengthen the activities in this aspect by resorting to crossing between unadapted genotypes (cultivated) allied species especially *Glycine soja* Siebet Zucc. and elite cultivars.

Strategies for broadening the genetic base of soybean in breeding and production in India have been suggested (Tiwari, 2001). These comprise : (i) assessing the genetic base through pedigree and other analyses, (ii) directed introductions, (iii) consolidating the national germplasm collections, (iv) evaluation and establishment of a core collection of soybean genetic resources, (v) pre-breeding and germplasm enhancement using the cultigen as well as wild species, (vi) population improvement, (vii) enhancing genetic diversity at farm level by farmer participatory approaches, and (viii) facilitated access to soybean genetic resources for the users. Directed introductions, further enhancement of genetic resources, pre-breeding and ultimate widening of the genetic base of the cultivars at farm level will eventually lead to the realisation of high productivity.

Successful use of Plant Introductions in Soybean Improvement

Introductions used as varieties per se

There is a sizable number of early soybean varieties which are introduced and used per se for cultivation after their evaluation to suit Indian conditions. The improtant introduced varieties are Bragg, Clark 63, Davis, Hardee, Hill, Improved Pelican, KM 1, Lee, and Monetta. It is to be remembered that these varieties played an important role during early phase of soybean spread in India along with the landraces or indigenous varieties like Kalitur, JS 2, Type 49 and Punjab White/ Punjab 1 (Selection from Nanking).

Depending on their breeding history, the Indian varieties can be grouped into two. The first group comprises varieties viz. Bragg, Lee, Improved Pelican, Hardee, Monetta, Shilajeet, Co 1, Gujarat Soy, Gujarat Soy 1, Gujarat Soy 2, VL Soy 2 and JS 71-05 which owe their evolution to direct selection from exotic and indigenous material. The second group comprises a bulk of the rest of the Indian varieties which were developed through hybridization among and mutation in the varieties of the first group (Karmakar and Bhatnagar, 1996).

The introductions were also used as base for mutation breeding and used in hybridization to develop varieties. The details are given in Table 9.

Table 9. Soybean introductions released *per se* and / or used for crop improvement

S. No.	Name of the introduction	Country from where introduced (Year of introduction)	Cultivar developed from it	Mode of development	Year of release of the cultivar
1.	Hill		ADT-1	Selection	1990
2.	Bragg	USA (1967)	Bragg	Introduction	1969
			NRC2	Mutation	1997
			NRC12	Mutation	1997
			Durga	Hybridization	1982
			Hara soya	Hybridization	2001
			JS 76-205	Hybridization	1984
			JS 79-81	Hybridization	1994
			MACS 450	Hybridization	1999
			Pant Soybean 564	Hybridization	1991
			Pant Soybean 1024	Hybridization	1997
			Pant Soybean 1029	Hybridization	1997
			Pant Soybean 1042	Hybridization	1997
			Pusa 20	Hybridization	1988
			Pusa 24	Hybridization	1987
			Pusa 37	Hybridization	1985
			SL4	Hybridization	1990
			SL 295	Hybridization	1997
			VL Soya-1	Mutation	1985
3.	S69-96		NRC7	Selection	1997
4.	D63-6094		Alankar	Hybridization	1978
5.	D61-4249		Alankar	Hybridization	1978
6.	Dortchsoy 67A	Italy	Ankur	Selection	1976
			Pant Soybean 564	Hybridization	1991
			SL295	Hybridization	1997
7.	Clark 63	USA	Clark 63	Introduction	1969
			JS 80-21	Hybridization	1991
			JS 90-41	Hybridization	1999
			JS335	Hybridization	1994
			MAUS 47	Hybridization	2000

	Name of the introduction	Country from where introduced (Year of introduction)	Cultivar developed from it	Mode of development	Year of release of the cultivar
			MAUS 32	Selection	2000
			MAUS 61	Selection	2001
			MAUS 61-2	Selection	2002
			Pusa 22	Hybridization	1983
			Shivalik	Selection	1987
			MAUS 81	Hybridization	2003
8.	S.3	Thailand	Co-1	Selection	1982
		Taiwan	JS 80-21	Hybridization 1	1991
			JS 90-41	Hybridization	1999
			JS335	Hybridization	1994
			KHSb2	Hybridization	1979
			MAUS 47	Hybridization	2000
			MAUS 32	Selection	2000
			MAUS 61	Selection	2001
			MAUS 61-2	Hybridization	2002
			Shivalik	Selection	1987
			MAUS 81	Hybridization	2003
9.	Shihshi	Taiwan	Co Soya-2	Hybridization	1997
10.	Davis	USA	Davis	Introduction	1973
11.	C.6	Australia	Durga	Hybridization	1982
12.	D60-9647	USA	Gaurav	Hybridization	1982
13.	CNS		Gaurav	Hybridization	1982
			MACS-13	Hybridization	1985
			RAUS5	Hybridization	2002
			Pusa 16	Hybridization	1987
14.	Nanking		Punjab-1	Selection	1975
			Gujarat Soybean 1	Selection from Punjab-1 (from Nanking)	1983
			Pant Soybean 471	Hybridization	1988
			PK 472	Hybridization	1986
			Pusa 22	Hybridization	1983
15.	Geduld		Gujarat Soybean 2	Selection	1983
16.	Hardee		Hardee	Introduction	1976
			Pant Soybean 471	Hybridization	1988
			PK262	Hybridization	1983
			PK.308	Hybridization	1985
			PK472	Hybridization	1986
			MAUS 61-2	Selection	2002
			KB 79	Hybridization	1997
17.	Improved Pelican		Improved Pelican	Introduction	1976
			JS 75-46	Hybridization	1987
			MACS-57	Hybridization	1992
			MACS-58	Hybridization	1989
			MACS-124	Hybridization	1992
18.	Lee type material		JS 71-05	Selection	1991
			MAUS 71	Hybridization	2002
			JS335	Hybridization	1988
			MAUS 81	Hybridization	2003
19.	Semmes	USA	JS 75-46	Hybridization	
			PK327	Hybridization	1983
20.	Harsoy-Deciduous		JS 79-81	Hybridization	1994
21.	Hark		JS 90-41	Hybridization	1999
			MAUS 47	Hybridization	2000
22.	Manloxi	Australia	KHSb2	Hybridization	1979
23.	KM1	AVRDC	KM1	Introduction	1982
24.	Lee		Lee	Introduction	1973
			Pusa 16	Hybridization	1987
			RAUS5	Hybridization	2002

	Name of the Introduction	Country from where introduced (Year of introduction)	Cultivar developed from it	Mode of development	Year of release of the cultivar
			Pusa 20	Hybridization	1988
			Pusa 40	Hybridization	1981
25.	Monetta		Monetta	Introduction	1985
			MACS 330	Hybridization	1990's
			KB 79	Hybridization	1997
26.	5831	USSR (1971)	MACS 330	Hybridization	1990's
			LSbl	Selection	2001
27.	Hampton		MACS-13	Hybridization	1985
28.	PI 171443		Pant Soybean 564	Hybridization	1991
			PK416	Hybridization	1986
			SL295	Hybridization	1997
29.	Bulomi No.3		PK327	Hybridization	1983
30.	8-3		Pusa 40	Hybridization	1981
31.	Rikun No 8	Japan	Shilajeet	Selection	1980
32.	Botato	Australia	SL96	Hybridization	1986
33.	Shelby		Pusa 24	Hybridization	1987
34.	Java 16		Pusa 37	Hybridization	1985

H = Hybridization, I = introduction, S = Selection.

For insect-resistance

Breeding for insect-pests is a priority in soybean improvement programme. During recent past, four accessions i.e. PI 171444, PI 171451, PI 227687 and PI 229458 were found to be resistant to various defoliators and stink bugs at AVRDC, Taiwan. All of them were not resistant to entire range of insect species, but together they covered practically all insect-pests prevalent in Taiwan. The resistance present in three multiple resistance donors namely PI171451, PI227687 and PF229358 was reported to be controlled by different genes. One of the insect aspects was reviewed by Maxwell and Jennings (1980). The pubescence on soybean i.e. density, length and orientation of hairs appears to be one of the resistance imparting factors. This has been observed that the pubescence characters interfere with oviposition, feeding, attachment mechanism and normal development and behaviour of insects (Tumipseed, 1977; Lee, 1983). Introduction of such sources and breeding advances utilizing the available sources of resistance are needed and are continuing in order to develop agronomically acceptable insect resistant varieties.

Two insect resistant strains, UPIR-1 and UPIR-2 were found promising at Pantnagar, in Northern India and are in use as resistant sources (Bhatnagar and Tiwari, 1996). Emphasis is given on leaf miner resistance and stem fly at Parbhani and Pune. They reported some resistant sources, viz. NRC-41, NRC-42, JS 92-22, MACS 124 and VLS 52 for leaf miner and Himso-1578, JS-92-12, JS(SH)-93-01, JS(SH)-93-07, JS(SH)-93-48, MACS 124, MACS 569, MAUS 63, TS 98-21, TS 98-91 and UGM 47 for stem fly. Previously reported resistant donor MACS 613 and MACS 74 are being used in breeding programme.

At NRCS Indore, in Central India, introduced *G. soja* as well as germplasm line L-592 were found to have resistance to girdle beetle and stem-fly (Tiwari, 2001b). *Glycine soja* was suggested as a promising source of resistance to Bihar hairy caterpillar (Ram *et al.*, 1989). Also, germplasm line Tax 855-53D was least damaged by lepidopterous defoliators. Such promising sources are being further evaluated for confirmation. The resistance appeared to be due to feeding preference rather than due to antibiosis or avoidance. The species was utilized in hybridization with the cultigen and a highly tolerant line, PK 515, was developed.

For resistance to diseases

Sinclair and Backman (1989) have summarized the sources of disease resistance for their use in breeding programme. Several introductions with these resistance genes have been obtained. The work for evaluation of existing germplasm diversity and development of new elite lines with advanced desired characters is continuing under the AICRPS and by various independent workers for different diseases. Also the large number of early generation segregants are being evaluated. All these efforts have led to resistance in soybean lines viz., high resistance to yellow mosaic virus (PK 416), bacterial pustules (PK 416, PK 472, PK 564, Bragg), pod blight (Bragg, Hardee, PK 472), rhizoctonia aerial blight (PK 472, PK 262, PK 416) and rust resistant (PK 1029, Ankur).

Besides, use of introduced germplasm and genes thereof has been made and is being made for crop improvement in regard to other economic characters including quality characters for food uses of soybean.

Specific PGR Needs for Meeting the Plant Breeding Objectives in India

In India, several breeding methods have been employed for attaining different breeding objectives and cultivar development in soybean (Table 10). Earlier soybean varieties cultivated were largely introductions from the U.S.A. The exotic soybean varieties released in India are 'Bragg', 'Clark 63', 'Davis', 'Hardee' 'Improved Pelican', 'KM 1' (Introduced from AVRDC, Taiwan) and 'Monetta' (EC 2587).

Table 10. Breeding methodology used in the development of varieties

Sl. No.	Breeding methodology	Number of varieties developed
1.	Pedigree/pureline selection	47
2.	Selection from variety/line	7
3.	Indigenous native variety or selection indigenous material from	5 *
4.	Mutation	4 **
5.	Introduction	2 ***
	Total Varieties	**65**

* Kalitur, ADT-1, JS 2, Gujarat Soybean 2, Punjab 1
** Birsa Soybean 1, MAUS 1, NRC 2, NRC 12
*** KM 1, Monetta

Most of the Indian varieties viz. JS 76-205, JS 75-46, JS 335, PK 262, PK 327, PK 308, PK 416, PK 472, PK 564, SL 96, MACS 13, MACS 58, KHSb 2, Pusa 16, Pusa 20 and Pusa 24 have been developed using pedigree method. Out of different breeding methodologies employed, the pedigree method and pureline selection have made predominant contributions (Table 5).

Till today 75 improved varieties of soybean have been bred and released for cultivation in the country since the mid-sixties. A study of genetic diversity among elite Indian soybean varieties was carried out at the NRCS. The varieties were grouped into six clusters with 75 percent of the varieties falling under two genetically less divergent clusters. These clusters were characterized by a moderate and probably balanced expression of the economically important characters. Maximum genetic divergence was observed between varieties JS 71-05 and T 49.

The following specific areas need focussed attention for soybean improvement.

i) High yield potential : 35-40 q in case of medium maturity and 25-30 q in case of early maturing varieties.
ii) Appropriate maturity and earliness in varieties to fit in existing and emerging cropping systems.
iii) Good seed longevity and resistance to mechanical damage in seeds.
iv) Resistance to rust and YMV diseases especially for Central zone.
v) Resistance to insect-pests like defoliators, girdle beetle, stemfly and leaf miner.
vi) Drought tolerance.
vii) Suitability for food uses; varieties with mill or low anti-nutritional factors.
viii) Suitability for mechanical harvest.
ix) High nitrogen fixing efficiency and promiscuity of the host in the soybean varieties.

These areas may be grouped as either germplasm need or breeding need as given in Table 11.

Genetic incorporation of promiscuity for nodulation as reported by I.I.T.A. (Pulver *et al.* 1985; Dashiel *et al.*, 1986) as also the use of supenodulating mutants of 'Bragg' (Carroll *et al.*, 1985) and 'Williams' (Gremaud and Harper, 1989) could lead to evolution of such improved soybeans which could have upto 25% higher yields over the present levels and yet require less fertilizers. The germplasm needs can be met by directed introductions and germplasm enhancement or pre-breeding. The elite lines can, then, be utilized for crop improvement.

Summarisingly, the collections of soybean PGRs in India have an abysmally small size. Introduction especially directed introductions are needed. Very little exotic material has been obtained from the known centres of origin, and diversity. A few accessions have come from China directly. Same is the case for obtaining accessions from Japan especially for food uses. Accessions from Australia, known for its diversity especially in case of wild soybeans, are also less. Directed introduction from these countries will improve the situation.

Introgression of desirable wild genes, both at intra-subgeneric and inter-subgeneric levels, could provide

Table 11. Breeding objectives and germplasm needs for soybean improvement in India

Sl. No.	Objective	Sources available: Source	Sources available: Details	Nature and comment
1.	Resistance to soybean rust	Cultivars viz. PI 462312 (Ankur), JS 8021,PK 1024, PK 1029, Indira Soya 9 with tolerance to rust are available.	Only tolerance or moderate resistance is available. PI 459025 is not available.	More of a breeding need than a germplasm need. ii. High resistance sources are needed which can be evaluated in hot spots and utilized.
2.	Varieties for food uses (null lines for trypsin inhibitor and lipoxygenases)	Relatively low level of trypsin inhibitor and lipoxygenases has been observed in some Indian varieties.	i. No null lines for antinutritional factors available. ii. Lines with improved protein and fatty acid composition are needed. iii. Vegetable types need to be introduced especially from AVRDC, Taiwan.	A germplasm need. The null lines are to be introduced and the character is to be put in the background of adapted genotypes (germplasm enhancement)
3.	Early maturity	Sources like 'Shelby,' 'Monetta' and others are available.	Early maturing varieties are available but diversification is needed.	The breeding programme needs Supplementation/diversification of parental lines by ay of availability of sources for long juvenility and early maturity.
4.	Stagnant genetic potential for yield	i. Diverse germplasm not available. ii. Early maturing bold seeded Indian varieties lines have relatively rapid seed fill.	Source for characters viz., long juvenility and rapid seed fill are needed. Some sources of long juvenility have been recently obtained from Brazil.	Both germplasm and breeding need. The present base of Indian soybean varieties is very narrow. Directed introduction from diverse components (representing different groups of a core collection) needed within a required photoperiodic adaptation. Sources with characters viz. long juvenility, rapid seed fill, high biomass, are etc. needed.
5.	High nitrogen fixation efficiency and promiscuity of the host.	Not available	Diverse Indian conditions call for promiscuity of host.	It is a germplasm need.
6.	Introgression of desirable genes from *Glycine soja* into the cultigen.*	*Glycine soja* is represented by probably one accession only in India.	i. Serveral resistant genes and other desirable characters like high protein are available in *G. soja.* ii. Some back cross derivatives are available.	It is a germplasm need. *Glycine soja* accessions should be introduced. Germplasm enhancement/pre-breeding may follow.

* *G. tomentella* derived elite diploid lines (Riggs *et al.*, 1998: Singh and Hymowitz, 1999) may also be introduced and utilised.

novel combinations of genes and stretch the range of present variability to ultimately evolve efficient soybean varieties suitable for diverse growing conditions. The wild species are represented meagrely. The genetic diversity within a wild species is also very low. In many cases, one wild species is represented by only one accession. Surprisingly, this is the case with *G. soja* also which is being utilized to some extent in the Indian soybean improvement programme.

Plant introduction and germplasm exchange, especially on *quid pro quo* basis, are important endeavours facilitating regional and global interdependence towards sustainable utilization of genetic resources. These efforts should be carried out to uphold the value of partnership for making the most of agricultural biodiversity i.e. diversity for well-being.

Acknowledgements

The author is thankful to Dr. Chellapilla Bharadwaj and Dr. T. Satyavathi, Sr. Scientists, NRCS, Indore, India for their forthcoming able help unstintingly rendered during the preparation of this manuscript.

References

Alton [Illinois] Telegraph and Democratic Review (1842) 15 October p.2, col. 1.

Badal PS, Praduman Kumar, SD Billore, AN Sharma and OP Joshi (2000) Socio-economic impact of soybean cultivation in Madhya Pradesh. Project Report of IARI and NRCS (ICAR). Pp. 1-35.

Bernard RL, GA Juvik and RL Nelson (1989) USDA Soybean Germplasm Collection Inventory (Volume 2). International Agricultural Publications. INTSOY Series No. 31. Pp. 203.

Bhatnagar PS and SP Tiwari (1996) Soybean *In* Genetics, Cytogenetics and Breeding of Crop Plants. Vol.-l, Pulses and Oilseeds. Oxford & IBH Publishing New Delhi, pp 175-216.

Brooks H (1966) Applied and economic botany, pp. 100-114. National Academy of Science. 'The plant science now and in the coming decade'. *Natl. Res. Council Publ.* 1405.

Burns W (1941) Soybean, its politics, performance and possibilities. *Indian Farming,* **2:** 451-458.

Chang Ruzhen (1989) Studies on the origin of cultivated soybean (*Glycine max* (L.) Mer.). *Oil Crops of China,* **1** : 1-6 (In Chinese with English Summary).

Chauhan VS and BB Singh (1982) Heterosis and genetic variability in relation to genetic divergence in soybean. *Indian Journal of Genetics and Plant Breeding,* **42**: 324-328.

Carroll BJ, DL McNeil and PM Gresshoff (1985) A super-nodulation and nitrate-tolerant symbiotic (nts) soybean mutant. *Plant Physiol.* **78:** 34-40.

Delannay X, DM Rodgers and R G Palmer (1983) Relative genetic contributions among ancestral lines to North American soybean cultivars. *Crop Science,* **23:** 944-949.

Dashiell KE, EA Kueneman, WR Root and SR Singh (1986) Breeding tropical soybean for superior seed longevity and for nodulation with indigenous rhizobia. P. 133-140. In: Soybean in Tropical and Sub-tropical Cropping Systems. *Proc.of Symp.* Tsukuba, Japan.

Gai Junyi (1999) Strategies and approaches for future breeding toward high yields in China. In *Proceedings of the World Soybean Research Conference VI,* held at Chicago, USA, August 4-7, 1999. Ed. HE Kauffman, The Univ. of Illinois,USA. pp 126-1.

Gremaud MF and JE Harper (1989) Selection and initial characterization of partially nitrate tolerant nodulation mutants of soybean. *Plant Physiol.* **89:** 169-173.

Hiromoto DM and NA Vello (1986) The genetic base of Brazilian soybean (*Glycine max* (l.) Merill) cultivars. *Brazil J. Genetic.* **9:** 205-306.

Hymowitz T (1970) On the domestication of the soybean. *Econ. Bot.* **24:** 408-421.

Hymowitz T and RL Bernard. (1991) Origin of soybean and germplasm introduction and development in North America. In *"Use of plant introductions in cultivar development - Part I".* CSSA Special Publication No. **17:** 147-164.

IPI. (1934) Progress report for the year ending 30th June, 1934 of the Institute of Plant Industry (IPI), Indore, Central India. Examiner Press, Bombay, p. 18.

Joshi A.B. (1979) Breeding methodology for autogamous crops. *Indian Journal of Genetics and Plant Breeding.* **39:** 569-578.

Karmakar PO and PS Bhatnagar (1996) Genetic improvement of soybean varieties released in India from 1969 to 1993. *Euphytica,* **90:** 95-103.

Karmakar PO, PS Bhatnagar, VS Bhatia and OP Joshi (1998) Genetic diversity among Indian soybean varieties. *Soybean Genetics Newsletter* **25:** 74-75.

Karmakar PG (2001) Speeding up the development of new soybean varieties. *Proceedings of India Soy Forum.* Indore. 65-69.

Kisha TJ, BW Diers, JM Hoyt and CH Sneller (1998) Genetic diversity among soybean plant introductions and North American germplasm. *Crop Sci.* **38**: 1669-1680.

Khalaf AGM, GD Brossman and JR Wilcox (1984) Use of diverse populations in soybean breeding. *Crop Sci.* **24**: 358-360.

Lal SK and VKS Rana (2000) Genetic enhancement of soybean. *Indian Journal of Genetics and Plant Breeding.* **60:** 483-494.

Lal SK, Hegde V and VKS Rana (2001) Screening and utilization of soybean *(Glycine max.* (L.) Merrill) genotypes for improving resistance against rust. *Indian Journal of Genetics and Plant Breeding.* **61**: 287-288.

Lee YI (1983) The potato leafhopper, *Empoasca fabea,* soybean pubescence and hopper bum resistance. Ph.D. dissertation. University of Ullinois, USA.

Manjarr ez-Sandoval P, TE Carter Jr, DM Webb and JW Burton. (1997) RFLP genetic similarity and coefficient of parentage as genetic variance predictors for soybean yield. *Crop Science* **30:** 1033-1040.

Maxwell FG and PR Jennings (1980) *Breeding plants resistant to insects.* John Willey and Sons, New York.

Morse WJ (1947) The versatile soybean. *Economic Botany.* **1:** 137-147.

Morse WJ (1950) History of soybean production, pp. 3-59. In *'Soybeans and soybean products* - **Vol. 1:** Markley, KS (ed). Interseience Publi. Inc., New York.

Murthy BD and V Arunachalam (1966) The nature of divergence in relation to breeding system in some crop plants. *Indian Journal of Genetics and Plant Breeding.* **26a**: 188-198.

Nagata T (1959) Studies on the differentiation of soybeans in the world with special regard to that of South-east Asia. *Proc. Crop Sci. Soc.* Japan, **28:** 79-82.

Nagata T (1960) Studies on the differentiation of soybeans in Japan and the world. *Men. Hyogo Univ. Agri.* 3(2) Ser. **4:** 63-102.

Pulver EL, Kueneman EA and Ranga Rao V (1985) Identification of promiscuous nodulating soybean efficient in N_2 fixation. *Crop Sci.,* **25:** 660-663.

Pushpendra and P Siddhu (2001) Reaction to certain disease-insect complexes of the breeding lines derived from two inter-specific crosses of soybean *(Glycine max.* (L.) Merrill.). *Indian Journal of Genetics and Plant Breeding.* **61**: 289-290.

Ram HH, K Pushpendra Singh and Ranjit (1989) *Glycine soja:* a source of resistance for Bihar hairy caterpillar, *Spilosoma (Diacrisia) obliqua* Wallace in soybean. *Soybean Genetics Newsletter* **16:** 52-53.

Raut VM, C Asok C and VP Patil (1984) Genetic divergence in soybean. *Biovigyanam,* **10(2):** 121-125.

Riggs RD, S Wang, RJ Singh and T Hymowitz (1998) Possible transfer of resistance to *Heterodera glycines* from *Glycine tomentella* to *Glycine max. J. Nematol.* **30**: 547-552.

Sinclair JB and Backman PA (1989) *Compendium of Soybean Diseases,* 3 edn. APS Press, The American Phytopathological Society, Minnesota, pp. 1-106.

Singh RJ and T Hymowitz (1999) Soybean genetic resources and crop improvement. *Genome,***42:** 605-616.

Thompson JA, and RL Nelson (1998) Utilisation of diverse germplasm for soybean yield improvement. *Crop Science* **38**: 1362-1368.

Tiwari SP, OP Joshi and AN Sharma (1999) The advent and renaissance of soybean - A landmark in Indian agriculture. NRC for Soybean (ICAR) publication. pp 1-58.

Tiwari SP (2001) Introduction, diversity and enhancement of Soybean Genetic Resources in India - A status report. Consultancy Report for the IPGRI, Rome, Italy. Pp. 1-67.

Tiwari SP (2001a) Soybean. In "Breeding Field Crops"-Chapter 10. Ed. VL Chopra. Oxford and IBH Publi. Co. Pvt. Ltd., New Delhi-Calcutta, pp 361-391.

Tiwari SP (2001b) Indian scenario and needs in soybean genetic resources. *Proceedings of India Soy Forum,* Indore. 48-57.

Tiwari SP (2001c) Status reports on introduction, diversity and enhancement of soybean genetic resources in India: A consultancy report for the IPGRI, Rome, Italy. pp 1-70.

Tumipseed SG (1977) Influence of trichome variations on population of small phytophagous insects in soybeans. *Environmental Entomology,* **6:** 815-817.

Verma VD, PN Gupta and RS Rana (1995) Soybean genetic resources at NBPGR. Poper presented at XXV Annual Workshop of AICRP on soybean. UAS, Dharwad.

Vello NA, OM Hiromoto and AJBV Azevedo Filho (1988) Coefficient of parentage and breeding of brazilian soybean germplasm. *Brazil J. Genetics* **11:** 679-697.

Plant Introduction : Achievements and Opportunities in Jute and Allied Fibre Crops in India

AK Mahapatra, A Bandyopadhyay, A Saha, D Gupta and HS Sen*
Central Research Institute for Jute & Allied Fibres, I.C.A.R., Barrackpore, Kolkata-700120, West Bengal, India

Collection and introduction of jute and allied fibre crops germplasm through different modes like institute efforts, correspondence, joining in National and International programmes from early twentieth century to recent time have been chronologically narrated. Variablities in different traits within the collected germplasm have been studied and short listed accessions are under use as base material in breeding programmes for crop improvement. Role of these valuable germplasm in developing different suitable varieties is enumerated. Their impacts on national productivity and in various industrial sectors have been dealt with. Further need and scope in collecting germplasm for developing varieties, required for diversified products for sustainability of these crops from competition with the synthetic fibres are indicated.

Key words: Jute, Mesta, Germplasm collection, Variability, Utilization

The genus *Corchorus* belongs to the family Tiliaceae and its two annual species viz., *C. capsularis* (White jute) and *C. olitorius* (Tossa jute) yield fibre from bark of the stem after being retted in water and termed as jute. Other two species, *Hibiscus cannabinus* (Kenaf / H.C. mesta) and *H. sabdariffa* var. *altissima* (Roselle / H.S. mesta) of family Malvaceae also produce similar fibre; and thus known as allied fibre. Fibres of all these four species, known as raw jute in trade and commerce are used in the jute industry either alone or in combination. There are several other non-cotton fibre plants cultivated in India, termed as allied fibres, such as ramie (*Boehemeria nivea*), sunnhemp (*Crotalaria juncea*), flax (*Linum usitatissimum*) and sisal (*Agave sisalana*). In all these plants, fibre is extacted from the bark of the stem except sisal where extraction is from the leaf.

Asian countries like Bangladesh, China, India, and Thailand are major producers of jute. World area under these crops varies from 4.3 to 4.6 million hectares with an average annual production of 3.43 million tons. About 0.8 million hectares and 0.2 million hectares of land are covered annually with jute and mesta respectively with an average annual production of little more than 1.7 million tons of fibres (Anonymous, 1998).

Cultivation of jute, kenaf and roselle is of high socio-economic significance since livelihood of more than 12 million small and marginal farm families in developing countries like India, China, Bangladesh, Thailand and Nepal depend very much on these crops. Moreover, thousands of other workers are employed in the jute industry, trade and commerce. An increasing competition from synthetic substitutes is causing a serious threat to this industry. The land area under jute and allied fibres is declining and these crops are gradually being pushed to the poor marginal land, which in turn reduces productivity. The productivity has remained low and static over the years. National and international efforts are being made to introduce germplasm from diverse agro-ecological and diversity rich areas from abroad as elucidated in earlier studies (Mahapatra and Saha, 1995; Saha *et al.*, 2004). Utilization of elite germplasm in breeding programme is the headway to enhance productivity along with judicious crop husbandry practices.

Germplasm Introduction

National Programme

To build up a rich and diverse genepool of these bast fibre crops, introduction of germplasm and utilization for selection for improvement of jute and kenaf started in early 20^{th} century (Patel and Ghosh, 1940). But the approach was sporadic and the plant breeders engaged in the crop improvement programme had to work with narrow gene pool of about 300 accessions of jute and 200 accessions of locally collected kenaf and roselle till early seventies.

The systematic approach for collection of jute and allied fibres germplasm was initiated during 1977. Distribution of all the *Corchorus* species found in India and their diagnostic features were studied in detail for strengthening germplasm collection programme either through direct exploration or through correspondence (Mahapatra *et al.*, 1998). Following information collected

**E-mail: senhs@crijaf.org*

from literature survey, study of herbarium specimen, and areas of diversity, different collection teams were sent to different regions. The scientists of Central Research Institute for Jute and Allied Fibres (CRIJAF) made majority of the collections between 1977 to 1985. Later on, National Bureau of Plant Genetic Resources (NBPGR) organized such collection missions in collaboration with CRIJAF.

After evaluation, such collections were found to display diversity, which could meet requirements of the breeders partially. Thereafter, germplasm collections were made under International programme during 1987-1993 which have been elucidated separately. From 1999-2004, under the aegis of National Agricultural Technology Project (NATP) on Conservation of Agro-biodiversity (Plant Genetic Resources), 14 exploration missions were undertaken for collection of trait specific germplasm in some target areas following fine grid method. Six hundred and fifty-five accessions were collected including landraces and wild relatives from different agro-climatic regions viz., Jharkhand, North Bengal including Tarai region, Bengal-Orissa border region, north-eastern and south-eastern Rajasthan, Gujarat, north-eastern Orissa, drier parts of Bengal, parts of Tamil Nadu, Kerala, Karnataka, Maharashtra and different islands of Sundarban Biosphere Reserve in West Bengal.

International Collection Efforts

With the initiative of International Jute Organization (IJO), intensive germplasm-collection programmes were undertaken in countries having rich genetic diversity. Although richest genetic diversity occurs in Republic of South Africa, IJO identified two East African countries like Kenya and Tanzania for direct exploration. Five germplasm collection missions were executed these countries with the logistic support from International Board on Plant Genetic Resources (IBPGR), now known as Bioversity International, regional office for Sub-Saharan Africa in Nairobi. Two scientists from each of the IJO project participating countires (India, Bangladesh, China, Nepal, Thailand) formed five collecting teams to explore the target area during 1987-1988 and collected 790 accessions. Further, IJO provided financial support to the countries like China, Indonesia, Thailand and Nepal during 1988-1990 for collection of jute and mesta germplasm from their own countries and acquired 927 accessions. IJO, later, funded a special mission in Pakistan for exploration in September-October 1990, which collected a total of 251 accessions. It also networked the agencies like USDA, CSIRO, IBPGR and CENERGEN to share the crop germ pool and the information generated.

Thus IJO acquired a total of 2,300 accessions from all sources and conserved these at the gene bank of Bangladesh Jute Research Institute (BJRI), as the IJO's Centralized Germplasm Repository. Germplasm thus acquired was distributed among member countries and India (CRIJAF) also received its due share. Duplicate base collection centre was built up with CSIRO Gene Bank in Canberra, Australia (Denton, 1992).

The total germplasm accessions collected by CRIJAF under different species through correspondence, national and international programmes are given in the Table 1. Crop specific explorations were undertaken for sunnhemp, flax, ramie and sisal germplasm.

Diversity in Jute and Mesta Gene Pool

Yield Parameters: For assessment of total variability and identification of desirable traits in the collected germplasm, the whole set of jute germplasm were grown over two environments and data were recorded on fibre yield and its contributing parameters. The observed range of variability is presented in Table 2. The range for each of the parameters was considerably wide in both the species of jute. For fibre yield range was 0.5-9.2 g per plant in white jute whereas the range was 1.0-10.5 g per plant in tossa jute. Plant height showed the strong correlation with fibre yield and varied between 70-360 cm and 60-420 cm in white and tossa jute respectively (Mahapatra and Saha, 1995).

Table 1. Germplasm holding of jute and allied fibre crops at CRIJAF

Species	No. of accessions
Corchorus capsularis	939
C. olitorius	1,647
Corchorus sp. (wild)	313
Hibiscus cannabinus	705
H. sabdariffa	605
Hibiscus sp. (wild)	125
Crotalaria juncea	149
Crotalaria sp. (wild)	75
Linum usitatissimum	64
Boehmeria nivea	52
Boehmeria utilis	2
Boehmeria sp. (wild)	1
Agave sp. (wild)	45
Agave hybrid	1
Total	**4,723**

Table 2. Range of variability in yield and yield contribution characters of jute

Characters	Range of variations	
	C. capsularis	*C. olitorius*
Plant height (cm)	70 to 360	60 to 420
Basal diameter (cm)	0.4 to 2.4	0.5 to 2.7
Number of nodes	25 to 84	34 to 102
Days to 50% flowering	41 to 186	29 to 175
Dry fibre yield (gm)	0.5 to 9.2	1.0 to 10.5

Early Flowering Resistance: Jute fibre is the product of vegetative growth and a prolonged growth period is essential before the crop enters into reproductive phase. Hence, resistance to early flowering is much sought after parameter. *C. olitorius* germplasm, collected from equatorial region of East Africa under the aegis of IJO were specially evaluated for resistance to early flowering. Eighty such germplasm lines/accessions were sown at four different dates (middle of February, early March, middle of March and early April). Number of days taken to bloom the first flower was recorded and mean values determined. All the accessions over all the dates of sowing were then classified into several groups on number of days to flowering Table 3.

Variability range for early flowering resistance was 48.7-130.4 days in the mid-February sowing. Nine genotypes, which were clubbed under group 1 for this date of sowing are the most desirable genotypes (Anonymous, 1987-89).

Growth Attributes: Investigation on genotypic variability in growth attributes of jute (*Corchorus capsularis* L.) was undertaken to elucidate the extent of genotypic variability of some physiological parameters of growth and yield viz., production of total dry matter, Relative Growth Rate (RGR), Net Assimilation Rate (NAR), Harvest Index (HI), and Leaf Area Index (LAI). Twenty-five jute genotypes representing wild, semi wild, elite types, and recommended commercial varieties were studied. Existence of significant genotypic variability could be observed for all the above-mentioned direct and derived attributes over the stages of growth except for RGR (Table 4).

Range of variability for dry weight ($\log_e W$) during 16th week (harvesting stage) was 5.45-6.26. HI ranged from 14.76-20.26% on the basis of whole aerial biomass. The NAR ranged from 0.141-0.926 g / cm^2 per week during 10th week, the peak time of vegetative growth. LAI during the same week varied between 1.68-3.37 (Saha, 1998).

Abiotic Stress Tolerance

Moisture Deficit : Moisture stress in the early growth phase is prevalent in the areas where jute is grown as rainfed crop. Fifteen representative white jute accessions of exotic and indigenous origin were evaluated for moisture stress tolerance. Parameters like relative turgidity and chlorophyll disintegration (CD) were used for such evaluation. Relative turgidity of the genotypes varied between 37-90% over control and CD varied between 0.03 mg-0.85 mg (Table 5). These 15 genotypes could be classified into susceptible, moderately susceptible and moderately tolerant types. Moderately tolerant types were JRC 212, and Cordate leaf and susceptible types were EC 41337 and Branca (Gupta and Saha, 1987).

Fifteen tossa jute accessions of exotic and indigenous origin were also evaluated for moisture stress tolerance using the same parameters as in case of white jute. Relative turgidity was observed to vary between

Table 3. African jute (*C. olitorius*) germplasm showing various degrees of resistance to early flowering

Group of germplasm	No. of accs. identified in each group	Mean number of days to flower			
		1st sowing (Mid-Feb.)	2nd sowing (Early March)	3rd sowing (Mid-March)	4th sowing (Early April)
Group I	9	130.4	128.8	181.2	171.4
Group II	12	65.9	113.8	181.8	180.3
Group III	38	59.2	50.2	188.4	181.7
Group IV	06	48.7	40.7	46.4	68.2
Control	03	54.2	51.9	191.2	172.2

Table 4. Diversity in physiological attributes of growth and yield in white jute

Growth stages week	Total dry weight $\log_e W$	Relative growth rate g / g / week	Net assimilation rate g/ cm^2 / week	Leaf area index	Harvest index %
12th	4.863 – 5.700	0.043 – 0.240	0.080 – 0.303	1.37 – 3.17	14.91 – 22.74
14th	5.227 – 5.894	0.015 – 0.210	0.045 – 0.581	1.28 – 3.60	15.51 – 20.66
16th	5.451 – 6.263	0.035 – 0.252	0.128 – 0.836	1.21 – 3.48	14.76 – 20.26

Table 5. Diversity range for moisture stress tolerance in white and tossa jute

Crops	Relative turgidity (%)	Chlorophyll disintegration (mg)
White Jute	37 – 90	0.03 – 0.85
Tossa Jute	45 – 85	0.33 – 1.60

45%-85% over control and CD varied between 0.33 mg to 1.60 mg (Table 5). Genotypes like Palmate leaf, Salyout and JRO 524 were identified as tolerant to moisture stress condition and long narrow leaf was susceptible to such situation (Gupta and Saha, 1984).

***Moisture Excess*:** Crop loss due to water inundation is noticed during pre-harvest stage particularly in low-lying areas of white jute belt. CRIJAF took initiative to assess the variability for tolerance to water inundation. Twenty accessions each of white and tossa jute and 6 wild species represented by one accession each were evaluated under inundated condition (30 cm water depth) from 60 days crop age. All the genotypes succumbed to the stress as evidenced by profuse growth of adventitious roots, stunted stem growth and early senescence of leaves. But *Corchorus trilocularis* showed no such symptoms and identified as only tolerant genotype.

Biotic Stress Tolerance

***Fungal Diseases*:** The pests, which are ubiquitous, infest jute crop every year and cause crop loss to the tune of 10-20%. There are as many as 14 diseases of jute caused by 6 fungal pathogens. The major diseases, which reduce the yield of jute, as well as fibre quality are, stem rot, root rot, collar rot and seedling blight. All these 4 maladies are caused by *Macrophomina phaseolina* (Tassi) Goid. syn. *M. phaseoli* (Maubl) Ashby.

A preliminary field evaluation of entire gene pool of white jute (*C. capsularis*) and tossa jute (*C. olitorius*) was carried out to find out the range of diversity with regard to natural incidence of diseases. The scale used in assessing the resistance/ susceptibility of an accession was : 0% infection – resistant, 0.1-5.0% infection moderately resistant, 5.1-10.0% infection moderately susceptible, 10.1- 20.0% infection susceptible and above 20% infection-highly susceptible. A summary of the observations is presented in Table 6 (Mahapatra *et al.*, 1994 and Saha *et al.*, 1994).

In mesta the major diseases are foot and stem rot, sclerotial rot and phoma leaf spot. Foot and stem rot is caused by *Phytopthora parasitica* Dast. Causal organism of sclerotial rot is *Sclerotium rolfsii* Sacc. and *Phoma* sp. causes *Phoma* leaf spot. The scale used in this case was same as mentioned for jute. But for *Phoma* leaf spot the % leaf area affected by the spots was considered for assessing resistance or susceptibility of a type. Thus the scale used was: no spot – resistant, 5.0% of leaf area affected – moderately resistant, 5.1-10.0% leaf area affected – moderately susceptible, 10.1-20.0% area affected – susceptible and above 20.0% area affected – highly susceptible. Observations have been presented in Table 7 (Mandal *et al.*, 1995 a, and 1995 b). Above observations primarily identified potential donor germplasm in respect of resistance to major fungal diseases. The short listed germplasm has formed the base material for resistance breeding in jute and mesta.

Table 6. Natural incidence of stem and root rot in white and tossa jute germplasm caused by *Macrophomina phaseolina*

Crops species	Diseases reaction	No. of accessions
C. capsularis (White jute)	Resistant	205
	Moderately resistant	437
	Moderately susceptible	116
	Susceptible	57
	Highly susceptible	6
C. olitorius (Tossa jute)	Resistant	182
	Moderately resistant	665
	Moderately susceptible	414
	Susceptible	177
	Highly susceptible	35

Table 7. Natural incidence of foot and stem rot, sclerotial rot and *Phoma* leaf spot in HC and HS mesta

Crop species	Disease reaction	Foot and stem rot	Sclerotial rot	*Phoma* leaf spot
H. cannabinus (HC Mesta)	Resistant	419	501	34
	Moderately resistant	107	27	446
	Moderately susceptible	2	Nil	28
	Susceptible	Nil	Nil	Nil
	Highly susceptible	Nil	Nil	Nil
H. sabdariffa (HS mesta)	Resistant	335	373	271
	Moderately resistant	70	41	147
	Moderately susceptible	13	4	4
	Susceptible	4	4	Nil
	Highly susceptible	Nil	Nil	Nil

Insect Pests: Insect pests, which cause substantial damage to jute crop, are *Apion corchori* Marshall (stem weevil), *Anomis sabulifera* Guen (jute semilooper), *Polyphagotersonemus latus* Bank (yellow mite) and *Diacrisia obliqua* Walker (hairy caterpillar). Three more pests cause serious damage but are localized and appear sporadically. These are *Spodoptera exigua* Hbn. (Indigo caterpillar), *Nupsera bicolor* (stem girdler) and *Barachytripes achatinus* Stoll (field cricket). Minor pests of jute are *Myllocerus discolor* Boheman (grey weevil) and *Oligonychus coffeae* Nietner (red mite). Besides these, 6 very minor pests also exist.

Both tossa and white jute germplasm have been evaluated for the three major insect pests of jute like yellow mite, semilooper and stem weevil in the field conditions. Wide range of diversity could be observed in tossa jute germplasm for susceptibility /tolerance to these insect pests (Table 8). Percentage of infestation varied between 5.36 (JRO 524) to 63.71 (OIJ 137) for yellow mite. Majority of germplasm showed infestation between 20-30%. No accession showed resistant reaction. Percent infestation for semilooper ranged between 21.00 (OIJ 203) to 39.14 (OIN 189). Most of the accessions showed infestation around 30%. For stem weevil, diversity range for infestation was between 12.68 (OIM 028) – 39.47 (OIN 857) and majority showed around 20% infestation (Pradhan, 1987-89; 1993-95).

In case of white jute yellow mite, infestation percent varied from 6.20 (CIN 362) to 16.96 (CIN 189). No resistant genotype could be identified in the studied materials. Percent infestation for semilooper varied between 15.43 (CIN 003) to 48.99 (CIM 084). Majority of the accessions showed around 40% infestation. Accessions of white jute showed stem weevil around 22% infestation with range between 18.28% (CIM 036)-33.36% (CIN 360) as shown in Table 8 (Pradhan, 1990-92).

Nematodes: The nematodes that attack roots of jute crop with consequential pathological symptoms are *Meloidogyne incognita* (Kofoid and White) Chitwood and *M. javanica* (Treub) Chitwood. Five hundred and seven accessions of white jute were screened against root knot nematode by growing them in the sick field having record of *M. incognita* infestation. Infestation was classified in 0-5 scale on the basis of gall intensity and extent of root damage (Mishra and Chakraborty, 1987).

Table 8. Diversity range of infestation (%) for three major insect pests in tossa and white jute germplasm

Crops	Insect pests	Diversity range of infestation (%)
C. capsularis (White jute)	Yellow mite	6.20 – 16.96
	Semilooper	15.43 – 48.99
	Stem weevil	18.28 – 32.36
C. olitorius (Tossa jute)	Yellow mite	5.36 – 63.71
	Semilooper	21.00 – 39.14
	Stem weevil	12.68 – 39.47

Eighteen genotypes were tolerant with index value upto 1.5%. Three hundred and fifty eight genotypes with index value between 1.6-3.5 were moderately susceptible. Highly susceptible group comprised 132 accessions with index value more than 3.5 (Table 9).

One hundred and eighty three genotypes of *Hibiscus cannabinus* (H.C. mesta) were screened against *M. incognita* under pot culture and results have been presented in Table 9. Nineteen genotypes with index value up to 1.5 were grouped as tolerant types. Moderately susceptible group consisted of 147 accessions with index value between 1.6-3.5. Seventeen types showed more than 3.5 index value and grouped as highly susceptible (Mishra, 1987-89).

Fibre Quality Parameters: Fibre quality parameters particularly bundle strength and fineness are of immense importance for production of value added diversified products. Two hundred germplasm of white jute and 300 germplasm of tossa jute were assessed for these two parameters and wide range of variability could be observed in both the species (Table 10). In white jute, observed range for bundle strength was 16.5-29.9 g per tex against check variety JRC 212 with 25 g per tex. This parameter for tossa jute varied between 15.2-32.1 g per tex and the check variety JRO 524 exhibited 26.4 g per tex of strength.

Table 9. Level of nematode infestation in gene pool of white jute and HC mesta

Crops	Gall index value	Category of infestation	No. of accession under each class
C. capsularis (White jute)	Upto 1.5	Tolerant	18
	1.6 – 3.5	Moderately susceptible	358
	3.5 and above	Highly susceptible	132
H. cannabinus (HC mesta)	Upto 1.5	Tolerant	19
	1.6 – 3.5	Moderately susceptible	147
	3.5 and above	Highly susceptible	17

Fibre fineness in white jute ranged between 1.3-2.4 tex while check variety JRC 321 showed 1.5 tex of fineness. In tossa jute this parameter varied from 2.07-3.89 tex whereas check variety JRO 878 exhibited 2.90 tex fineness; (Anonymous, 1998) Lower the "tex" value, finer is the fibre.

Table 10. Range of variability in fibre quality parameters of jute

Crops	Fibre fineness (tex)	Bundle strength (g / tex)
Tossa jute	2.07 – 3.89	15.2 – 32.1
Check variety	2.90 (JRO 878)	26.4 (JRO 524)
White jute	1.3 – 2.4	16.5 – 29.9
Check variety	1.50 (JRC 321)	25 (JRC 212)

Utilization of Germplasm in Varietal Improvement of Jute and Mesta

Systematic jute breeding started in the year 1904 by RS Finlow, appointed by the then Bengal Government as fibre expert. With sustained efforts a number of jute and mesta varieties have been developed to suit different objectives. Thus tossa varieties for early sowing and multiple cropping sequence, for late sowing in rainfed situation, for quality fibre, and for specific locations have been developed. Also in case of white jute, varieties for early sowing in low lying situations, for late sowing in mid and high land situations, responsive to high fertility level, for quality fibre, for specific locations and photo-insensitive varieties have been developed (Chaudhury *et al.*, 2004). Mesta varieties for semi-arid situations, for pulp and paper and with bristle free stem are also available in the varietal pool (Sinha, 2002).

The genetic base of released varieties is very narrow for all the major and minor crops which is a global trend and bast fibre crops are no exception. However, pedigree of all the released varieties of jute and mesta are presented in Tables 11, 12 and 13 which revealed that only 14 accessions parented all the 12 released varieties of tossa jute whereas only 24 accessions were involved in developing all the 13 released varieties of white jute. Nine varieties of mesta involved only 9 different parental accessions.

Realizing the danger of narrow genetic base CRIJAF has made attempts to reverse the trend. Thus JRO 66 and JRC 698, two recently released varieties of jute have been developed involving more number of new genotypes as shown in the Tables 11 and 12.

A paradigm shift in jute cultivation was brought by developing early flowering resistant varieties like

Table 11. Released varieties of tossa jute (*C. olitorius*) and their pedigree

Name of variety	Popular name	Pedigree	Year of release
JRO 632	Baisakhi Tossa	Selection from indigenous type	1954
JRO 878	Chaitali Tossa	JRO 620 x Sudan green	1967
JRO 7835	Basudev	JRO 632 x Sudan green	1971
JRO 524	Navin	Sudan green x JRO 632	1977
TJ 40	Mahadev	Selection from inter-mutant cross	1983
JRO 3690	Savitri	Tobacco leaf x Short internode	1985
KOM 62	Rebati	Gamma-ray derivative of JRO 878	1992
JRO 66	Golden Jubilee Tossa	Selection from multiple cross involving CG, TM, JRO 524, Peking, Bangkok and Tanganyika 1 exotic parents	1977
JRO 8432	Shakti Tossa	IC 15901 x Tanganyika – 1	1999
JRO 128	Surya Tossa	TJ 6 x Tanganyika – 1	2002
Bidhan Rupali		Selection from yellow mutant, x-ray derivative of JRO 632	2002
S 19	Subala	JRO 620 x Sudan green x Tanganyika - 1	2004

Table 12. Released varieties of white jute (*C. capsularis*) and their pedigree

Name of variety	Popular name	Pedigree	Year of release
JRC 321	Sonali	Selection from Hewti	1954
JRC 212	Spnikspma	Selection from an indigenous type	1954
JRC 7447	Sujata	X-ray derivative of JRC 212	1971
JRC 4444	Baldev	JRC 212 x D 154	1980
UPC 94	Reshma	JRC 321 x JRC 212	1983
Hybrid C	Padma	JRC 6165 x JRC 412	1983
KC 1	Jaydev	Gamma-ray derivative of JRC 4444	1992
KTC 1	Rajendra	Selection from an indigenous germplasm IC 30740	1994
JRC 698	Shrabanti	Selection from a multiple cross involving JRC 321, Tripura cap, JRC 212, JRC 918, Cordate leaf, Chinese 1, Egypt S5, EC 41336, EC 101572, Cap. Main land China, Japanese green, Cap. Non-branching and EC 117161.	1999
Bidhan Pat 3		D 154 x D 18 (photo insensitive mutant)	2000
Bidhan Pat 1		Gamma-ray derivative of D 154	2001
Bidhan Pat 2		D 154 x D 18 (photo insensitive mutant)	2001
JRC 80	Mitali	CIM 114 x JRC 321	2004

Table 13. Released varieties of mesta (*H. cannabinus* and *H. sabdariffa*) and their pedigree

Name of variety	Popular name	Pedigree	Year of release
HC 583		Selection from an exotic germplasm from Nigeria	1975
AMC 108	Bhimla	Pure line selection from indigenous germplasm	1982
MT 150	Nirmal	Selection from an exotic germplasm from Nigeria	2004
HS 4288		Selected from a cross between RT 1 x RT 2	
HS 7910	Ujjal	Selected from a cross between HS 4288 x RT 1	
AMV 1		Pure line selection from indigenous germplasm	1966
AMV 2		Pure line selection from indigenous germplasm	1982
AMV 3	Surya	Evolved by backcross method from the cross AMV 1 x AS 163	1989
AMV 4	Kalinga	Selection from a cross between AMV 1 x AS 163	1991
AMV 5	Durga	Selected from a cross between HS 4288 x AS 163	2005

JRO 878, JRO 7835 and JRO 524 during early seventies. In all these three varieties the early flowering resistant gene was contributed by an African accession 'Sudan green'. But the varieties developed during 9th plan period involved a different source for the same early flowering gene i.e. Tanganyika-1.

Utilization of Wild and Weedy Relatives

One hundred and seventy names of the species of *Corchorus* are given in the 'Index Kewensis'. But experts believe that the precise number of 'good species' is around 50 to 60. However, 10 *Corchorus* species including two cultivated ones are found distributed in India. Wild species available with CRIJAF are *C. aestuans* (India and Africa), *C. tridens* (India and Africa), *C. trilocularis* (India and Africa), *C. fascicularis* (India and Africa), *C. urticifolius* (India and Africa), *C. depressus* (India), *C. pseudo-olitorius* (India and Africa), *C. pseudo-capsularis* (Africa).

Potentialities of wild and weedy relatives of *Corchorus* have been assessed for biotic stress tolerance/resistance and fibre quality parameters, *C. pseudo-olitorius* showed immune reaction to fungal diseases like stem rot, root rot, black band, soft rot and anthracnose under conditions of natural infection. Similarly, *C. urticifolius* showed resistant reaction to all diseases but soft rot. *C. pseudo-capsularis* exhibited resistant reaction to all diseases but anthracnose (Palve *et al.*, 2004). Incidentally all the three species utilised were introduced from East Africa. Later on *C. urticifolius* and *C. pseudo-olitorius* were also collected from India. Identification of wild accessions resistant to fungal diseases is of immense value in preventing crop loss due to diseases *vis-à-vis* degradation of fibre quality.

Pre-breeding studies of quality parameters with 5 wild species of *Corchorus* revealed that all the materials produced very weak fibre and bundle strength varied between 5.63 g/tex for *C. trilocularis* to 8.40 g/tex for *C. aestuans* as against 28-32 g/tex for *C. olitorius* and 26-28 g/tex for *C. capsularis* (Table 14). But *C. pseudo-capsularis* produced the finest fibre (0.20 tex) followed by *C. urticifolius* (0.30 tex), *C. aestuans* (0.51 tex), *C. trilocularis* (0.77 tex) and *C. pseudo-olitorius* (0.95 tex) respectively (Palve *et al.*, 2004). Successful inter-specific cross between *C. pseudo-olitorius* and *C. capsularis* showed only 10% pollen fertility. F_2 seeds harvested were small and shriveled.

Table 14. Variability of fibre quality parameters in wild *Corchorus*

Corchorus species	Fibre fineness (tex)	Bundle strength (g/tex)
C. aestuans	0.51	8.40
C. trilocularis	0.77	5.63
C. pseudo-capsularis	0.20	5.67
C. pseudo-olitorius	0.95	7.27
C. urticifolius	0.30	5.50

Impact Assessment

Improvement of varietal status through utilization of introduced germplasm particularly of exotic origin has created significant impact in productivity of jute. During post partition days productivity was a little more than 11 q/ha and at present national productivity has reached 22 q/ha mark. Raw jute produced in the country very well saturates the demand of jute industry comprising 78 jute mills in organized sector and around 1,150 jute diversified units in unorganized sector.

Earlier, field duration of jute was 135-150 days. But at present this is a crop of moderate duration (110-120 days) with increased capacity to harvest more of solar energy. Roselle (H.S. mesta) was originally a long duration crop of 180 days. Reduction of field duration by 30 days has been possible with increased capacity of fibre production. All these have been possible due to employment of new donor parents in crop improvement programme from India and abroad. Curtailment of field duration coupled with advancement of sowing date by about 30 days has made jute crop suitable for multiple cropping. Crop rotations like jute-paddy-wheat/paddy/pulses/vegetables has made the crop sustainable with increased income of the farmers.

In the fibre quality front, exotic germplasm has left a footmark. The finest quality fibre producing white jute variety JRC 321 was selected from an exotic germplasm 'Hewti'. This variety is in high demand in speciality product development sector. Employing 'Sudan green' and JRO 620 from Africa and India respectively, the finest fibre yielding tossa jute variety JRO 878 was developed. Impact has been felt in marketed fibre grades over plan periods. Supply of grade 5 fibre (the bench mark grade for which minimum support price is declared every year by Agricultural Price Commission) has increased from 34.9% during 6th plan to 40.2% during 8th plan. On the contrary, supply of grade 6 fibre in the market has reduced from 23.7% to 14.8% during the same plan periods (Anonymous, 2005). There is no denying that improved crop husbandry played a role in up-gradation of marketed fibre but intrinsic property built through crop improvement programme had also collaborative role.

Unexploited Potentials of Jute and Mesta

Textile Sector: Jute has ruled the packaging sector for over one and a half century. But the golden era of golden fibre started down slide from sixties and more conspicuously from seventies mainly due to immense pressure from synthetics. Thus new growth areas of jute products became inevitable and technologists have projected various applications of jute fibre.

Manufacture of technical textiles is one of the important areas where jute can be used profitably. The technical textiles are classified into 12 application areas like Agro-tech., Build-tech., Geo-tech., Mobil-tech. etc. where jute can play a major role. Non-wovens and jute composites are also future growth areas. At present 3% of the global production of technical textiles is based on jute, 10% and 85% are based on cotton and man made fibres respectively. World market size has been projected to be US $ 60-70 billion by 2005.

Phytomedicine : A fresh look on the ultimate end uses of fibre as well as the plant as a whole revealed very fascinating information. Jute, mesta and their wild relatives are rich sources of many pharmacodynamic compounds like erysimosol, strophanthidin, helveticoside, β-sitosterol, ursolic acid etc. These compounds are used for drug preparation for cardiac, urological, gastroenteric and other health problems (Hazra *et al.*, 2003; 2004; Bandyopadhyay *et al.*, 2004).

Seed Oil: Jute and mesta seeds are rich sources of oil (jute seed contains 11-12% and mesta seed contains 21-22% oil) which can find their uses in industries. Fatty acid composition, saponification and iodine values of these oils are very close to edible oil like ground nut, soybean and rape. Mesta seed oil in particular can be made edible after purification (Bhaduri *et al.*, 1985; Gadgil *et al.*, 1988).

Pulp and Paper: Forest has been the main source of raw material for making pulp and paper till date. Rampant deforestation for pulp and paper production has a telling effect on ecology and forest bio-diversity. During 2000-01 share of agro-based materials for pulp making was 37.2% which consisted of cereal straw, bagasse and grasses. Jute and mesta can very well be used as replacement of forest based raw material (wood) whose share is now 53.2% (Hazra and Singh, 1997).

Wood Substitute: Global production of wood was around 8.5 billion cubic meter during the year 2000. Contribution of India was around 2% of global production amounting to 22 million cubic meter. Denundation of forest cover for production of timber is increasing at a faster rate and its impact on environment is being felt.

Jute and mesta being ligno-cellulosic material like wood has emerged as substitute of wood. These fibres can be processed for semi-rigid board by incorporating adhesive chemicals. Packaging of mango, orange, apple and grape in boxes made of 0.6-0.8mm thick sheet has been found suitable and transport worthy. Rigid jute composite board of various thicknesses (3 mm to 20 mm) can be produced and maybe used as wood substitute. The swelling behaviors, nailing and polishing properties of such boards are comparable to good quality timber (Mitra, 1996). Jute stick alone can be used to produce low-density composite board or particleboard using adhesive. Such board can be used for erecting room divider, sound proof lining and false ceiling (Mahapatra and Saha, 1999).

Energy Source: Jute and mesta waste after appropriate conversion can liberate profuse energy. It has been proved experimentally that one kg. jute waste liberates 3,300 K cal. of heat as against 5,200 K cal. from coal and 10,000 K cal. from mineral oil. If jute and mesta are grown in non-conventional areas and the whole plant is used for energy conversion, rural sector can be immensely benefited (Anonymous, 2002).

Information presented in the foregoing paragraphs amply indicate that jute and mesta along with their wild relatives are potential candidates for research to develop various diversified products other than those attempted so long.

Gaps in Germplasm Collection and Future Need

For such wide range of applications of jute and mesta, a diverse gene pool requires to be built up. Germplasm collected so far are mainly from India, East African countries, Nepal, Thailand, Indonesia and China. Collections from USA and Australia are also available with CRIJAF. It can be stated in general terms that East African germplasm are more variable for fibre yield and early flowering resistance, while Indian germplasm are more variable for fibre quality particularly fibre fineness. Wild species from east Africa are endowed with biotic stress tolerance as well as fibre fineness. It is indicative that trait wise variability has got regional distribution. Thus it is necessary to make endeavour to collect jute and mesta germplam from the areas / countries which have not been explored so far. Republic of South Africa is one among such countries with richest diversity of jute and mesta. However, trait specific germplasm are also available in other countries.

Conclusion

Collection and utilization of germplasm has made a phenomenal increase in productivity, but with the advent of synthetic materials, jute faces serious competition in traditional packaging products. Strong promotional efforts and price competitiveness have abated further erosion of the market of jute. To create demand in market, cost of production of jute fibre has to be reduced substantially. Weeding operation consumes about 35% of production cost and apart from crop loss due to diseases and pest, some efficient producing areas lie in flood and drought prone zones. Hence, introduction of trait specific germplasm has become a compulsion. Further, germplasm have to be assessed for desirable traits. Although preliminary evaluation for whole set of germplasm have been carried out for yield potential, diseases and pests resistance, specific evaluation were done only on some representative accessions for early flowering resistance, moisture stress tolerance, leaf area index, relative growth rate, harvest index etc. Whole set of germplasm needs to be evaluated to identify potential donor parents for breeding.

On the other hand, to make the crops suitable for other value added diversified products, evaluation for fibre quality parameters, total biomass production, pulp and paper, wood substitute, and pharmaceutical qualities are needed. Though some valuable traits have been identified in some wild relatives of jute and allied fibre crops germplasm, this could not be utilized due to their inter-specific incompatibility. Applications of modern tools of biotechnology are the need of the hour. CRIJAF has started activities in such areas. Apart from bio-diversity management, global trends towards sustainable development have brought to light the natural renewable, reuseable and biodegradable materials like jute and allied fibres. Consorted research and development efforts will help to regain country's monopoly in exports of this golden fibre. Collection of diversity and its utilization is the answer to these issues.

References

Anonymous (1987-89) CRIJAF Annual Report pp.3-5.

Anonymous (1998) World jute situation. Jute, Newsletter of IJO. **13(1):** p 6.

Anonymous (2002) Jute-caddy – a reliable renewable energy source. Background paper presented in Business Meet on "Biomass based power generation from jute-caddy" organized by WEBCON in collaboration with WBREDA sponsored by Ministry of Non-Conventional Energy Sources, Government of India, 26th August, 2002.

Bandyopadhyay A, AK Mahapatra and D Gupta. (2004) Jute and allied fibre crop species – their medicinal use. *Proc. Natl. Seminar on Indian System of Medicine.* RKM Ashrama, Narendrapur, Kolkata.

Bhaduri SK, M Haribabu, SK Sen, PC Dasgupta and P Majumdar (1985) Constituents of jute seed. *Ind. J. Agric. Sci.,* **55:** 750-753.

Chaudhury SK, D Kumar and A Saha (2004) Varietal development and improved varieties of jute. Technical Bulletin Series No. 1/2004, Division of Crop Improvement, CRIJAF, ICAR, Kolkata-700120.

Denton IR (1992) Collection and conservation of genetic diversity Proc. of IJO/BJRI Training course on specialized techniques in jute and kenaf breeding. BJRI, Dhaka, Bangladesh.

Gadgil JD, R Mitra, MK Sinha and MK Guha Roy (1988) Proximate chemical composition of seeds of *Hibiscus cannabinus* and *Hibiscus sabdariffa. Jute Development J.* **8:** 28-30.

Gupta D and A Saha (1984) CRIJAF Annual Report, pp.12-13.

Gupta D and A Saha (1987-89) CRIJAF Annual Report, pp.13.

Hazra SK and DP Singh (1997) Paper making from bast fibre crops – aspects and prospects. *Technical Bulletin* Series No. **4:** CRIJAF, Barrackpore, West Bengal, India.

Hazra SK, A Saha, AK Mahapatra, Dipankar Saha and D Gupta (2003) Kenaf (*Hibiscus sabdariffa* L. and *H. cannabinus* L.) and certain wild species: therapeutic uses and sources for phytomedicines. *J. Bot. Soc. Bengal*, **57**: 31-44.

Hazra SK, AK Mahapatra, A Saha, Dipankar Saha and D Gupta (2004) Therapeutic and medicinal potential of Indian *Corchorus* and their conservation. *Sci. and Cult.* **70** (7 and 8): 260-264.

Mahapatra AK, RK Mandal, A Saha, MK Sinha, MK Guha Roy, D Kumar and D Gupta (1994) Field evaluation of white jute (*Corchorus capsularis* L.) germplasm for major diseases. *Information Bulletin*, CRIJAF, ICAR, Barrackpore, W.B.

Mahapatra AK and Amitava Saha (1995) Collection and conservation of global genetic resources of *Corchorus*. *J. Natl. Bot. Soc.* **49**: 149-154.

Mahapatra AK, A Saha and SL Basak (1998) Origin, Taxonomy and distribution of *Crochorus* species in India. *Green J.* **1**: 64-82.

Mahapatra AK and A Saha (1999) Jute and kenaf research in environment conservation and poverty elimination In : P Palit, S Pathak and DP Singh (eds.) *Jute and Allied Fibres : Agriculture and Processing*, CRIJAF, ICAR, Barrackpore, W.B.

Mandal RK, A Saha and AK Mahapatra (1995a) Field evaluation of Kenaf (*Hibiscus cannabinus* L.) germplasm for major diseases. Information Bulletin, CRIJAF, ICAR, Barrackpore, W.B.

Mandal RK, AK Mahapatra and A Saha (1995b) Field evaluation of Roselle (*Hibiscus sabdariffa* L.) germplasm for major Diseases. Information Bulletin, CRIJAF, ICAR, Barrackpore, W.B.

Mishra C and NK Chakraborty (1987) Screening of jute (*Corchorus capsularis* L.) germplasm against root knot nematode *Meloidogyne incognita* (Kofoid and White) Chitwood. *Ann. Agric. Res.* **8**: 59-63.

Mishra C (1987-89) CRIJSAF Annual Report, p. 99.

Mitra BC (1996) Jute reinforced composite its quality and diversified use In : Occasional Paper on Jute 1/96. p. 13, NCJD, Calcutta.

Pradhan SK (1990-92) CRIJAF Annual Report p. 68.

Pradhan SK (1993-95) CRIJAF Annual Report p. 49.

Palve SM, MK Sinha and S Chattopahdyay (2004) Genetic variability for fibre strength and fineness in wild relatives of genus *Corchorus*. In SK Hazra and PG Karmakar (Eds.) Proceedings of National Seminar on "*Diversified Uses of Jute and Allied Fibre Crops*", CRIJAF, NIRJAFT and IFS (ER), Barrackpore, India.

Saha A, RK Mandal, AK Mahapatra, M.K Sinha, MK Guha Roy, D Gupta and D Kumar (1994) Field evaluation of Tossa jute (*Corchorus olitorus* L.) germplasm for major diseases. Information Bulletin, CRIJAF, ICAR, Barrackpore, W.B.

Saha A (1998) Genotypic variability in growth attributes of jute (*Corchorus capsularis* L.) *Green J.* **1**: 64-82.

Saha A, AK Mahapatra and K Srinivasan (2004) Jute and Allied Fibres. In BS Dhillon , RK Tyagi, S Saxena and A. Agrawal. *Plant Genetic Resources: Oilseed and Cash Crops*. Narosa, New-Delhi, pp. 184-198.

Sinha MK (2002) Mesta varieties for different situations. In BB Das and CR Biswas (eds.) Proceedings of "National Level Workshop – cum – Training on Jute, Mesta, Sunnhemp and Ramie under Special Jute Development Programme" organized by CRIJAF, ICAR and Directorate of Jute Development, Ministry of Agriculture, Government of India, 6-10 May, 2002.

Genetic Resources of Spices

KV Peter[1]* and K Nirmal Babu[2]
[1]*Former Vice Chancellor, Kerala Agricultural University, Thrissur-680656, Kerala, India*
[2]*Senior Scientist, Indian Institute of Spices Research, Calicut-673012, Kerala, India*

Spices play an important role in preservation, colouring and flavoring of food, cosmetics and medicine. India is the center of diversity for spices like black pepper, ginger, cardamom, turmeric, cinnamon, tamarind and has good collection of diverse germplasm. In introduced crops like nutmeg, clove, allspice, vanilla, seed and herbal spices though India has reasonable germplasm holdings the diversity is limited especially for quality and resistance to biotic and abiotic stresses. Introducing germplasm from the centers of diversity for general and specific characters is an important aspect to be considered in the latter group of crops.

Key words: Spices, Genetic resources, Conservation, Introduction

Spices played a major role in human life and history. Spices were used in preservation of food, religious ceremonies, cosmetics, dyes, medicines, embalming of the dead and folklore.

India is the land of spices and the lure of spices led many traders to India in the past. Many spices are native to India, and the most important of them are black pepper and cardamom followed by ginger, turmeric, cinnamon, tamarind and garcinia. India has a good amount of diversity in these crops. The other important spices relevant in Indian context are coriander, chili, fennel, fenugreek, cumin, nutmeg, clove and vanilla in addition to other minor spices. India is also a major producer and exporter of these spices. Being crops of exotic origin, except a few, the indigenous genetic diversity in these crops is narrow. Plant introduction from the centers of diversity has helped in broadening the genetic base, to a certain extent in coriander, chili, fennel, fenugreek and cumin. It is much needed in crops like paprika, nutmeg, clove, allspice and vanilla. In others, introduction of specific genotypes with special characters will augument our future breeding programmes.

Black Pepper (*Piper nigrum* L.)

Black pepper is the dried, mature fruit of *Piper nigrum* L. native to the South-Western India and the North-Eastern region from where it spread throughout the tropics. Though Central America is the centre of diversity of genus *Piper*, where over 2,000 species are known, the tropical forest of Malabar coast of India is the centre of diversity of *Piper nigrum*. About 110 species of *Piper* are reported from India and over 100 cultivars of black pepper are reported (Ravindran *et al.*, 2000). The diploid chromosome number of black pepper is 2n = 52. The major producing countries are India, Vietnam, Indonesia, Brazil, Sri Lanka, China and Thailand. In India, black pepper is cultivated in approximately 181,000 ha. The annual production is about 60-65,000 tons, out of which about 60% is exported.

India being the native home of black pepper, a very large collection of black pepper germplasm is conserved *ex situ* at Indian Institute of Spices Research (IISR), Calicut and at various centres of All India Co-ordinated Research Project on Spices (Table 1).

Local cultivar diversity is the richest in Kerala, followed by Karnataka. Unlike the wild forms of *P. nigrum* which are mostly dioecious, most cultivated ones are bisexual. Intra-cultivar variability was also reported in certain local cultivars grown extensively (Gopalam and Ravindran, 1986; Ravindran and Nirmal

Table 1. Collections of black pepper germplasm in India

Institution	Cultivated	Wild and related spp.	Total
Indian Institute of Spice Research, Calicut	2079	890	2969
NBPGR Regional Station, Thrissur, Kerala	417	341	758
Pepper Research Station, Panniyur, Kerala	167	72	289
Pepper Research Station, Sirsi, Karnataka	98	19	117
Regional Agricultural Research Station, Chintapalli, Andhra Pradesh	58	–	58
Horticultural Research Station, Yercaud, Tamil Nadu	122	10	132
Other AICRP Centres	83	–	83

Annual Reports of IISR and AICRP on Spices, 2005-2006.

**E-mail; kvptr2yahoo.com*

Babu, 1994; Ravindran *et al.,* 2006). There is good variability in germplasm with regard to morphological as well as yield attributes like spike length, number of bisexual flowers, fruit set, fruit size etc. The major quality parameters are volatile oil, oleoresin and piperine contents. Among the cultivars, the content ranges from 2.8-7.6% in piperine, 0.4-5.5% in volatile oil, 5.4-17.8% in oleoresin and 12.4-46.6% in starch. Gopalam and Ravindran (1986) categorised the common local pepper cultivars into high, medium and low quality classes based on the above parameters. The germplasm is utilized in various crop improvement programmes, which led to the release of about 16 elite varieties of pepper (Table 2).

Recently a few high yielding varieties of black pepper viz., IISR Girimunda, IISR Malabar Excel, Thevam, and Shakti were released from IISR. The first two are hybrids and are suitable for high elevations while the last two are selections, which are tolerant to *Phytophthora.*

Foot rot caused by *Phytophthora capsici,* is a major bottleneck in black pepper production and productivity. Resistance sources are not available in the indigenous germplasm but available in an exotic Central American species of Piper, *P. colubrinum.* This species is resistant to *Phytophthora capsici*- a fungal pathogen, pollu beetle – a major insect pest and *Radopholous similis* – a major nematode pest affecting black pepper. This indicates the availability of resistance genes in the primary centre of diversity of the genus. Identification and introduction of resistance sources from the Central and South American regions will be of great relevance in black pepper improvement.

The pepper growing countries have their own local diversity developed from segregating populations originally introduced from India. Introduction of some of the selections with special characters like resistance to *Phytophthora capsici* and *Radopholous similis* may be considered.

Cardamom - [*Elettaria cardamomum* (L.) Maton]

Elettaria cardamomum belongs to the family Zingiberaceae. Cardamom of commerce is the dried fruit of this rhizomatous, herbaceous perennial species. The centre of diversity of the genus *Elettaria* is the Malaysian-Indonesian region from where eight species are reported (Sakai and Nagamasu, 2000). The origin or phylogenetic

Table 2. High yielding black pepper varieties developed in India

Variety	Pedigree	Salient features
Panniyur 1	Hybrid between Uthirankotta x Cheriyakaniyakadan	Does not tolerate shade, moderately high oleoresin (11.8%), long spikes and bold berries.
Panniyur 2	Open pollinated progeny of Balankotta	Shade tolerant, rich in oleoresin, high piperine.
Panniyur 3	Hybrid between Uthirankotta x Cheriyankaniyakadan	Late maturing, suitable for all pepper growing regions, performs well under open situation. Long spikes and bold berries.
Panniyur 4	Clonal selection from Kuthiravally	Stable yielder, performs well under adverse conditions.
Sreekara	Selection from Karimunda	Suitable for all pepper growing regions.
Subhakara	Selection from Karimunda	High quality line (12.4% oleoresin), with wider adaptability to all pepper growing tracts.
Panchami	Clonal selection from Aimpiriyan	Late maturing variety with excellent fruit set.
Poumami	Clonal selection from Ottaplackal	High yielding variety, tolerant to root knot nematode.
Panniyur 5	Open pollinated progeny of Perumkodi	Suitable for both monocropping & mixed crop in coconut/ arecanut gardens. Long spikes.
PLD-2	Clonal selection from Kottanadan	High oleoresin line (15.5%), recommended for Trivandrum and Quilon districts of Kerala.
Panniyur 6	Clonal selection from Karimunda	Steady and stable yielder tolerant to drought and adverse climatic conditions. Suitable for open condition as well as partial shade.
Panniyur 7	Open pollinated progeny of Kalluvally	Vigorous, hardy and a regular bearer, long spike, high piperine (5.6%) tolerant adverse climatic condition suitable for open and shaded conditions.
IISR Thevam	Clonal selection from Thevanmundi	High yielding vigorous vine field tolerant to *Phytophthora.*
IISR Girimunda	Hybrid between Narayakodi X Neelamundi	High yielding vine suitable to high elevations and as a mixed crop.
IISR Malabar Excel	Hybrid between Cholamundi X Panniyur 1	High yielding vine suitable to high elevations and as a mixed crop.
IISR Shakti	OP progeny of Perambramundi	Moderate yielder but resistant to *Phytophthora.*

relationship of cardamom is not clearly known. Holttum (1950) felt that *E. cardamomum* and the Malaysian *Elettaria* represent parallel development from different points of origin in the *Alpinia* stock. Only one species occurs in India namely, *Elettaria cardamomum* and this is the only economically important species. Its closest species is the Srilankan wild cardamom *E. ensal* (Abheyv) (syn. *E. major* Thw). Cardamom has a somatic chromosome number of 2n = 48.

Cardamom occurs in its native state only in the tropical evergreen forests of the Western Ghats. The domestication of cardamom is relatively recent. Cultivated cardamom consists of three morphologically distinct types, namely Malabar, Mysore and Vazhukka. The wild populations of cardamom gradually declined as a result of disturbances in forest habitats. Currently in India, Cardamom is grown over an area of 72,000 ha and the annual production is around 6,000-8,000t. The major producer is Guatemala with an annual production of about 13,000t.

Cardamom is naturally cross-pollinated, the major pollinating agent is honey bee. It is propagated both by seed and suckers. Cardamom being a monotypic genus, general variability in the natural populations is restricted. Cardamom genetic resources are conserved at four centres (Table 3). The germplasm conservation is through field gene banks and *in vitro* gene banks.

Table 3. Holdings of cardamom germplasm in India

Institution	Cultivated	Wild and related spp.	Total
IISR, CRC, Apangala	423	13	436
ICRI, Myladumpara	600	12	612
AICRPS Centre, Pampadumpara	141	–	141
AICRPS Centre, Mudigere	132	–	132

IISR.CRC - Indian Institute of Spcies Research, Cardamom Research Centre, ICRI - Indian Cardamom Research Institute, AICRPS - All India Coordinated Research Project on Spices (Source: Annual Reports of IISR and AICRP on Spices)

Good variability exists in cardamom with regard to various morphological characters such as fruit (capsule) size, shape, leaf and plant pubescence and quality like characters such as essential oil and its components, 1,8-cineole and alpha-terperyl acetate (Zachariah and Lukose, 1992; Madhusoodanam *et al.* 1994; Zachariah *et al.* 1998; Padmini *et al.* 1999).

Utilization of germplasm for selection and hybridization led to the development and release of 12 high yielding varieties (Table 4). One of them (RR1) is tolerant to rhizome rot of cardamom.

Table 4. Released cultivars of cardamom

Cultivar	Pedigree	Mean yield (kg/ha)
Mudigere 1	Clonal selection in Malabar type with high yield.	275
PV 1	A selection in Walayar collection with long capsules	260
IISR Suvasini	Selection from open-pollinated progeny of CI. 37. Short statured plant	745
ICRI 1	Selection in Chakkupalam collection	325
ICRI 2	Clonal selection in germplasm collection	375
ICRI 3	Selection in Malabar type	440
Mudigere 2	Clonal selection in Malabar type	476
ICRI 4	Clonal selection in germplasm	455
IISR Avinash	Clonal selection of open-pollinated progeny of clone-37 with resistance to Rhizome rot	847
PV 2	OP selection from PV 1	982
IISR Vijetha	Clonal selection from katte resistant lines	643
Njallayani Green Gold	A farmers selection	1600

Two selections, tolerant to Katte virus, are also being released from IISR and another high yielding variety PV2 from Kerala Agricultural University (KAU).

In cardamom, there is reasonable amount of genetic variability in the indigenous sources. However, variability with regard to disease, viral and pest resistance is limited. Introduction of Srilankan wild cardamom *E. ensal* (Abheyv). (syn. *E. major* Thw) which is tolerant to stem borer is worth consideration. A look into genetic diversity of *Elettaria* in the Malaysian-Indonesian region from where, eight species are reported, is also needed.

Ginger (*Zingiber officinale* Roscoe)

Ginger (Zingiberaceae) is known to exist only under cultivation. Ginger is grown in most states in India, from Himachal Pradesh to Kerala. The total area under ginger is around 77,000 ha, the annual production is to the tune of 250,000 tons.

Zingiber is included in the tribe Hedychieae along with other genera such as *Curcuma, Hedychium* and *Kaempferia* (Holttum, 1950) and in the series Zingiberae which has only one genus *Zingiber.* Over 30 species were reported from Indo-Malayan region (Baker 1886, Fischer 1928). The species of *Zingiber* occurring in India are given in Table 5.

There is no conclusive evidence with regard to the origin of ginger. It is probably a sterile hybrid between two distant species that survived because of the successful

Table 5. Important *Zingiber* species occuring in India

S.No.	Species
1.	*Z. officinale* Roscoe
2.	*Z. zerumbet* (L.) Sm.
3.	*Z. purpureum* Roscoe
4.	*Z. roseum* (Roxb.) Roscoe
5.	*Z. wightianum* Thw.
6.	*Z. macrostachyum* Dalz.,
7.	*Z. cernuum* Dalz.
8.	*Z. capitatum* Roxb.
9.	*Z. cylindricum* Moon
10.	*Z. ligulatum* Roxb.
11.	*Z. spectabilis* Griff.
12.	*Z. clarkii* King ez Benth.
13.	*Z. marginatum* Roxb.
14.	*Z. intermedium* Baker
15.	*Z. chrysanthum* Roscoe
16.	*Z. rubens* Roxb.
17.	*Z. squarrosum* Roxb.
18.	*Z. elatum* R. Br.

vegetative mode of propagation. The chromosome number of the genus is 2n = 22 and all the Indian species studied so far have this number. It flowers under certain climatic conditions (as in Kerala), but does not set seed.

Variability in cultivated ginger exists mainly in the north-eastern region and Kerala. A botanically distinct variety *Z. officinale* var. *rubrum* with pink outer skin of rhizome is under cultivation in Malaysia.

There is moderate cultivar diversity in India, which is often named after the locality. Morphological variability is rather limited, however, chemical variations in essential oil content and components, are reported (Ravindran *et al.,* 1994; Zachariah *et al.,* 1998). Conservation of ginger germplasm is being done mainly in field gene bank (Table 6).

Table 6. Holdings of ginger germplasm in India

Institution	Accessions (No.)
Indian Institute of Spices Research, Calicut, Kerala	684
National Bureau of Plant Genetic Resources, Regional Station, Trichur, Kerala	173
Orissa University of Agriculture and Technology, High Altitude Research Station, Pottangi, Orissa	172
Y.S. Parmar University of Horticulture and Forestry, Solan, Hjmachal Pradesh	288
Rajendra Agricultural University, Dholi, Bihar	43
N.D. University of Agriculture and Technology, Faizabad, Uttar-Pradesh	45
Uttar Banga Krishi Vishwa Vidyalaya, Pundibari, West Bengal	38
Other Centres	44

Annual Reports of IISR and AICRP on spices, 2005, 2006

Seven high yielding and high quality varieties were released for cultivation so far (Table 7). All of them are clonal selections from the germplasm. Though variability for yield attributes and quality parameters are reported in ginger germplasm (Ravindran *et al.,* 1994; Sasikumar *et al.,* 1992) none of the cultivars possess resistance to the serious diseases such as *Pythium* rot and bacterial wilt.

Table 7. Released cultivars of ginger

Cultivar	Pedigree/Method	Mean yield (kg/ha)
Suprabha	Clonal selection in Kunduli local	16.6
Suruchi	Clonal selection in Kunduli local	11.6
Surabhi	Induced mutant in Rudrapur local	17.5
Himgiri	Clonal selection in Himacnal collection	13.5
IISR Varada	Selection in germplasm	22.6
IISR Rejatha	Selection from germplasm	22.4
IISR Mahima	Selection from germplasm	23.2

Ravindran *et al.,* 2006; Johny and Ravindran, 2006.

Though variability of ginger is reasonable in the country except for disease reistance, introduction of local varieties of ginger from South East Asian countries, China, Jamaica, Nigeria and Australia may yield varieties with less fibre and with resistance to rhizome rot which is the most important disease affecting ginger.

Turmeric (*Curcuma longa* L.)

Turmeric (Zingiberaceae) is one of the most ancient spices used in India and is part of Indian culture and the socio-religious practices. The processed and dried rhizomes of *C. longa* constitute the spice of commerce. India is the largest producer and exporter of turmeric. Turmeric is grown in most of the states in India, and the important states are Andhra Pradesh, Tamil Nadu, Maharashtra, Madhya Pradesh, Uttar Pradesh and Bihar. It covers an area of about 140,000 ha and has annual production of about 550,000 tons. A few cultivars such as Aleppey grown in central Kerala area are regarded as high yielding and of high quality. The cultivars are mainly known after the place where the particular type is grown traditionally.

The genus *Curcuma* is mainly distributed in the Indo-Malayan region and about 100 species are known. The most striking feature of turmeric is the bright yellow colour of the rhizome. Holttum (1950) reported that at least two other species, namely, *C. colorata* Val. and *C. xanthorhiza* Roxb. have equally deep yellow rhizome colour but they never gained any prominence either as spice or as a source of colour. Very little is known about its ancestors and phylogenetic relationship. Turmeric is a triploid having chromosome number 2n (3x) = 63. A related species *C. aremali* has 2n = 84. It is generally propagated by rhizomes but it occasionally sets seed that have been used in breeding programmes (Ravindran *et al.*, 2006).

The distribution of *Curcuma* species in India is given in Table 8. Among the related species, *C. aromatica* is important in preparation of medicine and toiletry articles. The pale yellow rhizome of *C. aromatica* has a camphor-like odour. *C. amada* (mango ginger) is used as vegetable. *C. zedoaria,* is medicinal and is also a source of starch for tribal people in many parts of India.

Table 8. Distibution of *Curcuma* species in India

Sl. No.	Species without fingers or rhizome	Region of occurence
1.	*C. aeruginosa* Roxb.	North Eastern India
2.	*C. albiflora* Thw.	Karnataka
3.	*C. amada* Roxb.	Throughout India
4.	*C. amarassima* Rosc.	North Eastern India
5.	*C. aromatica* Salisb.	Karnataka/Kerala
6.	*C. aurantiana*	Kerala
7.	*C. brog*	North Eastern India
8.	*C. caesia* Roxb.	North Eastern India
9.	*C. cannanorensis*	Kerala, Ansari et al.
10.	*C. comosa* Roxb.	North Eastern India
11.	*C. coriaceae*	Kerala, Mangaly & Sabu
12.	*C. decipiens* Dalzell	Kerala
13.	*C. ecalcorata* Sivarajan and Indu.	Kerala
14.	*C. haritha* Sabu	Kerala
15.	*C. karnatakensis**	Karnataka
16.	*C. kudagensis**	Karnataka
17.	*C. latifolia* Rosc.	North EAstern India
18.	*C. longa* L.	Throughout India
19.	*C. lutea*	Kerala/Karnataka
20.	*C. malabarica*	Kerala/Karnataka
21.	*C. montana* Roxb.	Andhra Pradesh
22.	*C. nilamburensis**	Kerala
23.	*C. nilgherrensis* Wight	Sourth India
24.	*C. oilgantha* Trimen	Kerala
25.	*C. pseudomontana* Graham	South India & Maharashtra
26.	*C. raktakanta* Mangaly and Sabu	Kerala
27.	*C. soloensis*	North Eastern India
28.	*C. sylvatica*	North Eastern India/Kerala
29.	*C. thalakkaveriensis**	Karnataka
30.	*C. vamana* sabu & Mangaly	Kerala
31.	*C. vellanikkariensis**	Kerala
32.	*C. zedoaria* (Chistm.) Roscoe	Throughout India

* Velayudhan *et al.* (1999)

The status of turmeric germplasm in the country is given in Table 9. There is an urgent need for collecting and conserving many spices reported from North-eastern region of the country. Several species, such as *C. leucorrhiza, C. petiolata, C. angustifolia, C. montana,* etc., are to be collected.

Characterization of turmeric based on morphological characters was carried out at IISR and NBPGR. A total of 21 distinct morphotypes and six taxonomic groups were identified and reasonable variability for yield, yield attributes, quality attributes and dry recovery were observed (Velayudhan *et al.*, 1991, 1999, Nirmal Babu *et al.*, 1993b).

So far, 24 high yielding cultivars of turmeric were released for cultivation throughout India. Of these, only two were selected from the seedling progenies of turmeric and one is an induced mutant (Table 10).

Introduction of germplasm from exotic sources do not hold much promise in turmeric.

Seed Spices

The major seed spices grown in India are coriander, cumin, fennel, fenugreek, celery, ajwain, dill, caraway black caraway, black cumin (kala zira), white mustard, black mustard, and Indian mustard. The main seed spices growing states in India are Andhra Pradesh, Tamil Nadu, Gujarat, Rajasthan, Uttar Pradesh, Madhya Pradesh and

Table 9. Germplasm holdings of turmeric and their related species

Institution	Accessions (No.)
Field gene bank	1040
Indian Institute of Spices Research, Calicut, Kerala	
National Bureau of Plant Genetic Resources, Regional Station, Trichur, Kerala	954
Orissa University of Agriculture and Technology, Pottangi, Orissa.	193
Regional Agriculture Research Station, Jagtial, Andhra Pradesh	352
Y S Pawar University of Horticulture and Forestry, Solan, Himachal Pradesh	145
Rajendra Agricultural University, Dholi, Bihar	145
Indira Gandhi Agricultural University, Regional Station, Raigarh	42
N.D. University of Agriculture and Technolgy, Faizabad, Uttar Pradesh	114
Uttar Banga Krishi Vishwa Vidyalaya, Pundibari, West Bengal	140
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu	255

Annual Reports of IISR and AICRP on Spices, 2005, 2006

Table 10. Released varieties of turmeric

Cultivar	Pedigree/method	Mean yield (kg/ha)
CO-1	Induced mutant in Erode local	30.5
Krishna	Clonal selection in Tekurpeta collection	9.2
Sugandham	Clonal selection in germplasm	15.0
BSR.1	Induced mutant in Erode local	30.7
Roma	Clonal selection in T. Sunder	20.7
Suroma	Induced mutant (Clonal selection) in Tsundur	20.0
Rajendra Sonia	Selection in local germplasm	4.8
Suguna	Selection in germplasm	29.3
Suvarna	Selection in germplasm	17.4
Sudharsana	Selection in germplasm	28.8
Ranga	Clonal selection in Rajpuri local	29.0
Rasmi	Selection in germplasm	32.0
BSR.2	Clonal selection in Rajpuri local	32.7
IISR Prabha	Open-pollinated progeny selection	37.4
IISR Prathiba	Open-pollinated progeny selection	39.1
Megha turmerica 1	Selection in Lakadong type	23.0
Sobha	Clonal selection from local type	35.8
Pant Peethabh	Clonal selection from local type	20.0
Sona	Clonal selection from local type	7.0 (dry)
IISR Alleppey Supreme	Clonal selection from Alleppey	29.2
IISR Kedaram	Selection from germplasm	27.9
Varna	Clonal selection from local type	4.1 (dry)
Kanti	Clonal selection from Mudukur	5.2 (dry)
Suranjana	Clonal selection from local type	29.2

Ravindran *et al.*, 2006; Johny and Ravindran, 2006.

Haryana. Among them, only coriander, cumin, fennel and fenugreek are grown on a commercial scale. Cultivation of the remaining seed spices is limited.

Though not native to India, a good collection of seed spices germplasm is available in India (Table 11).

Coriander *(Coriandrum sativum,* Apiaceae) is the most important seed spice. It is native to southern Europe, Asia Minor and Caucasus where it also grows wild. This crop is commercially grown in Russia, Hungary, Poland, Romania, Czechoslovakia, Morocco, India, Mexico, Gautemala and also in USA. It was introduced into India from the Mediterranean region and now India is a major producer of coriander. It is cultivated on a large scale in the states of Rajasthan and Andhra Pradesh; and also in Gujarat, Madhya Pradesh, Uttar Pradesh, Bihar and Chattisgarh. Coriander is a major component of masala mixes and curry powders. The main chemical constituents of coriander essential oil are linalool (60-70%) and hydrocarbons (about 20%) such as dl α-pinene, β-pinene, dipentane, p-cymene and α-terpinene. In coriander germplasm, essential oil content varies from 0.17 to 0.26% (Sharma, 1994). A total of 1,767 accessions are being maintained at various research centres in India. The released varieties of coriander are given in Table 12.

Cumin is a member of family Apiaceae and probably a native of Turkistan or Upper Egypt. Cumin is cultivated in Ukraine, Morocco, Algeria, Syria, Malta and Cyperus. In India, it is cultivated in the states of Gujarat and Rajasthan. About 621 accessions of cumin are being maintained and 10 varieties were released (Table 13). Cuminaldehyde is the major component in cumin oil. Oil content is low in indigenous germplasm but high in exotic collections (Sharma, 1994). Hence introduction of cumin genotypes with high oil is important.

Fennel *(Foeniculum vulgare)* belongs to Apiaceae. It has two sub-species. *F. vulgare* ssp. *capillaceum* (garden fennel) and ssp. *piperitura* (wild fennel). Sub-species *capillaceum* comprises var. *vulgare* (bitter fennel), var. *dulce* (sweet fennel or French sweet fennel or Roman fennel) and var. *panmoriwn* (Indian fennel). Sharma (1994) reported that oil content ranges from 0.7 to 6% in fennel germplasm. Five research stations are maintaining 529 accessions of fennel and so far and 14 varieties have been released (Table 14).

Table 11. Seed spices germplasm collections in india

Centre	Accessions (No.)			
	Coriander	Cumin	Fennel	Fenugreek
Rajasthan Agricultural University, Jobner	885	376	187	353
Gujarat Agricultural University, Jagudan	120	226	115	63
Tamil Nadu Agricultural University, Coimbatore	274	–	3	255
Andhra Pradesh Agricultural University, Guntur	124	–	–	126
Rajendra Agricultural University, Dholi	85	–	31	109
Narendra Dev University of Agriculture and Technology, Kumarganj	75	19	39	63
Chaudhary Charan Singh Haryana Agricultural University, Hisar	204	–	94	134
Indira Gandhi Krishi Vishwa Vidyalaya, Raigarh, Solan, Himachal Pradesh	20	–	–	225
Total	**1767**	**621**	**469**	**1141**

Annual Reports of AICRP on Spices, 2005-2006.

Table 12. Improved varieties of coriander

Cultivar	Pedigree/method	Mean yield (kg/ha)
Guj. Coriander-1	Selection in germplasm	1100
Co-1	Selection in Koilpatti local	440
Co-2	Selection in culture P2 of Gujarat	520
Guj. Coriander-2	Selection in Co-2	1450
Rajendra Swathi	Selection in Muzaffarpur collection	1300
RCr-41	Recurrent selection in local type	909
Sadhana	Mass selection in Alur local collection	1025
Swathi	Mass selection in Nandyal germplasm,	855
CS-287	Selection in Guntur collection	600
Co-3	Selection in Acc.695 of IARI type	650
Sindhu	Mass selection in local germplasm	1050
Hisar Anand	Mass selection in Haryana collection	1400
RCr-20	Recurrent selection in Jaipur local	900
RCr-435	Recurrent selection in local germplasm	1000
RCr-436	Recurrent selection in local germplasm	1200
RCr-684	Induced mutant in RCr-20	990
Co-4	Reselection from ATP-71	600
Rcr-446	Half sib selection from Jaipur local	1200
Hissar Suganth	Mass selection from germplasm	1400
Hissar Surabhi	Mass selection from germplasm	1800
Azad Dhania-1	Mass selection from germplasm	1000
Pant Haritima	Selection Pant Dhania	1200
DWA-3	Pure line selection	440 dry
CIMPOS-33	Selection from Bulgarian introduction	2100
NRCSS-ACR-1	Re selection from Russian introduction	1100

Table 13. Released varieties of Cumin

Cultivar	Pedigree/method	Mean yield (kg/ha)
Mc-43	Selection in germplasm	580
Guj. Cumin-1	Selection from Vijaypur-5	550
RZ-19	Recurrent selection in UC.19	560
Guj. Cumin-2	Induced mutant in NIC-49	620
Guj. Cumin-3	Recurrent selection from German germplasm EC-232689	620
S-404	Selection from germplasm	350
Guj. Cumin-4	Selection from germplasm	1250
RZ- 209	Recurrent selection from Jalore	650
RZ- 223	Mutant selection from UC -216	600
AC - 01-167	Re selection from EC- 243375	515

Johny and Ravindran, 2006

Bitter fennel is commercially cultivated in India, Romania, Russia, Hungary, Czech Republic, Germany, France and Italy. It grows wild in France, Spain, Morocco and Algeria. Sweet fennel is cultivated in France, Italy and Greece and has the best odour and flavour quality. The oil of fennel contains mainly anethole, α-pinene, α-phellandrene, dipentene etc. The bitter taste is due to presence of d-fenchone. Sweet fennel contains mostly anethole, and smaller quantities of d-phellandrene and d-limonene and no fenchone. Introduction of

Table 14. Released varieties of fennel

Cultivar	Pedigree/method	Mean yield (kg/ha)
PF-35	Selection in germplasm	1280
Co-1	Selection in PF35	570
Guj. Fennel-1	Pure line selection	1720
Guj. Fennel-2	Pedigree selection in local germplasm	1940
RF-101	Recurrent selection in local germplasm	1550
Guj. Fennel-II	Selection from local germplasm	2489
Co- 1	Re selection from PF-35	570
Hissar Swarup	Mass selection from germplasm	1600
Azad Sonuf-1	Selection from germplasm	1500
Pant Madhurika	Pure line selection	1200
Rajendra Sourabha	–	–
NRCSS-AF-1	Recurrent selection	1950
RF-143	Recurrent selection	1200

sweet fennel types from europion region is worth considering.

Fenugreek *(Trigonella foenum-graceum),* Fabaceae is native of eastern Mediterranean extending to central Asia. In addition, Ethiopia is also an independent centre of origin. In India fenugreek is grown in an area of about 38,500 ha, mainly in Rajasthan, Gujarat and Andhra Pradesh with an annual production of about 50,000 t. The seed is used as spice and leaf as vegetable. It is also grown in Argentina, Egypt, France, Morocco, Lebanon etc. It has bitter taste of seeds due to alkaloid trigonellin and steroid sapogenin (diosgenin), but in appropriate quantities, it adds a special taste and flavour to culinary dishes. It also has high medicinal and nutritive value. Conservation of fenugreek germplasm is being taken up at seven centers, with about 908 collections of which 7 were released as improved varieties (Table 15).

Celery (Apium graveolens), Bishops weed or Ajwain *(Trachyspermum ammi)* and Dill *(Anethum graveolens),* of the family Apiaceae, are other seed spices of importance. Celery is a native of Eastern Europe while Dill and Ajwain are native of the Mediterranean region, where they grow wild. The main celery producing countries are India, France and to some extent sub-tropical America. In India, celery is grown in about 2,000 ha, mostly in Punjab, mainly for seeds. The main chemical constituents are d-limonene, elimene, sedanolide and sedanonic anhydride. The characteristic flavour is due to selinene. Ajwain has two morphological types; a larger type is grown in most ajwain growing regions in Northern India

Table 15. Improved varieties of fenugreek

Cultivar	Pedigree/method	Mean yield (kg/ha)
Co-1	Selection in TG-2356	680
Rajendra kanti	Pure line selection in Reghimathpur local	1300
RMt-1	Pure line selection in Nagpur local	1400
Lam selection-1	Selection in germplasm collection	740
Hisar Sonali	Pure line selection in germpalsrn	1700
Co-2	Selection in CF 390	482
RMt-303	Mutation breeding in RMtl	1900
Gujarat Methi-1	Recurrent selection based on pure line selection in J. Fenu 102	1864
RF - 125	Recurrent selection from EC- 243382	1700
S-7-9	Selection from germplasm	1100

and a small form grown in Indore and adjoining regions. The larger type is used as a medicine and in the manufacture of curry powders and the smaller one is mainly exported. Other ajwain growing countries are Egypt and Iran. The most important constituent is thymol followed by carvaorol and hydrocarbons such as α-pinene, p-cymene, dipentene, γ-terpinene etc. Dill grows wild in parts of Europe, Africa and Asia. It is cultivated in USA, Hungary, Germany, India and in Eastern Europe. Dill seed oil contains carvone, d-limonene and phellandrene. Dill apiole, a poisonous component in oil, occurs in Indian dill but not in the European dill oil.

Anise or aniseed is yet another seed spice grown in India and countries like Egypt, Syria, Tunisia, Morocco, China, Chile, Mexico, USA etc. In India anise is grown in many North Indian states. The oil contains mainly anethole. It is extensively used in baked food industries.

The variability in the germplasm of seed spices in India is limited and does not represent the actual diversity available in these crops (Sharma, 1994). Careful and unbiased collections from the centers of diversity can enhance the utility of the collection for crop improvement especially in developing high quality disease resistant types.

Tree Spices

There are many tree spices grown in India, some native, others introduced and a few of them are cultivated commercially (Table 16). Of these, nutmeg, clove and cinnamon are widely grown in the states of Kerala, Karnataka and Tamil Nadu. Allspice is a recent introduction, but is less popular. Tamarind, curry leaf and *Garcinia* are indigenous to India and are grown widely.

Nutmeg *(Myristica fragrans* Houtt)

Nutmeg tree produces two separate spices, namely, nutmeg (kernel of the seed) and mace (aril covering the seed). Nutmeg belongs to Myristicaceae, one of the most primitive families of dicots. Indonesia, New Guinea and Grenada are the major producers. It originated in the Moluccas Islands of Indonesia.

The species occurring in India are *M. amygdalina* Wall., *M. andamanica* Hook, *M. attenuata* Wall., *M. dactyloides* Gaertn. (*M. laurifolia* Hook. f.), *M. beddomeii* King., *M. gibbosa* Hook., *M. glabra* Blume, *M.glaucescens* Hooker., *M. irya* Gaertn., *M. kingii* Hook., *M. longifolia* Wall. and *M. magnified* Bedd. Most of these are endemic to the Indo-Malayan region and the Western Ghat forests. The mace and seeds of *M. dactyloides* are used in tribal and indigenous medicine.

The IISR, Calicut, maintains 484 accessions of *M. fragrans* and related species. The genetic base of nutmeg germplasm in India is rather narrow as these are derived from a very few trees, originally introduced to India. But being a sexually propagated dioecious plant, some variability exists in these populations, especially for characters such as fruit size and shape, mace, seed volume and chemical composition (Gopalakrishnan, 1992). They also show quantitative variations for major quality components. The concentration of hallucinogenic principles (myristicin, elemicin, myristic acid) are reported high in Indian nutmeg (Gopalakrishnan, 1992). Two high yielding varieties namely Konkan Sugandha and IISR Viswasree were released for cultivation.

Cinnamon and Cassia *(Cinnamomum* spp.)

True cinnamon (C. *verum* Bercht & Presi) belonging to Lauraceae is indigenous to Sri Lanka and southern Western Ghats of India. Cassia cinnamon is obtained from various sources, the most important being *C. cassia* Bercht. & Presl. (Chinese cassia, Vietnam cassia or Saigon cassia). The other cassia cinnamons are: Indonesian (Javan) cassia (*C. burmanii* C.G. & Th. Nees), Saigon (Vietnam) cassia (*C. loureirii* Nees,) and Indian cassia (*C. tamala* Nees). Rich variability exists both in Western Ghat forest and the North-eastern region of India. Hooker (1886) reported 26 species from Indian subcontinent and adjoining areas. Only a few species are being exploited commercially. Apart from cinnamon and cassia, *C. tamala* (Indian cassia, Tejpat) leaves are

Table 16. Tree spices occuring in India

Botanical name	Common name	Family	Useful part
Cinnamomum bejholgota	Tejpat	Lauraceae	Leaf
C. cassia Brecht. & Presl.	Cassia	Lauraceae	Leaf bark
C. impressinervium	Tejpat	Lauraceae	Leaf
C. tamala	Tejpat, Indian Cassia	Lauraceae	Leaf
C.verum Brecht. & Presl.	Cinnamon	Lauraceae	Leaf, bark
Garcinia kowa	–	Clusiaceae	Fruit rind
G. gummi-gutta (L.) N. Robson	Gamboge	Clusiaceae	Fruit rind
G. indica Choisy	Kokum	Clusiaceae	Fruit (rind)
Murraya koenigii (L.) Sprengel	Curry leaf	Rutaceae	Leaf
Myristica fragrans Houtt. (introduced)	Nutmeg, mace	Myristi-caceae	Seed and aril
Pimenta dioeca (L.) Merr. (introduced)	Allspicae	Myrtaceae	Fruit
Syzgium aromaticum (L.) Merr. et Perry (introduced)	Cloves	Myrtaceae	Unopened flower bud
Tamarindus indica L.	Tamarind	Caesalpi-niaceae	Fruit pulp

Table 17. Germplasm holdings of Tree spices in India

Crop / center	Number of accessions
Nutmeg	
IISR	484
AICRP, Peechiparai	20
AICRP, Dapoli	95
Clove	
IISR	233
AICRP, Peechiparai	22
AICRP, Dapoli	3
AICRP, Yercaud	13
Cinnamon	
IISR	408
AICRP, Peechiparai	12
AICRP, Dapoli	49
AICRP, Yercaud	16
All Spice	
IISR	2
Garcinia	
IISR	86
NBPGR	71

extensively used in northern and North-Eastern India for flavouring various dishes. *C. impressinervium* and *C. bejholgota* are also used as Tejpat in the North-Eastern India, the latter is traded as the best quality tejpat The wild populations of cinnamon are in real peril because of the indiscriminate bark extraction from them. Species like *C. malabaricum, C. macrocarpum, C. riparium* and *C. pauciflorum* are also aromatic and are being used like *C. tamala* leaves.

Cinnamon trees are naturally cross-pollinated, and hence much variation exists in natural populations for morphological, chemical as well as bark characters among species (Krishnamoorthy and Rema, 1994). The quality of cinnamon depends on the essential oil content and composition of leaf and bark oil. The leaf oil contains eugenol as the chief component while the bark oil has cinnamaldehyde. So far 7 improved varieties were released in cinnamon (Table 18).

The Chinese cassia cinnamon is the dried bark of *C. cassia,* found in China, Vietnam, Thailand and up to the Malaysian region. China and Vietnam are the major producers. Indonesian cinnamon is the dried bark of *C. burmanii,* and is produced mainly in the Sumatra-Java region of Indonesia. At IISR, a small germplasm collection of Chinese cassia exists, which was derived from an earlier introduction in the Sri Kundra estate of Valparai, Tamil Nadu. Seed progenies from these trees were collected and raised at IISR to develop a small gene pool of this species. The genetic variability is very narrow. Since the cinnamon, we use in India, is actually Cassia, introduction of Cassia germplasm from the centers of diversity i.e. China and South East Asia will help in brodening the gene pool.

Clove *(Syzygium aromaticum* (L.) Merr. & Perry)

Clove, belonging to family Myrtaceae, is a native of Moluccas Islands (Indonesia) from where it has spread to many tropical countries. Britishers introduced clove to India. The clove buds contain around 15-17% volatile oil, the main component of which is eugenol. Clove is grown as inter-crop in many households in Kerala

Table 18. Released vareties of cinnamon

Cultivar	Pedigree/method	Mean yield (kg/ha)
Nithyasree	Open-pollinated progeny selection in Indian collection	200
Navasree	Open-pollinated progeny selection in Srilankan collection	250
YCD-1	Clonal selection in open-pollinated progeny	360
KonkanTej	Single plant seedling selection from Ceylon type	102
RKL(B)C-6	Selection from germplasm	250
PPI(C)1	Selection from op progenies of Sri Lankan type	980
Sugandhini	Single tree selection from waynad collection (Sri Lankan type)	640

Johny and Ravindran, 2006

and Karnataka and in some pure plantations in southern Tamil Nadu and in Kerala. Though many species of *Syzygium* occur in India, but none of them are related to clove. Because of the limited introductions and self-pollinating nature of the species, the genetic base of clove in India is very narrow in any meaningful crop improvement programme. At IISR, 233 collections are maintained, the notable variants are a dwarf clove accession and a king clove, having bold flower bud. Introducing more variability in clove will help in clove breeding.

Garcinia spp.

The genus *Garcinia* belonging to Clusiaceae, is distributed in the tropics of the old world, chiefly Asia, with approximately 200 species. Malaysia and Africa with large number of endemic species appear to be the two main centres of diversity of the genus *Garcinia.* There are two major centres of diversity in the Indian sub-continent: the Northeastern region from Assam extending up to Burma, and the Western Ghats. In India, three important species, namely, .*G. gummi-gutta* (L). N. Robson (Malabar tamarind), *G indica* (Thouars) Choisy (Kokam) and *G. mangostana* L. (Mangosteen) are cultivated. *Garcinia gummi-gutta* is wild in evergreen or semi-evergreen forests of Western Ghats up to 1800 MSL in Maharashtra, Goa, Karnataka, Kerala and also the Shola forests of the Nilgiris, Tamil Nadu. *Garcinia indica* occurs wild in the evergreen forests of Western Ghats in South Maharashtra extending southwards up to Kerala (Kasargod district). *Garcinia mangostana* is successfully cultivated in very small areas in Kerala and Tamil Nadu for its delicious fruits termed as 'queen of tropical fruits' and believed to have originated in West Malaysia. Overall, there is no large-scale cultivation of *Garcinia* and no released cultivar has been identified.

The dried fruit rind of *Garcinia* is the spice and is also used as a substitute for tamarind. They are also used (especially *G. indica)* to manufacture syrup and squash and in pharmaceutical industry as a source of hydroxycitric acid, an anti-obesity compound. Many species of *Garcinia* especially *G. morella,* are also the source of gamboge, a vegetable dye, used in earlier times for various purposes including hand painting clothes, potteries, etc.

Garcinia is a cross-pollinated species with separate male and bisexual trees. A few germplasm collections exist at IISR, NBPGR and KAU. At present 86 accessions of 4 species, namely, *G. gummi-gutta* (60 accessions), *G. indica* (6 accessions), *G. mangostana* (3 accessions) and *G. xanthochymus* (Mysore gamboge- 2 accessions) are being maintained. There is considerable variation in yield, leaf, fruit and seed characters (Ravindran *et al.,* 2005).

Tamarind *(Tamarindus indica* L.)

Tamarindus is a monotypic genus and belongs to Caesalpiniaceae. Tamarind originated in tropical Asia (India) but also occurs in Central Africa. It is used both as spice and also is important in medicine. The main flavour component of the pulp is 2-acetylfuran. Major constituent is tartaric acid (8-18%). Kernel powder is an important sizing material for jute and textiles. The kernel powder contains xyloglycan, used as a gelling agent.

Limited work carried out on germplasm collection and evaluation, though, resulted in development of 5 released cultivars, namely, *Periakulam-1* (PKM-1), *Prathissthan,* DTS-1, No.263 and Yogeswari for cultivation. Two other well-known elite genotypes are *Urukumpuli* and *Kambum* Tamarind, very popular among growers. Being a crop native to India, priority must be given to collect and conserve indigenous genetic variability.

Curry Leaf [*Murraya koenigii* (L.) Sprengel]

Curry leaf, belonging to family Rutaceae is an essential leafy spice in South Indian food preparations. It had originated in India and cultivated extensively as a backyard plant in most households. The genus *Murraya* is represented by only three species in India. *Murraya koenigii* is distributed from the foot hills of Himalayas in the North to Kerala in the South, except in the arid regions. It also occurs in Andaman and Nicobar Islands, Myanmar (Indo-Burman region), Malaysia and Sri Lanka and in Pacific Ocean Islands. It is grown as a commercial crop in Tamil Nadu, Karnataka and Andhra Pradesh. Very little conservation and improvement work were undertaken in this crop. The type with pink midrib is usually preferred over green midrib and broad leaves over narrow leaves as the former has better aroma.

Small germplasm collections are being maintained at the University of Agricultural Sciences, Dharwad, Karnataka and Andhra Pradesh Agricultural University. A selection, namely, Suvasini was released for general cultivation. Much is not known about the genetic variability in quality characters. The studies revealed more than 62 components, the important ones are phellandrene (2 to 4%), a-pinene (17.5%), 3-caiyophyllene (7.3%) and P-terpene-4-ol (6.1%). This essential oil has high antifungal and antibacterial activity. Curry leaf contains many alkaloids such as koenigicine, mahanimbine, koenine, koenigine, isomahanimbine, murrayccine etc. Curry leaf also has many medicinal properties and is being used in traditional medicine, as an ingredient in certain toothpastes, hair oil etc.

Vanilla *Vanilla planifolia* Andrews syn. *V. fragranse* (Salis.) Ames

V. planifolia, is the member of Orchidaceae, the only commercially important species in this family. It originated in Mexico but is grown in many pacific ocean islands, Indonesia and many African countries. It was introduced into India 100 years back but the interest in the cultivation is very recent. A small germplasm collection of about 93 collections exists with Spices Board and IISR, Calicut. The related species available in the collection are *V. andamanica* Rofle, *V. aphylla* Blume (syn. *V. vatsalana), V. pilifera* Holtt., *V. tahitensis* Moore and *V. wightiana* Li. The germplasm available in vanilla in India has very narrow genetic base for any meaningful crop improvement programme, and the base must be broadened. Since *Vanilla* is a cross-pollinated species in its native home, attempts are made to exploit variation in the segregating progenies. *Vanilla andamanica* is reported to be resistant to *Phytophthora meadii* and *Fusarium oxysporum* while *V. aphylla* is resistant to *F. oxysporum.* A few species are reported from Central America with resistance to major fungal diseases affecting vanilla. In view of the very narrow genetic base, vanilla is another crop where the plant introduction from centers of origin and diversity will help crop improvement programmes in India.

Future Strategies

India being the center of diversity of many spices the genetic variability in major spices like black pepper and cardamom followed by ginger, turmeric, cinnamon, tamarind and garcinia is quite reasonable. But other spices grown in India like coriander, chili, fennel, fenugreek, cumin, nutmeg, clove and vanilla are crops of exotic origin. The available genetic diversity in these crops in India is either very narrow and hence has to be augumented further. Plant introduction from the centres of diversity both in general as well as for specific characters will help in broadening the genetic base and in meaningful crop improvement programmes. Though this is presently being done in some of these crops like coriander, chili, fennel and fenugreek, introduction of genetic diversity from the centres of diversity is much needed in crops like paprika, nutmeg, clove, allspice and vanilla.

Also worth considering is introduction of other useful but at present not so popular spices and herbs like chives, lavender, anise, dill, rosemary, oregano, sage, marjoram, thyme etc. as they help in diversifying our spices production and introducing them to non traditional areas too.

References

AICRP (2006) Annual report. All India co ordinated Research Project on Spices, IISR, Calicut.

Baker JG (1886) Scitamineae (In) JD Hooker (ed.) *Flora of British India.* **6:** 198-264.

Fischer CEC (1928) A survey of the flora of Anamalai Hills in Coimbatore district, Madras Presidency. *Rec. Bot. Surv. India.* **9(1):** 151.

Gopalakrishnan M (1992) Chemical composition of nutmeg and mace. *J. Spices and Aromatic Crops.* **1**: 49-54.

Gopalam A and PN Ravindran (1986) Indexing quality parameters in black pepper cultivars. *Indian Spices.* **22/23:** 8-11.

Holttum RE (1950) The Zingiberaceae of the Malay-Peninsula. *Gard. Bull.* Singapore. **13:** 1-249.

IISR (2006) Research Highlights 2006-2007. Indian institute of Spices Research, Calicut.

Johny AK and PN Ravindran (2006) High yielding spices varieties developed in India. pp- 93-138. In PN Ravindran, K Nirmal Babu, KN Shiva and AK Johny (eds) *Advances in Spices Research,* Agrobios, Jodhpur.

Kathiria KB (1980) Variability and correlation in selected and unselected bulk of fennel. M.Sc. (Ag.) thesis. Univ. Udaipur, Jobner Campus, Rajasthan.

Kostermans AIGH (1983) The south Indian species of Cinnamomum Schaeffer (Lauraceae). *Bull. Bot. Survey of India.* **25(1-4):** 90-133.

Krishnamoorthy B and J Rema (1994) Genetic resources of tree spices. In: KL Chadha and P Rethinum (eds.) *Advances in Horticulture,* Malhotra Publishing House, New Delhi, India, **9:** pp. 169-192.

Madhusoodanan KJ, KM Kuruvilla and PM Priyadarshan (1994) Cardamom improvement. In: KL Chadha and P Rethinum (eds.) *Advances in Horticulture,* Malhotra Publishing House, New Delhi, India. **9:** pp. 307-314.

Minoo D (2002) Seedling and somaclonal variations and their characterisation in vanilla. Ph.D. Thesis, Calicut University, Kerala, India.

Nirmal Babu K, G Naik and PN Ravindran (1993a) Two new taxa of *Piper* (Piperaceae) from Kerala, with a note on their origin and interrelationships. *J. Spices and Aromatic Crops,* **2 (1&2):** 26-33.

Nirmal Babu K, RR Nair, G K Johnson and PN Ravindran (1992) *Piper barberi* Gamble - A redescription of the species with a note on its kaiyotype. *J. Spices and Aromatic* Crops. **1(1)**: 88-93.

Nirmal Babu K, B Sasikumar, MJ Ratnambal, GK Johnson and PN Ravindran (1993b) Genetic variability in turmeric *(Curcuma longa* L.) *Indian J. Genetics.* **53(1):** 91-93.

Padmini K, MN Venugopal and VS Korikanthimath (1999) Biodiversity and conservation of cardamom *(Elettaria cardamomum* Maton). In: B Sasikumar, B Krishnamoorthy, J Rema, PN Ravindran and KV Peter (eds.) *Biodiversity Conservation and Utilization of Spices, Medicinal and Aromatic Plants,* IISR, Calicut, pp. 73-78.

Raju K, PN Ravindran and NK Nair (1983) Quality evaluation of black pepper cultivars. *Indian Spices.* **20:** 3-5.

Rama Rao RSM (1914) *Flowering plants of Travancore,* Government Press, Trivandrum. pp. 336-368.

Ravindran PN and K Nirmal Babu (1994) Genetic resources of black pepper. In: KL Chadha and P Rethinam (eds.) *Advances in Horticulture.* Malhotra Publishing House, New Delhi. **9:** 99-120.

Ravindran PN, B Krishnamoorthy, B Sasikumar, KG Johnson, K Nirmal Babu, J Rema, RR Nair, PA Mathew, R Mulge, A Dhamayanthi, TJ Zacharia and KV Peter, (1996) Genetic Resources of spices in India, their utilisation and conservation. 2nd International Crop Science Congress, New Delhi.

Ravindran PN, K Nirmal Babu, B Sasikumar and KS Krishnamoorthy (2000) Botany and crop improvement of black pepper, pp. 23-142, In: PN Ravindran (ed.) Black pepper. *Piper nigrum.* Hardwood Academic Publishers, Amsterdam, The Netherlands.

Ravindran PN, K Nirmal Babu, KV Peter, Z Abraham and RK Tyagi (2005) Spices – pp. 190-227. In BS Dhillon, RK Tyagi, S Saxena and GJ Randhawa (Eds) *Plant Genetic Resources: Horticultural Crops,* Narosa Publishing House, New Delhi

Ravindran PN, K Nirmal Babu and KN Shiva (2006) Genetic Resources of Spices and their conservation. pp 63-91. In PN Ravindran, K Nirmal Babu, KN Shiva and AK Johny (eds) Advances in Spices Research, Agrobios, Jodhpur.

Ravindran PN, K Nirmal Babu, KN Shiva and AK Johny (eds) (2006) *Advances in Spices Research,* Agrobios, Jodhpur. pp 994.

Ravindran PN, B Sasikumar, KG Johnson, MJ Ratnambal, K Nirmal Babu, TJ Zachariah and RR Nair (1994) Genetic resources of ginger and its conservation in India. *Plant Genetic Resources Newsletter,* (IPGRI) **98:** 1-4.

Saji KV, KG Johnson, B Sasikumar, K. Nirmal Babu and PN Ravindran (1999) Genetic resources and conservation of black pepper. pp: 54-61, In: B Sasikumar, B Krishnamoorthy J Rema. PN Ravindran and KV Peter (eds.) *Biodiversity, Conservation and Utilization of Species, Medicinal & Aromatic Plants,* Indian Institute of Species Research, Calicut.

Sakai S and H Nagamasu (2000) Systematic studies of Bornean Zingiberaceae: II. Elettaria of Sarawak. Edinb. *J. Bot.* **57:** 227-243.

Sasikumar B, K Ninnal Babu, A Jose and PN Ravindran (1992) Variability, correlation and path analysis of ginger germplasm. *Indian J. Genetics.* **52(4):** 428-431.

Sevda PL (1980) Study on variability and correlation in local collection of coriander *(Conundrum sativum* L.). M.Sc. (Ag.) thesis. Univ. Udaipur, Jobner Campus, Rajasthan.

Sharma RK (1994) Genetic resources of seed spices. In: KL Chadha and P Rethinum (eds.) *Advances in Horticulture.* Malhotra Publishing House, New Delhi, India. **9:** 193-208.

Velayudhan KC and VA Amalraj (1992) *Piper pseudonigrum* - a new species from Western Ghats. *J. Econ. Taxon. Bot.* **16:** 247-250.

Velayudhan KC, VA Amalraj and VK Muralidharan (1991) The genus *Curcuma* in India: A morphotaxonomic assessement. In: KS Manilal and AK Pandey (eds.). *Taxonomy and Plant Conservation,* CBS PubL, New Delhi, pp 281-296.

Velayudhan KC, KI Asha, SK Mithal and PL Gautam (1999) Genetic resource of turmeric and its relatives in India. In: B Sasikumar, B Krishnamoorty, J Rema, PN Ravindran and KV Peter (eds) *Biodiversity, Conservation and utilization of Spices, Medicinal and Aromatic Plants,* Indian Institute of Spices Research, Kerala pp 101-109.

Wight (1864) A dictionary of economic products of India (reprint). Peridiual Experts, New Delhi.

Zacharia TJ and R Lukose (1992) Aroma profile of selected germplasm accessions in cardamom *(Elettaria cardamomum* Maton). *J. Plantation Crops.* **20(Suppl):** 310-312.

Zacharia TJ, R Mulge and MN Venugopal (1998) Quality of cardamom from different accessions. In: NM Mathew and CK Jacob (eds.) *Developments in Plantation Crops Research,* Allied Publishers, India, pp. 337-340.

Tropical and Sub-tropical Vegetables: Plant Introduction, Achievements and Opportunities in South Asia

BS Dhankhar[1] and JP Mishra[2]
[1]*Department of Vegetable Science, CCS Haryana Agricultural University, Hisar-125004, Haryana, India*
[2]*Division of Vegetable Science, Indian Agricultural Research Institute, New Delhi-110012, India*

Tropical and sub-tropical vegetables form a major part of the diet in South Asian countries and are also important as a valued source of nutrition. Enormous variability exists in these countries for one or more groups of such crops, but collection, introduction and exchange of stress resistant and high yielding germplasm is an ever-important consideration. Exchange of elite germplasm among South Asian countries under SAVERNET Phase has shown usefulness. India is the largest source of supply of indigenous as well as introduced/imported material for improving vegetable production in these countries. Till July 2006, 34,482 accessions of tropical and subtropical vegetables were introduced and 4,871 were exported from NBPGR, New Delhi (India) while 25,406 were maintained at its regional stations. Conservation status in seed gene banks in these countries as per SANPGR Report 2002 is 5,953 in Sri Lanka, 5,162 in Bangladesh and 1,216 in Nepal and low number in Bhutan and Maldives. Introductions have been utilized for improvement breeding in India, Sri Lanka and Bangladesh. In spite of newer and stricter guidelines imposed recently for movement of germplasm, the introductions are going to give a fillip in development of high yielding and/or stress (biotic and abiotic) resistant varieties. The article deals with the present status of introduction, conservation, utilization and classification of germplasm of important vegetables in South Asia and identifies trait-specific germplasm, the specific characters and sources for their introduction, particularly with reference to tropical and sub-tropical vegetables.

Key words: South Asia, Vegetable germplasm, Conservation, Introduction

It is well understood that while adaptability is a set of characters specific to a particular region or agro-climate, the attributes related with yield and sustainability (stress resistance) have to be pooled from diverse sources which highlights the need of plant introduction. Among South Asian countries, India has the advantage of having almost all types of agro-climates, a large area under undisturbed/partially disturbed forests as reservoir of variability, and a group of tropical and sub-tropical vegetables having maximum diversity and distribution (Seshadri, 1988). The existing variability is getting depleted irrespective of the national boundaries with the adoption of only few high yielding genotypes most suited to present day conditions of a particular region. The ill effects of this are due to narrowing of genetic base of varieties getting prone to biotic and abiotic stresses. Even a 'refuge' area is recommended in conjunction while using genetically modified (GM) pest resistant crops (varieties) in order to promote resistance management strategy which will help to prevent the break down of pest resistance in the GM crop. Such situations warrant for continued interchange and recombination of plant improvement material, particularly in South Asian countries where a good number of vegetables are grown and farmers are the most important part of the population.

South Asia comprises countries namely, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. Bhutan and Nepal have difficult sub-terrain and vegetables are of secondary importance, yet successive erosion of bio-diversity due to increasing population pressure, deforestation, land degradation and settlement requirements warrant conservation of native and introduced variability in vegetable crops and its systematic utilization in these countries. Sri Lanka and Bangladesh have established Plant Genetic Resources (PGR) Centre and sizable variability has been collected/ introduced. The status of genetic resources in tropical and sub-tropical vegetable crops in Sri Lanka, Bangladesh, Bhutan and Nepal is given below (SANPGR, 1998, 2000 and 2002).

Sri Lanka

Country's requirement of vegetables including root and tuber crops is fully met with local production. Though Sri Lankan farmers have maintained a rich bio-diversity in the country, however, with the increasing population pressure and need for economic development, there has been a progressive erosion of bio-diversity in the country. Also, there are areas unsuitable for high yielding varieties, sometimes due to un-favourable climatic conditions. Additionally, extensive deforestation, land degradation and opening of new lands for settlement have resulted in the erosion of the genetic diversity of crops and their wild relatives.

Sri Lanka comes under Indo-Burma Mega Centre of Diversity where mostly tropical and sub-tropical vegetables are grown. Vegetable crop species that exhibit high genetic diversity are *Abelmoschus esculentus, Alternanthera sessilis, Amaranthus* spp., *Bassela alba, Canavalia gladiata, Centella asiatica, Cucumis melo, C.sativus, Ipomoea batatas, Lablab purpureus, Lagenaria siceraria, Luffa acutangula, Momordica charantia, Mucuna pruriens, Phaseolus lunatus, Solanum melongena, Trichosanthes anguina, Vigna umbellata, V. unguiculata* and also *Alocasia, Amorphophallus, Colocasia* and *Dioscorea.*

Among 288 crop wild relatives identified in Sri Lanka (up to 2003), 39 are in vegetables and 21 in root and tuber crops. These comprise vegetables *Abelmoschus* (4), *Amaranthus* (2), *Bassela* (2), *Lablab purpureus* (2), *Citrullus* and *Luffa* (1 each), *Momordica* (2), *Mucuna* (4), *Solanum* (8), *Trichosanthes* (4), *Vigna* (6), and tuber crops *Alocasia* (3), *Celosia, Coccinea, Colocasia, Cucumis, Aerva, Alternanthera, Ipomoea,* and *Amorphophallus* (1 each) and *Dioscorea* (9). Open canopy forest areas, secondary forests, disturbed grasslands and shrub jungles are rich in crop wild relatives.

Status of conservation of PGR in seed gene banks shows that vegetable legumes (1,042), solanaceous vegetables (1,057), cucurbits (648), leafy vegetables (134), other vegetables (298), root and tuber crops (301) and *Brassica* species (93) have been conserved till Nov. 2002. Additional collection/ introduction comprised vegetable legumes (311), solanaceous vegetables (440), cucurbitaceous vegetables (295), cruciferous vegetables (303), leafy vegetables (540), root and tuber crops (338) and other vegetables (153). The work on utilization of collections/ introductions is in progress. Regional variability in *Solanum* and *Lycopersicon* has been studied. Biochemical characterization of wild species and inter-specific crosses was made in *Abelmoschus* and *Solanum* (SANPGR, 2002).

Germplasm introduction from India (through exchange) has benefited significantly the vegetable improvement programme of Sri Lanka. Varieties in several tropical and sub-tropical vegetable crops have been developed and released utilizing indigenous and introduced germplasm. These include *Abelmoschus esculentus* (3), *Allium cepa* (5), *Capsicum annuum* (6), *Citrullus lanatus, Colocasia esculenta, Cucurbita maxima, Cucumis sativus* (1 each), *Ipomoea batatas* (9), *Luffa àcutangula* (2), *Lycopersicon esculentum* (8), *Momordica charantia* (2), *Solanum melongena* (3), *Trichosanthes cucumerina* (3), and leafy vegetables (4). In tomato, marker development for resistance against bacterial wilt and heat tolerance is in progress. *Abelmoschus* and *Solanum* species are being utilized in improvement of these crops. Descriptor lists have been prepared and PGR catalogues with characterization and passport data have been published in tomato, okra, brinjal, winged bean and yard-long bean. A sizable number of germplasm has been supplied to international organizations as well.

Bangladesh

Bangladesh is a part of the Indian Gene Centre and significant diversity exists in agro-ecology. This helped in maintenance of rich diversity of vegetable crops, particularly in okra, eggplant, different cucurbitaceous crops, cowpea and a wide range of leafy vegetables. There is a wide distribution of wild relatives of eggplant and okra. Based on the survey of the variability, a Plant Genetic Resource Centre (PGRC) has been established in Bangladesh Agricultural Research Institute (BARI). Up to the year 2000, the PGRC had an *ex-situ* conservation of 4,310 germplasm of tropical and sub-tropical vegetables. A total of 4,389 accessions of vegetables, 773 of tuber crops and 344 of spices were collected till 2000 and all these have been conserved at PGRC, BARI. This covers almost all important vegetable crops. The characterization has been done for 1,470 accessions of vegetables, 289 of tuber crops and 126 of seed spices (SANPGR, 2000).

A good number of varieties have been developed primarily from indigenous germplasm or from those collected under Indo-Bangladesh collaborative programme some time back. Important among these are brinjal Uttara, Tarapari, Suktara; cabbage Provati; okra Bari Deros-1; bottle gourd Bari Lav-1; garden pea Bari Matorsuti-1, Bari Matorsuti-2, Tasa Kisan; radish Bari Mula-2; tomato Raton, Manik, Bari Tomato-3, Bari Tomato-4, Bari Tomato-5, hyacinth bean Bari Sim-1, Bari Sim-2; sweet potato Doulatpuri developed from indigenous material, and Tripti, Kamla, Sunduri sweet potato and 12 varieties of potato developed from exotic introductions (SANPGR, 1998).

Bhutan

Bhutan has a topography characterized by rugged mountains and fragile eco-systems and has largely sub-tropical/temperate climate. Only 7.8 per cent of the total land of the country is under cultivation, mainly vegetables. The agriculture in this country is in initial stage of modernization. There are around 27 traditionally grown vegetables. Potato is the major vegetable crop in Bhutan, followed by chili, radish, eggplant and turnip. The diversity is preserved in home gardens and back yards due to least disturbances and subsistence farming based on traditional practices. This way variability in the form of land races, primitive forms and some rare wild species are preserved *in situ*. Only traditional cultivars are in cultivation and little attention has been given to introduction of more promising germplasm from suitable destinations. National capacity building is in progress and thus *ex-situ* conservation is in the preliminary stage. In view of this there is a strong need for introduction of germplasm and its systematic utilization in Bhutan. A National Biodiversity Centre has been established under the Ministry of Agriculture and the *ex-situ* conservation of vegetable germplasm is in progress.

Nepal

Biodiversity has remained a neglected sector in Nepal and as such there is limited diversity in vegetable crops. About 600 edible plant species were identified up to the year 2000 and the *ex-situ* conservation of germplasm in vegetable crops numbered around 600. Important vegetable crops in Nepal are cucumber, eggplant, radish, beans, cauliflower and sponge gourd. The registration of indigenous variability in the form of vegetable germplasm has been initiated and registered genotypes in different crops are, amaranth (101), cucumber (154), beans (498), cowpea (220), peas (188) and pumpkins (55). The prospects of introductions in sub-tropical vegetable crops are bright.

Several crop varieties have been developed and released either by direct use of indigenous germplasm or through incorporation of useful genes from local germplasm through breeding programmes. The varieties Kathmandu Local cauliflower, Pyudiane Rato radish, Khumal Tane asparagus, Khumal Tane bean, Sarlahi Green eggplant, Kusle cucumber, Kantipure sponge gourd and Khumal Broad Leaf, Marpha Broad Leaf and Khumal Rato Pat broad leaf mustard- all have been developed through local selection for commercial cultivation (SANPGR, 2000).

Maldives

Maldives has exclusively a humid tropical- littoral environment. Most of the vegetables for consumption are transported from India. As such there is not enough indigenous variability. Very little attention has been given to introduce vegetable germplasm for conservation and utilization.

India

India has a rich reservoir of genetic diversity, particularly in tropical and sub-tropical vegetable crops. This is primarily due to ecological diversity and related subjects. Indian Gene Centre can be considered to be (a) Primary Centre of Diversity for *Luffa aegyptica, L. acutangula, Trichosanthes dioica*; (b) Secondary Centre of Diversity for *Vigna unguiculata* (cowpea), *Cyamopsis tetragonoloba* (cluster bean), *Abelmoschus esculentus* (okra) introduced from Africa and *Lycopersicon esculentus* (tomato), *Cucurbita* spp. (pumpkins), *Sechium edule* (Chocho, chayote), *Capsicum* spp. (chilies), *Amaranthus* spp. (amaranth) introduced from tropical America; or (c) Regional (Asiatic) Centre of Diversity for *Cucumis sativus* (cucumber), *Momordica charantia* (bitter gourd), *Lagenaria siceraria* (bottle gourd), *Trichosanthes anguina* (snake gourd) and certain *Brassica* spp. Some of these crops have originated here (Paroda and Arora, 1986).

A total of 34,482 accessions of tropical and sub-tropical vegetables were introduced upto July 2006 into India from over 50 countries (Dhankar and Mishra, 2005). The major contributors to these introductions into India are institutions like USDA, AVRDC and countries like USA, UK, Japan, Holland, USSR, Bulgaria, France, the Philippines, Australia and several others. During 2005, an additinal 244 germplasm of Indian origin were repatriated and 142 were received for national accessioning. Under cryo-preservation 432 vegetable seed samples have been preserved so far. A large amount of variability is maintained *in situ* as well as *ex-situ*. Sizable collections, both indigenous and exotic, are being maintained in National Gene Bank and Indian Institute of Vegetable Research (IIVR) (Table 1).

A large number of vegetable germplasm (25,406) is being maintained at 11 NBPGR Regional Stations and 40 National Active Germplasm Sites (NAGS) as per crop agro-ecology, and with breeders for specific crops.

The germplasm holding of tropical and sub-tropical vegetables at different regional stations of NBPGR and

Table 1. Conservation of germplasm of tropical and sub-tropical vegetables in India

Crop	PGR in National Seed Gene Bank, Delhi up to date	PGR at IIVR, Varanasi up to Dec. 2004
Ashgourd	172	84
Bittergourd	527	215
Bottlegourd	636	135
Brinjal (cultivated)	3,437	650
Brinjal (wild)	728	15
Cauliflower (Indian type)	147	81
Cucumber	226	50
Cucurbits	1,410	1,267
Ivygourd	18	15
Kakoda (*Momordica cochinchinensis*)	4	8
Kakrol (*M. dioica*)	38	26
Muskmelon	525	95
Okra (cultivated)	1,302	168
Okra (wild)	338	63
Peas and Beans	210	841
Pointed gourd	27	200
Pumpkins	65	150
Radish (tropical type)	251	75
Ridgegourd and Spongegourd	505	139
Snapmelon	190	150
Tomato (cultivated)	1659	1,174
Tomato (wild)	101	44
Watermelon	315	–
Total	**12,831**	**5,645**

Source: NBPGR, New Delhi

Table 2. Germplasm holdings of tropical and sub-tropical vegetables (at different NBPGR centres and NAGS)

(as in July 2006)

Crop	Holding
Bottlegourd	144
Brassicas	1,158
Brinjal (eggplant)	2,931
Carrot	7
Chili	1,589
Cowpea	2,698
Cucumber	245
Cucurbita	2,514
Fababean	548
Frenchbean	3,310
Lablab bean	1,100
Pea	1,859
Okra	3,469
Ridgegourd	28
Round melon	33
Snakegourd	8
Spongegourd	36
Tomato	3,478
Wingedbean	507
Total	**25,406**

Source: NBPGR, New Delhi

National Active Germplasm Sites is presented in Table 2.

Also a good number of vegetable germplasm has been exported for meeting outside demands. Till July 2006, 4,871 accessions were given to different countries on their request for research purposes.

Utilization of Introduced Germplasm in India

The germplasm in this group of vegetables has been acclimatized and directly released for commercial cultivation (Primary Introductions), or it has been used as donors for specific traits in breeding varieties (Brahmi, 1995). An account of primary and secondary introductions is given below.

A. Primary Introductions

Brinjal: Black Beauty (ex USA)

Cowpea: Pusa Barsati (sel. ex Phillippines), Pusa Phalguni (sel. ex Canada)

Garden Pea: Early Badger, Bonneville (ex USA), Arkel (ex France), Harbhajan (EC 33866 ex Portugal)

Okra: Perkin's Long Green, Clemson's Spineless (ex USA)

Onion: Early Grano, Red Grano, Pusa Ratnar (sel. from Red Grano), Bermuda Yellow (ex the Phillippines)

Radish: Pusa Chetki (sel. from Hawaiian germplasm)

Sweet Potato: Varieties mostly direct introductions or selections after hybridization

Tomato: Sioux, La Bonita, Marglobe, Kekruth (ex USA), Fire Ball, Scotia (ex Canada), Dwarf Money Maker (ex Israel), Molaki (ex Australia), Roma (ex Italy)

Watermelon: Sugar Baby (ex USA), Asahi Yamato (ex Japan)

B. Secondary introductions (Donors for desirable traits):

Cowpea: Aseem (tol. to root-knot nematodes, evolved from a cross between Pusa Phalguni and Pusa Barsati ex Philippines); Rituraj (developed from a cross between Pusa Do Fasli and EC 26410)

Cucumber: Tropical gynoecious lines with multiple resistance have been developed using Gy4 and Gy5 ex. USA)

Muskmelon: Pusa Sharbati, Punjab Sunehri (evolved utilizing cantaloupes ex USA)

Okra: Parbhani Kranti, Punjab Padmini, Pusa A-4, Sel.2, Sel.6-2, G-2 (tolerant to YVMV, evolved utilizing Ghana Collection ex. USA), Pusa Sawani (YVMV tolerant, evolved utilizing Best One ex. USA)

Sweet Potato: Rajendra Sakarkand (RS)-5, RS-35, Sree Nandini, Sree Vardhini, Varsha, Gouri are selections/ hybrid derivatives from introduced material.

Tomato: Pusa Ruby (prolific bearer and virus tolerance, evolved from cross between Sioux and Improved Meeruti), Pusa Early Dwarf (from cross Red Cloud x Improved Meeruti), Pusa Red Plum (evolved by crossing cultivated variety with *L. pimpinellifolium*)

Tomato: Kekruth Ageti (sel. from Kekruth), H-24, H-36 (resistant to TLCV, developed utilizing *L. hirsutum f. glabratum*), MRT 3, MRT 8, MRT 12 resistant to root-knot nematodes, developed utilizing Nematex and Resistance Bangalore)

Watermelon: Arka Manik (resistant to PM, DM and Anthracnose, developed utilizing Crimson Sweet ex USA), Improved Shipper (sel. from Shipper ex USA), Pusa Bedana (seedless, developed utilizing tetraploid Tetra-2 ex USA).

Introductions as Source of Stress Resistance

The introductions are usually done with certain target traits like resistance against particular biotic or/and abiotic stresses (Mishra and Mishra, 2004). Some of such introduced germplasm have been identified as sources for resistance against one or more stresses under our conditions. A short account of some such examples is given in Table 3.

Such resistance sources have been utilized to develop varieties in India (Table 4) (Pandey *et al.*, 2005) which are available for introduction and utilization in other South Asian countries. Indian varieties of vegetables tolerant to abiotic stresses (Dhillon *et al.*, 2004) and those bred for improved nutrition are mentioned in Table 5 and 6.

Table 3. Identified sources of stress resistance in tropical and subtropical vegetable germplasm introduced in India

Crop	Stress	Sources of resistance
Brinjal	Bacterial wilt	EC104107, Florida Market
	Phomopsis fruit rot	EC305069, EC316274
	Root-knot nematode	*Solanum torvum, S. sisymbrifolium*
	Shoot and fruit borer	*S. khasianum*
	Frost	Black Torpedo, Long Tom 4
	Drought	Supreme, Violette Round
Chilli	CMV	EC312342, EC312349
	PBNV	EC121490
	Aphids	EC28, EC30, EC34
Cucumber	PM and DM	Poinsette
Muskmelon	Gummy Stem blight, PM and DM	AC70-54
	PM and DM	Campo, Edisto, PMR-45
Okra	YVMV	EC133408, EC169333, EC169334, Ghana Red
	Jassids	EC305656, EC305694, EC305695, *Abelmoschus moschatus*
Onion Short-Day	Purple blotch	EC328494, EC328492, EC328501, EC321463
Peas	Powdery mildew	EC342007
Tomato	Bacterial wilt	EC467725, EC438314-317, EC182761-182874, EC26511-13,
	Fusarium wilt	Florida, Pan American, PI 79532, Walter, Columbia, Roma, Floradade, *Lycopersicon pimpinellifolium* (for *Fusarium oxysporum* race 1, 2)
	Root- knot nematode	VFN-8, Nemared, Florida, Hawai Cross, Nematex, *L. peruvianum*
	High temperature	EC198416, EC501573-83, EC479027, -31, -34, 36,-139, -140, -141, -143, PS-1, 84 #42, Miniros
	Early blight	*L. pimpinellifolium, L. hirsutum*
	TLCV	*L. pimpinellifolium, L. hirsutum*
	Buck eye rot	*L. pimpinellifolium*
	Fruit borer, Fruit fly	*L. hirsutum, L. hirsutum f. glabratum*
	Low temperature	Cold Set, Ostenkinstkiz
	Drought	*L. pimpinellifolium*, 64#8
	Salinity	*L. cheesmanii*
Watermelon	DM, PM, Anthracnose	Crimson Sweet, Shipper, Charleston Gray

Male sterile, tetraploid and self-incompatible lines introduced in several crops to ease hybrid development
CMV–*Cucumber mosaic virus;* PBNV – *Peanut bud necrosis virus*; PM–Powdery mildew; DM–Downy mildew; TLCV–*Tomato leaf curl virus;* YVMV–*Yellow vein mosaic virus.*

Table 4. Biotic stress-resistant Indian varieties/ elite lines of tropical and sub-tropical vegetables

Crop	Biotic stress	Resistant varieties
Brinjal (egg plant)	Bacterial wilt	BB-7, BB-44, BWR-12, SM-6-6, SM-6-7
	Phomopsis blight	Pusa Purple Cluster, Hisar Shyamal, Pusa Bhairav
	Little leaf (tol.)	H 7, H 8, H 9, H 10
Chili	CMV, TMV, LCV	Pusa Jwala, Pusa Sadabahar
	CMV, TMV, LCV, Fruit rot, Die-back	Punjab Lal
	LCV	Bhagya Lakshmi, Andhra Jyoti, Pant C-1, Pant C-2
Cowpea	Bacterial blight	Pusa Komal
Cucumber	PM, DM	Poinsette
	PM (tol.)	Swarna Poorna
	PM, DM, *Alternaria*	IIHR-177-1
Lablab bean	Viral diseases, Jassids, aphid and fruit borer	Pusa Sem-2, Pusa Sem-3
Muskmelon	PM, DM	IHR 352, Punjab Rasila
	PM	Arka Rajhans, Punjab Rasila, RM-43
	Fusarium wilt	Punjab Sunehri, Pusa Madhuras, Arka Jeet, Durgapura Madhu, Harela
	PM, DM, Anthracnose, *Alternaria, Fusarium* wilt	IIHR-190, IIHR-352
	CGMMV and DM	DMDR-2, DMDR-1, DVRM-1
Okra	YVMV	Pusa Sawani, Parbhani Kranti, Punjab-7, Punjab Padmini, Hisar Unnat, Varsha Uphar, Arka Abhay and Arka Anamika, Azad Kranti
	YVMV, Shoot and Fruit borer	Pusa A-4
Pumpkin	Fruit fly	Arka Suryamukhi
Tomato	Root-knot nematode	Pusa-120, Pusa Hybrid-2, NRT 3, NRT 8, NRT 12
	TLCV	H 24, H 36
Watermelon	Anthracnose, PM, DM	Arka Manik

CGMMV: *Cucumber green mottle mosaic virus* , TLCV: Tomato leaf-curl virus, CMV: *Cucumber mosaic virus*, TMV: *Tobacco mosaic virus;* PM–Powdery mildew; DM–Downy mildew; LCV–Leaf curl virus; YVMV–*Yellow vein mosaic virus.*

Table 5. Indian varieties of tropical and sub-tropical vegetables resistant to abiotic stresses

Abiotic stress	Resistant varieties
High Temperature	**Cluster Bean:** Pusa Nav Bahar
	Tinda: Arka Tinda, Tinda Ludhiana, Tinda Tonk
	Long melon: Arka Sheetal, Punjab Long
	Bittergourd: Pusa Do Mausami, Kalyan Sona
	Bottlegourd: PSPR, PSPL, Pusa Naveen, Pusa Sandesh, Arka Bahar
	Radish: Pusa Chetaki
	Turnip: Pusa Sweti
Low Temperature	**Bottlegourd:** Pusa Santushti
	Tomato: Pusa Sheetal, Pusa Sadabahar
Warm humid climate	**Bittergourd**: Arka Harit, Priya, MC-84, MDU-1, Konkan Tara, Co-1, Co-Long
Soil Salinity	**Okra:** Pusa Sawani

Table 6. Indian varieties of tropical and sub-tropical vegetables bred for improved nutrition

Crop	Varieties	Superior nutrition factor
Muskmelon	Arka Jeet, Durgapura Madhu	Vitamin C
Bitter gourd	Arka Harit, Priya, Pusa Hybrid1, Pusa Hybrid 2	Vitamin C and iron
Pumpkin	Arka Chandan, Pusa Hybrid1, Pusa Vikas	Vitamin A
Amaranth	Pusa Kiran, Pusa Kirti, Pusa Lal Chaulai	Vitamin A, C, Calcium and Iron
French bean	Pusa Parvati	Protein
Garden pea	Arkel, Pusa Pragati	Protein
Cowpea	Pusa Phalguni, Pusa Barsati, Pusa Do Fasli	Protein
Lablab bean	Pusa Sem 2, Pusa Sem 3	Protein
Cluster bean	Pusa Mausami, Pusa Sadabahar, Pusa Nav Bahar	Protein
Indian spinach (Palak)	Pusa Jyoti, Pusa Bharati, Pusa Harit	Vitamin A, C, Iron and Calcium
Bathua (Chenopod)	Pusa Bathua-1	Vitamin A, C, Iron and Calcium
Tomato	Pusa Uphaar, Pusa Hybrid-2, Pusa Rohini	Vitamin C
Carrot	Pusa Meghali, Pusa Yamadagni	Vitamin A

Future Considerations for Introduction of Tropical and Sub-Tropical Vegetable Germplasm in South Asia

A. Search for sources of resistance

Crop	Considerations
Bittergourd:	Resistance against viruses and fruit fly, higher sex (female: male) ratio, less temperature sensitivity for fruiting
Bottlegourd:	Suitability for fruit setting under high and low temperatures, variable vine length, small, slow developing seed, resistance against virus, mildews and pests
Brinjal:	Resistance against little leaf, bacterial wilt, *Phomopsis* blight, fruit borer and root-knot nematodes, heat tolerance (for fruit-set)
Chili:	Multiple virus (TMV, CMV, LCV), anthracnose and bacterial spot resistance, perennial types, suitability for tropical conditions with export potential
Cucumber:	Suitability for hot and hot-humid weather cultivation, multiple disease and virus complex resistance, stable gynoecious forms
Lablab bean:	Low sensitivity to photoperiod and temperature, resistance against viruses and anthracnose, bushy habit and drought tolerance
Muskmelon:	Resistance to viral diseases, downy mildew, wilt, fruit fly, and also non-dessert forms.
Okra:	Resistance against YVMV, powdery mildew, Cercospora, *Fusarium* wilt and damping off. Also resistance against major pests, viz., shoot and fruit borer, jassids, white fly, mites and root-knot nematodes; suitability for export.
Onion:	Photo-insensitivity, resistance against thrips, purple blotch, blight and storage diseases, allied *Allium* spp. and primitive forms
Pumpkin:	Suitability for fruit setting under LD and SD conditions, particularly in *C. moschata*, resistance against viruses and powdery mildew
Tomato:	Tolerance to high/low temperature (for fruit-set) and cracking; resistance against TLCV, TMV, bacterial wilt, *Fusarium* wilt and root-knot nematodes, suitability to wet tropic and drought conditions
Watermelon:	Suitability for transport (tough skin) and storage, resistance against anthracnose, WMV, collection of allied species
Amaranth:	Low oxalate, high protein and vit. A in leaves, fast regeneration potential
Gardenpea:	Suitability for high temperature and humidity conditions, resistance against wilt, mildew and leaf miner
Sweet potato:	Earliness, high protein and Beta-carotene content; resistance against weevil

B. Search for improved nutrition and quality

Crop	Improved quality	Improved nutrition
Bittergourd	Fruit shape, colour, surface	Phosphorus and potassium in fruits
Bottlegourd	Slow seed development, flesh thickness	Anti-oxidants, minerals, vitamins
Brinjal	Desirable shape, colour, lustre and low seed content in fruits	High folic acid in fruits
Chili	Oleoresin, fruit colour, shape	High capsaicin, oleoresin and vit. C in fruits
Cucumber	Fruit shape, colour, size and flesh thickness	Carotene content and aroma
Gardenpea	Fruit shape, colour and seeding	Protein content of pods
Leafy vegetables	Leaf colour, size and regeneration rate	Anti-oxidants, minerals and vitamins
Muskmelon	Colour, thickness, firmness, aroma/flavour in flesh	TSS, vit. C, flavonoids and phenols
Okra	Fruit shape, size, colour	High protein in fruits
Pumpkins	Fruit size, shape, flesh colour and thickness	Ascorbic acid, β-carotene and anthocyanin content in fruits
Tomato	Firmness, shelf life, acidity	High TSS, vit. A, C, and lycopene
Watermelon	Flesh colour, texture and seed arrangement	TSS, carotenoids, phytochemicals, phenols

Source Countries for Introductions*

Bittergourd	: South East Asia
Bottlegourd	: African countries, Indo-gangetic plains
Chilies (hot)	: Principally from South America
Cucumber	: Multiple locations
Ivygourd and Chow-Chow	: India (north-eastern part and middle Himalayas)
Lablab bean	: Eastern peninsular tract, Orissa (India), etc.
Muskmelon	: Feral forms from North-Eastern India, resistance sources from Central Asia, Middle East, Africa and global gene banks and cultivated types from India, Afghanistan, Pakistan, Japan, etc.
Okra	: African countries, South East Asia and India
Pointedgourd	: India (Bihar, Bengal, Assam)
Pumpkin	: Central and South America
Snakegourd	: Southern India and peninsular parts
Sweet Potato	: USA, Japan, China, Fiji, New Zealand, Taiwan, Australia, Tanzania, Nigeria, India
Tomato	: Various destinations
Watermelon	: Allied species from African countries; cultivated forms from USA, Japan and India

*Also from institutions like AVRDC, Taiwan, USDA Gene Banks and PGR Centres of South and South-East Asia

Germplasm Exchange among South Asian Nations

The experience under the South Asia Vegetable Research Network (SAVERNET) programme Phase I and II emphasizes the continuance of such programmes with better zeal. Some of the results of SAVERNET are given below.

Six countries exchanged 96 varieties of 13 vegetable crops for evaluation. Indian tomato varieties Pusa Sheetal, Pusa Ruby, Arka Vikas, Pant Bahar, Punjab Chhuhara performed well in Bhutan, Nepal and Pakistan. Sri Lankan Tomato T245, T89 did well in India, Nepal and Pakistan. Bangladeshi tomatoes Ratan and Manik did well in India, Nepal and Sri Lanka. Indian brinjal varieties Pusa Purple long, Pusa Kranti and Pant Rituraj did well in Bangladesh. Sri Lankan chili MI 2 and KA 2 performed well in India and Bangladesh. Indian okra varieties Parbhani Kranti, Pusa A-4, Arka Anamika and Arka Abhay performed superior for yield and YVMV resistance in India, Pakistan and Sri Lanka. Pusa A-4 gave highest pod number (45/plant). Cucumber varieties Shabi Ghenchu from Bhutan and Ly 58 from Sri Lanka, along with Pusa Samyog from India were found superior at various locations. Muskmelon hybrid Pusa Rasraj from India, and Ravi and T96 from Pakistan were superior in yield and quality.

Conclusion

Cultivated types with wider adaptability and higher productivity, processing quality and stress resistance will still form the major thrust in introductions. Besides wild related forms having resistance against one or more biotic/abiotic stresses need to be introduced for developing pre-breeding material where crossability is difficult or else for direct utilization in developing commercial varieties. An integrated gene management strategy has to be developed in each mandate vegetable crop. In addition to varieties, new vegetable crops also need to be introduced, particularly for improved nutrition, value addition and export. Even exchange of elite germplasm among South Asian countries can help a lot in boosting vegetable production as experienced in one of the SAVERNET programmes on varietal evaluation.

In agricultural terms, the richest country is one that has maximum bio-diversity. During earlier days bio-diversity was considered a common heritage of mankind and introduction used to be a free and frequent activity. Global conventions during recent years have altered the concept. Now bio-diversity is the sovereign property of the nation in whose political frontiers it occurs, and as such, the introduction of germplasm now involves certain procedures, commitments and cautions on part of the ordering agency or person. Further, as suggested by Dr. M. S. Swaminathan, concerned public institutions should create novel genetic combinations under well-designed pre-breeding program and through participatory breeding involving grass-root farmer breeders, get the novel genetic traits for resistance to biotic and abiotic stresses incorporated in to locally adapted varieties (Swaminathan, 1999). This will ensure ecological, economic and social sustainability as well.

References

Anonymous (2005) Division of Vegetable Science – A Profile. Division of Vegetable Science, Indian Agricultural Research Institute, New Delhi. Pp 24.

Brahmi Pratibha (1995) Promising introductions and prioritize needs of exotic germplasm in different groups of vegetable crops. In: *Exchange and Quarantine of Plant Genetic Resources,* (RS Rana, VK Mathur, M Kazim, Arjun Lal, Manjulata Kapur and Pratibha Brahmi (Eds.). NBPGR, New Delhi. Pp 110-114.

Dhankhar BS and JP Mishra (2005) Germplasm introduction in tropical and sub-tropical vegetables in South Asia- achievements and opportunities. *Indian J. Plant Genet. Resour.* **18(1):** 20-21.

Dhillon BS, JC Rana and AK Singh (2004) Collection, conservation and utilization of indigenous horticultural crops germplasm. In: *Crop improvement and production technology of horticultural crops. Proceedings of the First Indian Horticultural Congress-2004,* **Vol. 1**: Pp 10-35.

Mishra JP and Akhilesh C Mishra (2004) Resistant varieties as a component in organic farming and sustainable vegetable production. In: *Organic Farming in Horticulture. Proceedings of the National Symposium.* (Eds. RK Pathak, Ram Kisun, RM Khan and RA Ram). Central Institute of sub-tropical Horticulture, Lucknow. Pp 128-139.

Pandey Chitra, J Radhamani and Anjali Kak (2005) Utilization of exotic introductions for crop improvement in vegetables. *Indian J. Plant Genet. Resour.* **18(1)**: 98-99.

Paroda RS and RK Arora (1986) Plant Genetic Resources Activities – An Indian Perspective. In *Proceedings of International Symposium on S E Asian Plant Genetic Resources*, Jakarta, Indonesia (Eds. KL Mehra and S. Sastraprodja). Pp 47-54.

Seshadri VS (1986) Genetic resources and their utilization in vegetable crops. In Proc. International Symp. on S E Asian Plant Genetic resources, Jakarta, Indonesia (Eds. KL Mehra and S. Sastraprodja). Pp 335-343.

South Asia Network on Plant Genetic Resources (SANPGR) (1998) Proceedings of the 4th Meeting, Kathmandu, Nepal; 1-3 September 1998 (Eds. Bhag Mal, PN Mathur and V Ramanatha Rao).

South Asia Network on Plant Genetic Resources (SANPGR) (2000) Proceedings of the 5th Meeting, New Delhi, India, 9-11 Oct. 2000 (Eds. Bhag Mal, PN Mathur V Ramanatha Rao and Percy E Sajise).

South Asia Network on Plant Genetic Resources (SANPGR) (2002) Proceedings of the 6th Meeting, Peradeniya, Sri Lanka, 9-11 Dec. 2002 (Eds. Bhag Mal, PN Mathur and V Ramanatha Rao and AHM Jayasuriya).

Swaminathan MS (1999) Integrating Science and Society towards effective conservation and utilization of PGR. Relevant excerpts from the Volvo Environment Prize Lecture delivered in New York on October 26, 1999. 14p.

Temperate Vegetables: Germplasm Resources, their Utilization and Achievements in India

TS Verma and Chander Parkash*
Indian Agricultural Research Institute, Regional Station, Katrain (Kullu Valley)-175 129, Himachal Pradesh, India

Temperate vegetable crops need chilling temperature (4-7°C) for about two months for changing their vegetative phase into reproductive phase. The different pockets in the Hindukush Himalayas namely Humid Western and Eastern Himalayan Region comprising Jammu and Kashmir, Himachal Pradesh, Uttaranchal and North-East states have congenial climate for seed production of temperate vegetable crops. The history of germplasm introduction in respect of temperate vegetables and their breeding dates back prior to second world war when seeds of all the temperate vegetable crops were imported from abroad mainly from England by seed companies such as M/s Suttons & Sons. Later Imperial Government of India established a research station at Quetta (Baluchistan) in 1942-43 which went to Pakistan after independence. Subsequently, Government of India set up a Central Vegetable Breeding Sub-station at Katrain in Kullu Valley in Himachal Pradesh in 1949 that was transferred to IARI in 1955 in order to strengthen the improvement work on temperate vegetable crops. From historical facts, it is evident that most of the temperate/ European vegetable crops were introduced into India by the Portuguese during 18th century followed by English in 19th century. Jenson from Kew introduced cauliflower varieties as early as in 1822 and grew it in botanical garden at Saharanpur. After independence several organizations like NHRDF, DARL, VPKAS, GBPUA&T etc. were established and different programmes namely AICRP were implemented at different times to give further fillip to breeding of temperate vegetable crops. In recent times, under open general license (OGL) the private seed companies have introduced lot of seed material and started their own R&D programmes. India has also collaborated with AVRDC, Taiwan, China, USSR and SAVERNET (South Asian Vegetable Research Network) countries for testing of vegetable entries. Some of the research projects on temperate vegetable crops were funded by NATP (National Agriculture Technology Project). A detailed account on utilization of vegetable crops has been highlighted with special reference to cole crops and root crops. Cauliflower being the most important cole crop received maximum attention and lot of varieties of late cauliflower (Group IV), namely, Pusa Snowball 1, 2, Pusa Snowball K-1 were developed using exotic lines. In cabbage majority of ruling varieties are through introductions e.g. Golden Acre, Pride of India etc. Pusa Mukta, a black rot resistant variety was developed by crossing two exotic lines (EC 24855 x EC 10109). Hybrid KGMR-1, the first from the public sector was identified for release during 2005 under the AICRP (VC). Many tropical cabbage hybrids such as KK cross, Golden cross were introduced and tropical cabbage lines DTC 50-7-4, 513, 528 etc. were developed. CMS system has also been transferred successfully to various cabbage lines from EC 173419 at Katrain. In root crops also the improved cultivars are developed either through introductions followed by selection or by hybridization with exotic lines as one of the parents. The sources of pests and diseases resistance in cole crops are mainly exotic lines through introduction. The vast genetic resources of temperate vegetable crops have opened up the prospects of breeding using introductions made from different countries.

Key words: Temperate vegetables, Introductions, Genetic resources, Varietal improvement

A large number of vegetable crops are grown in India, perhaps more than any other country of the world. On the basis of seed production, these vegetable crops can be classified into two groups, first group includes those vegetables, the seeds of which can be produced in the plains and lower hills of Indian sub-continent (tropical, sub tropical or Asiatic group). The second group includes temperate vegetable crops requiring chilling temperature (4-7^{0}C) for about 2 months for changing their vegetative phase into reproductive phase. However, the period of chilling requirement differs according to the kind of crops and also varieties. The temperate vegetables occupying a significant position generally include cole crops (cabbage, late cauliflower, knol-khol, kale, collard, brussels sprouts, broccoli etc.), root crops (beet, temperate varieties of carrot, radish and turnip) and some other crops. These are also commonly known as European or biennial vegetables.

The different pockets in the Hindukush Himalaya are suitable for seed production of temperate vegetables. In India, Humid Western Himalayan Region consists of states like Jammu and Kashmir, Himachal Pradesh, Uttranchal and Humid Eastern Himalayan Region with Sikkim, Meghalaya, Manipur, Nagaland, Mizoram, Tripura and Arunachal Pradesh. Likewise Pakistan Himalayan Region of Baluchistan, whole of Nepal and Bhutan are suitable for this purpose.

* *E-mail: cp1968@gmail.com*

Germplasm Introductions in South Asia

Temperate vegetable breeding in India has a short history of about 5 decades plus. Earlier to Second World War (1939-45), the seeds of all temperate vegetable crops were being imported from abroad mainly by England based seed company M/S Sutton's and Sons. Later they established their office in India in 1916. During the war, there were difficulties in the import of seeds and therefore, the then Imperial Government in India established a research station at Quetta (Baluchistan) in 1942-43. After the partition of India in 1947, the Quetta centre went to Pakistan and the Government of India on the recommendations of an Expert's committee set up a Central Vegetable Breeding Sub-Station at Katrain in Kullu valley (H.P.) in May 1949. The main objectives were production and distribution of quality seeds of temperate vegetables, and to give advice to the growers on these aspects.

The historical facts reveal that most of the European/ temperate vegetables were introduced into India by the Portuguese during 18th Century and little later by the English during 18th and 19th Centuries. Dr. Jenson, a botanist from 'KEW' introduced cauliflower varieties in 1822 and grew it in Botanical Garden, Saharanpur, which is the basis for bringing out Indian cauliflower varieties. The first four Indian varieties listed by Sutton and Sons in 1929 were Early and Main Crop, Patna, and Early and Main Crop, Banaras. The Royal Agri-Horticultural Society, Calcutta introduced seeds of English vegetables from South Africa during 1824. English rulers also brought seeds of European vegetables to India during their regimes.

In view to intensify the improvement work on temperate vegetables, the Katrain Station was transferred to the Indian Agricultural Research Institute, New Delhi in 1955 with its changed name as Vegetable Research Station and now as IARI, Regional Station Katrain (Kullu Valley) H.P. Soon after the transfer of the station to IARI, breeding work was taken up under the leadership of Dr. Harbhajan Singh (1955-1957) who also contributed greatly to the standardization of seed production technology. In 1958, the late cauliflower seed was produced for the first time in India. Indigenous production of temperate vegetable seeds is a unique example of import substitution leading to the development of viable vegetable seed industry in Himachal Pradesh. Government of India launched National Seed Project in 1976-77 with the financial aid from the World Bank under which the Katrain and Solan centres were strengthened for temperate vegetable seed production and processing. Besides Kullu and Kashmir Valley, seed production work was also carried out in Kalpa Valley (H.P.), Kalimpong (Darjeeling), Saproon Valley (H.P.) and Nilgiri Hills (T.N.) during 1950 and 1960 but this was not in organized manner (Seshadri and Chatterjee, 1996).

Vegetable research further received a boost with the establishment of the Division of Horticulture at IARI, New Delhi in 1956-57 and subsequently by the Division of Vegetable Crops and Floriculture which came into existence in 1970 and Division of Vegetable Crops in 1982, and Katrain Centre was strengthened. The National Seed Corporation was established in 1963 to produce foundation and certified seeds and took seed production of temperate vegetables in Kashmir and Kullu valleys. The organizations like National Horticultural Research and Development Foundation (NHRDF) founded in 1977 by NAFED has been doing seed Production in Kullu valley. Under ICAR, All India Coordinated Vegetable Improvement Project came in to being in 1970-71 and gave further fillip to temperate vegetable research having main centres at Katrain, Srinagar and Solan and voluntary centres at Vivekanand Parvatiya Krishi Anusandhan Research Sansthan (VPKAS), Almora; Defence Agricultural Research Laboratory (DARL), Pithoragarh; and Govind Ballabh Pant University of Agriculture & Technology (GBPUA&T), Ranichauri. The VPKAS, Almora (after transfer to ICAR in 1974); ICAR Complex for NEH region, Shillong; National Bureau of Plant Genetic Resources, Regional Station, Shimla were established in 1976; Central Institute of Temperate Horticulture, Srinagar created in 1996 have been doing research on temperate vegetables. Food and Agricultural Sciences Defence Research and Development organisation (DRDO- Ministry of Defence) also established its Research and Production Centres at many places like Pithoragarh, Auli, Leh, Tejpur etc. The main centres involved in research are G.B. Pant University of Agriculture and Technology, Pantnagar (1960); Mahatama Phule Krishi Vidyapeeth, Pune (in 1969); Tamil Nadu Agricultural University, Coimbatore (in 1971); Bidhan Chandra Krishi Vishwa Vidyala, Heringhastta (in 1974); Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishwa-vidyalaya, Palampur (in 1978); Sher-e- Kashmir University of Agricultural Sciences and Technology, Srinagar (in 1982) and Dr. Y.S. Parmar University of Horticulture and Forestry, Solan (in 1985).

The private seed companies have been developing their own Research & Development (R&D) programmes.

Many of them are getting temperate vegetable seeds in Open General Licence (OGL) from abroad and are distributing among users. Similarly Non-governmental Organizations (NGOs) have their involvement. National Horticulture Board, Gurgaon has been financing to the different government organizations and NGOs to create facilities for R&D. The visionary National Agricultural Technology Project (NATP), the largest project ever funded by the World Bank also included programmes on temperate vegetable research.

India has collaborative programmes with Asian Vegetable Research and Developmental Corporation (AVRDC), China and USSR. There is a South Asian Vegetable Research Network (SAVERNET) of the countries like India, Pakistan, Bangladesh, Sri Lanka, Nepal and Bhutan, which deals with the testing of elite vegetable entries. Testing of varieties as per the criteria of distinctness, uniformity and stability (DUS) under Union for Protection of Plant Varieties (UPOV) guidelines has also been undertaken in some of the temperate vegetable crops.

Utilization and Impact

Improvement in Varieties

A lot of improvement work has been done, though all of these crops are introduced ones:

Cauliflower: Earlier cauliflower was considered as a purely temperate crop but in recent years due to the development of early types (Group I, II, and III), it is possible to produce seeds of these Indian cauliflowers in northern plains. Among cauliflowers, the late cauliflower (Group IV), which is commonly known as summer cauliflower in Europe is not a strictly temperate type but requires mild temperature at the time of its seed settings has been dealt with.

The farmers continued to grow EC12013 (Snowball-16 from Holland) for many years. This was replaced by Pusa Snowball-1 (EC12013 x EC12012), Pusa Snowball K-1 (selection from exotic material). Another variety Pusa Snowball-2 (EC12012) could not become popular because of shy seed bearing. A few others like Indian Snowball, Dania, and Dania Kalimpong need a mention as late cauliflower. Kala Patta is being grown near Chandigarh. Of Kt 9 (Sel 12 x PSBK-1) and Kt 25 (EC103576 x PSBK-1) tested under All India Coordinated trials, Kt 25 was identified for release in the AICRP workshop 2002. The other varieties identified by AICVIP are given in Table 1.

Though number of hybrids are marketed by Private seed companies, it is heartening to note that no hybrid has been released by the public sector in the snowball group but efforts are being made at Katrain centre to develop S.I and CMS lines. Some of the hybrids like Himani, Guardian (Indo-American), Candid Charm, White Flesh, Cashmere (Sakata), Serrano (Sandoz), Early Himlata, Early Himanagiri (Century), Nath Ujwala, Nath Shweta (Nath), Namdhari 84 (Namdhari), Pusa Hybrid-2, Pusa Kartik Sankar (IARI) of course belong to variable groups.

Cabbage: Many varieties like Golden Acre, Pride of India, Copenhagen Market, September, Pusa Drum Head, Late Large Drum Head etc. are either introductions or

Table 1. Cauliflower Varieties identified for release by All India Coordinated Vegetable Improvement Programme (AICVIP)

Variety	Maturity group	Developing centre	Year of identification
Early Kunwari	Early group	PAU, Ludhiana	1975
327-14-8-3	September	IARI, New Delhi	1975
Pusa Deepti (351-4-1	October	IARI	1975
Improved Japanese	November	IARI	1975
Pusa Synthetic (Synthetic-1)	December	IARI	1975
Pusa Snowball-2 (EC 12012	January	IARI, Katrain	1975
Pusa Snowball-1	January	IARI, Katrain	1975
Pusa Snowball K-1	January	IARI, Katrain	1979
Pant Gobhi (114-5-1)	October	GBPUA &T	1981
Pusa Subhra (Line 6-1-2-1)	December	IARI	1985
Pusa Early Synthetic	Early group	IARI	1990
Pant subbra (235-S)	November	GBPUA & T	1990
Pusa Hybrids-2	November	IARI	1992
Pusa Snowball K-25	January	IARI, Katrain	2002
Pusa Kartik Sankar (DCH-541)	October	IARI, New Delhi	2003

Source: Kalloo, 2000

PAU – Punjab Agricultural University, IARI – Indian Agricultural Research Institute,
GBPUA&T – Govind Ballabh Pant University of Agriculture & Technology.

selections from IARI Katrain. Pusa Mukta (EC 24855 x EC 10109) has been developed by hybridization and released from IARI, Katrain. Among red cabbage, Kinner Red from exotic material has been recommended by University of Horticulture and Forestry (UHF), Solan.

Cabbage is the one among cole crops where F_1 hybrids have become very popular. Hybrid KGMR-1, the first from the public sector, has been indentified for release during 2005 under the AICVIP from the IARI, Regional Station, Katrain. Other hybrids like H 44 (F_1 hybrid by using S.I.), H 64 (F_1 hybrid by CMS system) and BRH-5 (Sel-8 x AC 204, hybrid with a marker) were found promising only for hills. The requirement of F_1 hybrid seed is very high (>150 q) and being taken care of through OGL by the private seed merchants, and National and State Seed Corporations. Some of hybrids/synthetics have been identified through AICVIP i.e. Pusa Synthetic (from IARI Katrain in 1992), Sri Ganesh Gol (from MAHYCO in 1992), Nath-401 (from Nath Seeds in 1993), BSS-32 in the name of Swarna (from Bejo Sheetal in 1995), Nath 501 (from Nath Seeds in 1997), and Quisto (from Novartis Seeds in 1998). The other hybrids (Bahar, Pragati and Unnati from Pro Agro; Kalyani, Kranti and Hari Rani Gol from Mahyco; Hero, Mitra and Aditya from Sungrow; Yamuma, Ganga and Kaveri from IAHS; Masrgan, Meenaxi and Kuwaxi from Century; Vishesh and Uttam from Hindustan Lever; H-30, H-50, H-10 and H-20 from National Seeds Corporation (NSC); Gloria, Runa and Ratan from Dechan-Feldt; Rare Ball from Kaneko; Green Challenger from Hungnong are brought under cultivation directly without testing under AICVIP.

Similarly, many tropical cabbage hybrids were introduced e.g. Golden Cross, KK Cross, OS Cross, Resistlaka, Green Cornet, Autumn Queen, Green Ball (Takii); Green Boy, Green Express, Herculis, Stone Head, Regalia (Sakata). Japanese seed companies have also undertaken seed multiplication of their S.I. lines in South Asian Countries. Another significant achievement in cabbage breeding is the development of tropical lines e.g. DTC-50-7-4, 513, 528 (released as Pusa Ageti) etc. at the IARI, New Delhi. Cytoplasmic male sterility system (CMS), has been transferred successfully from EC173419 to all the cole crops at IARI Katrain but this source was associated with some undesirable traits and now an improved source of CMS obtained from IARI, New Delhi is being transferred to promising varieties/lines of cabbage.

Knol-khol: White Vienna, Purple Vienna, Kyote No. 3 and King of North are the introduced promising varieties.

Brussels sprout: The recommended varieties are Hild's Ideal and Rubine. The imported hybrids are Jade Cross, Doreman, Alkazar, Meron, Poster, Fortress, Predora, Rovoka, Somora, Ladosa etc.

Broccoli: The recommended varieties are Pusa Broccoli KTS-1 (selection from EC005559) from IARI Katrain, Palam Samridhi from HPKV, Palampur, Italian Green and Green Head from UHF, Solan. All are green sprouting broccoli and have been developed from the introduced exotic material. A cauliflower x broccoli hybrid (EC 243384 from Taiwan) produced greenish cauliflower heads with taste and flavour of broccoli (Gautam *et al.*, 2000). Many hybrids like Southern Comet, Premium Crop, Clipper, Laser (early), Corsair, Excalibur Cruiser, Emerald Carona (mid season), Late Carona, Stiff, Kayak, Green Surf (late) are being imported for cultivation in India.

Kale and collard: Kale is under cultivation in J&K. The variety Westo has been recommended from IARI Katrain.

Chinese cabbage: The Chinese cabbage as such could not be popularized, however, heat tolerant and black rot resistant line (EC345978) introduced from Taiwan is promising. Three genotypes have been developed at IARI Katrain from the crosses Petsai x Sarson, Wong Bok (Sutton's) x Sarson and Wong Bok (Sutton's) x Turnip to replace local mustard being used as *saag*.

Radish: The improved cultivars in European types have been recommended after introduction and selection e.g. Japanese White, White Icicle, Rapid Red White Tipped (all from IARI, Katrain), Chinese Pink (from NSC), Scarlet Globe, Scarlet Long etc. and by hybridization e.g. Pusa Himani by crossing Black x Japanese White, Sel 9 by crossing White Icicle x EC9005 (both from IARI, Katrain). No hybrid has been evolved in radish in India.

Turnip: The improved cultivars by selection or introduction have been developed. These are Snow Ball, Golden Ball, Purple Top White Globe, L-1 (Purple Top White Globe x 4-White), Pusa Swarnima (Golden Ball x Japanese White) and Pusa Chandrima (Snow Ball x Japanese White) have been developed by hybridization.

There is no variety available in foliage type; however, one line (Pusa Saag) has been developed by crossing

Chinese cabbage cv. Wong Bok (Sutton's) x Turnip cv. Golden Ball. There is no hybrid developed yet in turnip.

Carrot: The temperate carrots are orange coloured with pleasant flavour and have good root quality specially texture and high carotene content. They are preferred over Asiatic for candying, canning and drying. Among frozen vegetables for export, the prospect of carrot is bright. Many exotic cultivars Chantenay, Denverse, Nantes, Eary Horn, Zeno and Early Gem Imperator are grown. Carotene 'A' rich collection obtained from USA (EC187207), early maturing hybrid (EC288579-82 from Denmark), male sterile and restorer lines (EC274883-86 from Netherlands) could not be utilized. Kuroda has been an imported variety to put under cultivation.

Efforts have been made to combine successfully the high yielding capacity of Asiatic types into temperate types having good qualities. Consequently, the improved cultivar, Pusa Yamdagini (EC9981 x Nantes) at IARI Katrain has been developed by hybridization. Carrot No.-1 a hybrid from Mahyco has been identified by AICVIP. To breed F_1 hybrids, the male sterile lines of Nantes (39 x N) and Pusa Yamdagini (28x PY) have been developed at Katrain.

Garden beet: All the cultivars belong to temperate type. Most of the cultivars in India are exotic. Two varieties, Crimson Globe and Detroit Dark Red have been recommended by IARI Katrain.

A variety of palak, Pusa Harit, has been evolved by crossing sugar beet (EC13001) and Local palak, yielding very high for green foliage.

Lettuce: Lettuce accessions (EC329320-22) could not be utilized. Among the different types, only crisp head (cv. Great Lakes), and Leaf Lettuce (cv. Chinese Yellow) are under cultivation in India.

Breeding for disease resistance

Black Rot: In cauliflower, Sn 445, MGS 2-3, Puakea, EC162587 and RBS-1 possess resistance to black rot. Sel-12 evolved through inter-varietal hybridization between Sn 445 and EC12012, has been identified as a source of resistance. Kt-9 (Sel-12 x PSB-1) is also showing field resistance.

In cabbages, Greenland Hammer, EC10109 and Spitzkool have been identified. Pusa Mukta (EC24855 x EC10109) has been identified by AICVIP as resistant cultivar. BRH-5 (Pusa Mukta x AC 204) is another combination showing resistance.

Sclerotinia rot: Heading broccoli EC103576, EC131592, Janavon, Early Winter Adam's White Head, EC177283 and Kn-81 possess resistance to sclerotinia rot. Kt-25 identified as Pusa Snowball K-25 cauliflower, which has been developed as resistant variety by crossing broccoli EC103576 and Pusa Snowball-1. In carrot, line NV-1 has shown resistance to sclerotinia rot.

Other diseases: MR-1, an introduction from USA, in cabbage carries multiple resistance to soft rot, wire stem, black rot and sclerotinia rot. AC 238, Spitzkool and EC93559 have been found resistant against cabbage yellows. BR-2, MGS 2-3, 3-5-1-1, CC-12, EWAWH in cauliflower and Spitzkool in cabbage possess resistance to downy mildew. MGS 2-3, Puakea, 1-6-1-4, 6-1-2-1 and Pusa Subhra in cauliflower have resistance against black spot disease. Selection-1301 has high degree of tolerance to diseases like sclerotinia rot, downy mildew and black rot coupled with desirable horticultural traits.

Breeding for pest resistance

In cabbage, cultivars Large Blood Red and Red Pickling (all red types) were identified to possess preferential resistance against caterpillars of cabbage butterfly (*Pieris brassicae*) and susceptible to aphid (*Brevicoryne brassicae*). The white cabbage varieties All Season and Round Sure Head showed resistance to these pests as *vice-versa*. Cabbage IRCH-4 to 6 and KK Cross have shown tolerance to aphids.

A good number of collections have been made on temperate vegetables at the IARI, Regional Station, Katrain since its inception till date. Some of the promising collections/introductions are given in Table 2.

The major countries from where the temperate vegetables have been introduced are Russia, Canada, USA, Australia, Brazil, France, U.K., Netherlands, Germany, Italy, Polland, Hungary, Denmark, Turkey, Yugoslavia, Egypt, Zambia, Israel, Korea, Japan, Taiwan etc. Table 3.

Immediate needs

- Import of parental lines of desirable F_1 hybrids: In cross-pollinated crops (cole and root crops), the parental lines of F_1 hybrids may be introduced. The seed production of F_1 hybrids and maintenance of those lines may be taken up to reduce or cease the import of commercial F_1 seeds under OGL.

Table 2. Promising collection / introductions in temperate vegetable crops

S. No.	Crop	Total no. of collections	Promising collections / introductions
1.	Cabbage	1050	Golden acre, Pride of India, Early Drum Head, Copenhagan Market, Late Drum Head, Spitzkool, MR 1, AC204, AC208, AC238, EC240613, EC173419 (CMS), EC490162, EC490165, EC490174, EC490176, EC490185, EC490191 and EC490200
2.	Cauliflower	724	Snowball No.16, Janavon, EC103576, EC162587, EC12012, Puakea
3.	Capsicum	660	Yolo Wonder, HC-201, Vindale, California Wonder
4.	Carrot	334	Nantes, Chantenay
5.	Brussels sprout	35	Hild's Ideal, Rubine
6.	Knol-khol	39	White Vienna, Purple Vienna
7.	Radish	308	White Icicle, Japanese White
8.	Turnip	114	Purple Top White Globe, Snow Ball, Golden Ball
9.	Spinach	90	Virginia Savoy
10.	Lettuce	217	Great Lakes, Chinese Yellow
11.	Broccoli	97	EC005559
12.	Beet	111	Detroit Dark Red, Crimson Globe

Table 3. Major Introductions in temperate vegetable crops

Crop species and accessions	Source	Desirable traits
Cole crops		
Cabbage		
EC187228-187230	Canada	Club root resistant
EC287707-287708	Japan	Resistant to yellows and tolerant to black rot
Cauliflower		
EC205372-205373	USA	Smooth, medium maturity in 60-70 days, disease tolerant.
EC175800-175806	USA	Multi-disease resistant
Root crops		
Carrot		
EC178385	Italy	High carotene content
EC187207 Beta III	USA	Good flavour and eating quality, high carotene content
EC277678	USA	Blunt and short root type, good flavour high carotene content and resistant to Alternaria blight.
Radish		
EC170668 Summer Top ACC No. 107	Taiwan	Attractive shape and colour

Source: Rana, 1993

- New temperate vegetables may be introduced e.g. asparagus, celery, parsley, leek, globe artichoke, swish chard etc.
- Seed production techniques may be refined to produce seed indigenously and efficiently.
- The lines with the minimum post harvest losses should be introduced. The quality aspect should be given preference.
- High yielding and wider adaptable lines need to be introduced.
- Monogerm varieties of garden beet need to be introduced. Likewise high temperature resistant lines in cabbage and cauliflower; white colour retentivity mainly due to curd coverage by newly borne leaves in cauliflower, bigger and non woody knobs in knol-khol; compact, medium sized sprouts with close internodes in Brussels sprout; more foliage in kale and Chinese cabbage; high carotene content, smooth, self core coloured roots in carrot; smooth and non pithy roots in radish; good taste and non puffy roots in turnip, good colour without distinct zones in beet; non bitter leaves in lettuce; the important characters with high yield and quality lines are to be introduced.
- For off-season supply from the hills to the plains, the introduction of temperate vegetables should be made for those accessions which may adapt for lower to higher temperature conditions adverse to the plains where their cultivation is done in winter months (higher to lower) for vegetables.
- Though not temperate, but the lines of long day onions and garlic with better quality may be imported and introduced for their multiplication under the so called natural glass house of Western Himalayas.

Important traits

- Marketable yield and its related components
- Growth characters including DUS traits
- Quality aspects including physical and chemical components
- Consumer's preferential characters (external and internal)
- Nutritional status and pesticidal residues including heavy metallic element status
- Resistance to biotic and abiotic stresses
- Maturity period, storability and staying period

- Seed production ability
- Transportability and exportability in relation to transport and supply system
- Varietal suitability for efficient cropping systems
- Characters suitable for adaptability in different regions or climates and for sustainable production
- Other specific characters of the vegetable concerned

Emerging scenario

- Rapidly shrinking genetic diversity must be stopped.
- Long term/medium term conservation and regeneration programmes should be initiated.
- Characterization, Evaluation and Documentation should be taken up.
- Zero or low energy storages should be constructed in the hills for germplasm/vegetables.

Future needs and scope

The next generation of research for vegetable crops may include:

- Genetic engineering- cellular and molecular biology-cell and tissue culture-genetic diversity.
- Greater resilience to environmental stresses-cold, droughts, heat problem soils, and air pollutants-to ensure dependability of production.
- Greater resistance to biological stresses including integrated pest management and disease resistant varieties.
- Biological transformations-nitrogen fixation, mycorrhizal root interactions, nitrification, denitrification, "bacterization", protein synthesis.
- Hormonal mechanisms-control of plant growth, flowering, fruiting, seed production, tuberization.
- Enhancement of photosynthesis, total metabolism and differentiation processes for improvement of yields and harvest index.
- Alternative integrated resource (land, water, energy, capital) sparing production systems.
- Quality of fresh and processed vegetables.

The need for genetic variability in all breeding programmes is evident. The germplasm on temperate vegetables may be procured from NBPGR, AVRDC, NVRS etc., however, all the introductions in India must be routed through NBPGR, New Delhi.

References

Anonymous (1987) Research Achievements – A Decade. National Bureau of Plant Genetic Resources, New Delhi. *Sci. Monogr.* **11:** 151.

Anonymous (1989) Directory of national active germplasm sites. *NBPGR Newslett.* **6(4):** 7.

Gautam PL, GD Sharma, V Srivastava, BM Singh, A Kumar, RK Saxena and K Srinivasan (2000) *Twenty Glorious Years of NBPGR.* NBPGR, Pusa campus, New Delhi-110012.

Kalloo G (2000) AICVIP Recommendations (1971-98). IIVR, Varanasi-221005 (U.P.).

Paroda RS, RK Arora and KPS Chandel (1988) Plant genetic resources – Indian perspective. *Proc. Natl. Symp.*, NBPGR, New Delhi. p. 545.

Rana RS (1990) Partnership in conservation and use of plant germplasm. Golden Jubillee Lecture, Indian Society of Genetics and Plant Breeding, New Delhi.

Rana RS (1993) Genetic resources in Vegetable Crops. In Chadha K.L. and G. Kalloo (eds): *Advances in Horticulture* **Vol. 5:** Malhotra Publishing House, New Delhi. pp. 27-43.

Seshadri VS and SS Chatterjee (1996) The history and adaptation of some introduced vegetable crops in India. *Veg. Sci.* **23(2):** 114-140.

Swaminathan MS (1983) Genetic Conservation: Microbes to Man in Genetics – New Frontiers (VL Chopra, BC Joshi, RP Sharma and HC Bansal (Eds)). *Proc. XV Int. Cong. of Genetics.* **Vol. 1.** Oxford & IBH, New Delhi.

Verma TS (1999) History and present scenario of improvement of temperate vegetables in India. Improvement and production of temperate vegetables. Dr. YS Parmar Univ. of Horticulture & Forestry, Nauni, Solan (H.P.). pp. 4-14.

Zeven AC and JMJ de Wet (1982) Dictionary of cultivated plants and their regions of diversity. Centre of Agricultutral Publishing and Documentation, Wageningen. p. 263.

Germplasm Introduction of Underutilized and New Crops

BS Phogat[1], RP Dua[1] and RK Arora[2]
[1] *National Bureau of Plant Genetic Resources, New Delhi-110012, India*
[2] *Bioversity International, Regional Office for South and South-East Asia, New Delhi-110012, India*

The region of South Asia is very diverse in its physiology, agro-ecology and climate, and possesses rich diversity in cultivated crops. Several under-exploited and underutilized species occur which include native diversity and also, well acclimatized species introduced particularly in the past few decades. In India, a total of 25,077 accessions of over 60 underutilized and new crops have been introduced since independence. Out of these, 3,361 accessions of 21 underutilized plants have been evaluated under the aegis of All India Coordinated Research Project on Underutilized Crops, which led to identification of 395 promising lines. Some of these materials, have been very useful as food and industrial crops and through germplasm evaluation several promising varieties have been released for cultivation at national level. To mention among them are Suvarna in amaranth, Himpriya in buckwheat, BRS 1 in rice bean, VH 82-1 in faba bean, Arizona-2 in guayule and EC 33198 in jojoba. These are now well adapted to diverse agro-ecosystems/ agricultural systems. Further, about 70 species of underutilized crops have been identified to have promise in Asia-Pacific region and can play a pivotal role in diversification of the agriculture, management of wastelands and meeting the nutritional requirements of the people.

Similar diversity of known potential has been documented for other centres of diversity of crop plants, so as to introduce germplasm from the respective mega diversity regions and evaluate these for their adaptation and usefulness in South Asia region. In this paper, which is based on work carried out by NBPGR and other centres in India, an attempt has been made to assess the impact of such diversity and the opportunities envisaged through further exotic introductions.

Key words: Germplasm introduction, Underutilized crops, New crops, Diversity

South Asia, comprising the countries Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka is situated between Equator and 40°N latitude. The region has altitudinal variations from sea level to more than 3500 masl and exhibits extreme diversity for edapho-climatic conditions, agro-climatic regions and ecosystems. The Hindustani Gene Centre, one of the twelve Vavilovian centres of biodiversity, is located in South Asia and possesses a rich diversity of over 17,000 species of higher plants occurring in 16 vegetation types (Ramachandran *et al.*, 1986). Apart from India, countries such as Nepal, Bhutan and Sri Lanka also have rich agro-biodiversity.

It is estimated that 82 per cent of total land area in South Asia suffers from one or the other kind of stress (drought – 43%, mineral stress – 5%, shallow soil depth 23% and excess water – 11%) and only 18 per cent area is free from any serious limitation (Dent, 1980). Decreasing availability of land for agriculture, due to diversion of land for industrial use, urbanization, etc. has led to more dependence on degraded lands to meet the increasing requirements of food, fodder, fibre, firewood and timber during the 21st century. The sustainability of intensive agriculture in such areas is circumspect. Therefore, underutilized crops, which are adapted to stressed environments and provide food and nutritional cover to about 10 per cent population inhabiting remote, tribal and backward areas, offer scope for diversification of agriculture. About 70 species of underutilized crops have been identified to have promise in the Asia pacific region (Eyzaguirre *et al.*, 1999; Arora, 2002).

Apart from the domestically available diversity of plants, there is a lot of scope of further enrichment of agro-biodiversity through introduction of suitable species from similar environments. In India, 25,077 accessions of over 60 underutilized/new crops have been introduced during the last fifty years (Table 1). Out of these, 3,361 germplasm lines of 21 crops were evaluated under the aegis of All India Coordinated Research Project (now Network) on Underutilized Crops, which led to identification of 395 promising lines and release of several varieties for cultivation. In this paper, an attempt has been made to review the performance of introductions of underutilized and new crops and to enlist the potential plant species suitable for introduction in South Asia.

Amaranth (*Amaranthus* spp.)

Amaranth is a crop with multiple uses and has a potential for usage as grain, vegetable and fodder. Its grains have high protein content with high lysine and balanced

Table 1. Germplasm introductions of underutilized and new crops

Genus	Common name	Total no. accs.	Sources	Species introduced
Acacia	Babool	636	Argentina(1), Australia(519), Belgium (1), Denmark (7), Egypt (1), Ethiopia (6), France (14), Indonesia (2), Japan (3), Pakistan (2), Philippines (2), Sabauerde Islands (1), Senegal (5), Syria (1), Thailand (1), UK (55), Uruguay (1), USA (9), Zambia (1), Unknown (4)	*A. acinacea, A. acradenia, A. acuminata, A. adsurgens, A. adunca, A. albida, A. alleniana, A. ammobia, A. ampliceps, A. ancistrocarpa, A. aneura, A. angutissima, A. aphanoclada, A. aphylla, A. araneosa, A. arepta, A. argyraea, A. argyrophylla, A. armata A. atkinsiana, A. aueura, A. aulacocarpa, A. auricoma, A. auriculiformis, A. baileyana, A. bancroftii, A. beauverdiana, A. bidwillii, A. binervata, A. bivenosa, A. blakei, A. blayana, A. brachystachya, A. brassii, A. brivenosa, A. brochystachya, A. brownii, A. burkittii, A. burrowii, A. buxifolia, A. calamifolia, A. calcicola, A. cambagei, A. cardiophylla, A. caven, A. cheelii, A. chinchillaensis, A. chisholmii, A. chrysotricha, A. cincinnata, A. citrinoviridis, A. clerosperma x ligulata, A. colei, A. colletioides, A. comnferta, A. complanata, A. concurrens, A. confusa, A. confusa merril, A. continua, A. coolgardiensis, A. coriacea, A. coriacea* var. *coriacea, A. cowleana, A. crassicarpa, A. cultriformis, A. cyanophylla, A. cyclops, A. dealbeta, A. deamii, A. dictyophleba, A. diffcilis, A. diffusa, A. elata, A. eptocarpa, A. estrophiolata, A. extensa, A. farneciana, A. fimbriata, A. flavescans, A. fleckeri, A. floribunda, A. frigescens, A. gennerae, A. gladiiformis, A. hateroclita, A. hemignosta, A. heterochita, A. holosericea, A. hylonoma, A. implexa, A. iteaphylla, A. ixiophylla, A. juncifolia, A. kempeana, A. laccata, A. latzii, A. leptocarpa, A. ligulata, A. longifolia, A. loptcarpa, A. lysiphloia, A. macronochieana, A. mangium, A. mearnsii, A. melanoxylon, A. moconochieana, A. mollissima, A. muelleriana, A. murrayana, A. myrtifolia, A. neriifolia, A. notabilis, A. oswaldii, A. pachycarpa, A. paradoxa, A. pennatula, A. penninerris, A. peregrina, A. podalryiaefolia, A. polystachya, A. pravissima, A. pulchella, A. pycnantha, A. pyonduthagit, A. quriculiformis, A. ramosissima, A. ratinodes, A. rhetinocarpa, A. rotundifolia, A. rupicola, A. saligna, A. satigna, A. savveolens, A. sclerosperma, A. sclerosperma x ligulata, A. semilunata, A. senegal, A. seyal, A. shirleyi, A. silvestris, A. simsii, A. spectabilis, A. steedmanii, A. stenophylla, A. stipuligera, A. stowardii, A. striatifolia, A. strieta, A. subporosa, A. tortlis* ssp. *spirocarpo, A. trinervis, A. trineura, A. tumida, A. urophylla, A. validinervia, A. victoriae, A. victorial, A. penninervis*
Actinidia	Kiwi fruit	34	Australia (5), Italy (1), Japan (2), New Zealand (10), USA (14), USSR (2)	*A. arguta, A. callosa, A. chinensis, A. delocosa, A. fairchild, A. kolomicta, A. olomitka, A. michurins, A. polygama, A. rufa plancli*
Amaranthus	Chaulai	889	Argentina (3), Australia (5), Bangladesh (14), Benin (1), Botswana (2), Cameroon (2), Canada (1), China (9), Costa Rica (1), Denmark (1), France (6), Germany (11), Guatemala (1), Hong Kong (6), Hungary (5), Italy (7), Japan (5), Kenya (35), Latvia (1), Nepal (8), Netherlands (20), Nigeria (48), Philippines (1), Poland (8), Russia (60), Syria (15), Taiwan (102), UK (3), USA (485), USSR (4), Yugoslavia (6), Unknown (13)	*A. acutilobus, A. adulis, A. albus, A. aurens, A. australis, A. blitoides, A. blitum, A. spinosus, A. tricolor, A. bouchoni, A. cannabinus, A. caudatus, A. celosia, A. chorostachys, A. crassipes, A. crispus, A. cruentus, A. dubius, A. spinosus, A. tricolor, A. deflexus, A. fimbriatus, A. flavus, A. floridanus, A. gangeticus, A. gangiticus* var. *re-del fuoco, A. graecizans, A. hypochondriacus, A. eucocarphus, A. mangostanum, A. mante gazziannus, A. melancolicus, A. palmeri, A. panicular, A. paniculatus, A. powellii, A. pumilus, A. quitensis, A. retroflexus, A. rudes, A. sanguinens, A. silvestris, A. spinosus, A. tataneum, A. tricolor, A. viridis*
Asimina	Paw-paw	6	USA (5), USSR (1)	*A. triloba*

(Contd.)

Genus	Common name	Total no. accs.	Sources	Species introduced
Atriplex	Salt bush	256	Australia (87), Chile (2), France (8), Germany (17), Hungary (7), Israel (6), Italy (3), Japan (1), Morocco (2), Poland (2), Spain (1), Sweden (3), Tunisia (3), USA (97), USSR (5), Yugoslavia (1), Unknown (17)	*A. angulatum, A. atacamensis, A. breweri, A. bunbunlana, A. calotheca, A. calothecus, A. canescens, A. halimus, A. hortensis, A. inflala, A. lentiformis, A. leptocarpa, A. leucoclada, A. muelleri, A. nitens, A. rosea, A. semibaccata, A. spongiosa, A. suberecta, A. amanicola, A. campanulatum, A. canescens, A. cherea, A. fissivalvis, A. glabriuscula edmondston, A. glauca* var. *rotundifolia, A. halimoides, A. halimus, A. hastata, A. holocarpa, A. hortensis, A. hortensis, A. hortensis l.v. atropuryurea hot., A. hortensis l.v.puryure a hort., A. hortensis linn, A. hortensis rcoberrina, A. hortensis* var. *lutea, A. hostansis* var. *rubes, A. inflata, A. isatidea, A. laciniatum, A. latifolia wg., A. lentiformis, A. leptocarpa, A. leptocarpum, A. leptoearpa, A. leucoclada, A. lindleyi, A. litrolis. A. maritima, A. nitens, A. nitens schkuhr, A. niteus, A. nummularia, A. oblongifolia, A. paludosa, A. patula, A. patulus, A. prostrata, A. pseudo campanulatum, A. raghodioides, A. semibaccata, A. spongiosum, A. undulata, A. vesicaria, A. leutiformis*
Atylosia		90	Australia (41), Hong Kong (1), Italy (3), Malawi (2), Mali (1), Nepal (1), Netherlands (1), Nigeria (1), Sri Lanka (17), Sweden (1), Thailand (12), UK (1), Unknown (8)	*A. acutifolia, A. grandifolia, A. marmorata, A. platysepala, A. pluriflora, A. scaraboides, A. serica, A. viscida*
Avena	Oats	2,362	Australia (112), Austria (3), Belgium (4), Brazil (100), Canada (231), Cyprus (2), Czekoslovakia (12), Denmark (8), Ecuador (1), Ethiopia (1), Finland (26), France (9), Germany (12), Greece (1), Holland (25), Hungary (156), Israel (4), Italy (22), Japan (9), Kenya (9), Mexico (15), Mongolia (6), Nepal (8), New Zealand (4), Norway (2), Portugal (13), Russia (6), South America (2), Sweden (50), Switzerland (1), Taiwan (3), Turkey (7), UK (92), USA (1252), USSR (135), Yugoslavia (13), Unknown(8)	*A. sativa*
Bambusa	Bamboo	1	Japan (1)	–
Brachychiton		1	Australia (1)	*B. populaneus*
Carya	Pecan nut	137	Argentina (1), Germany (12), USA (123), USSR (1)	*C. illinoensis*
Cassia		1	Australia (1)	*C. strutii*
Casuarina	Horse tail tree	25	Australia (62), Cuba (1), Cyprus (1), France (1), Philippines (2), Tanzania (2), UAR (1), UK (1), USA (11), Unknown (3)	*C. equisetifolia*
Chenopodium	Chenopods	285		*C. ambrosioides, C. berlandieri* subsp. *nuttalliae, C. capitatum, C. giganteum, C. pallidicaule, C. quinoa, C. album, C. amaranlicolor, C. amaranthicolor, C. amaranticular, C. ambrosides, C. anthelminticum, C. anthelmintica, C. aristatum, C. auricomum, C. berlandieri, C. bonus, C. bonus henricu, C. bonus henricus, C. bonus-henricus. C. canihua, C. capitatum, C. ficifolium, C. giganteum, C. glauam, C. guinoa, C. hybridium, C. murale, C. nutalliac, C. pallidicaule, C. pallidicaulle, C. pallidieaula, C. polyspermum, C. quinoa wild, C. quiroa, C. quoinoa, C. schraderanum, C. vulvaria, C. bonus-hernriens, C. capitatum, C. foliosum, C. giganteum, C. alba*
Coix	Job's tear	17	Brazil (2), Burma (1), Costa Rica (1), Germany (1), Japan (5), Nepal (1), Sri Lanka (1), Switzerland (1), UK (1), USA (3)	*Coix lachryma – jobi*

Genus	Common name	Total no. accs.	Sources	Species introduced
Citrullus	Bitter apple /Tinda	12	Australia (1), Canada (1), Switzerland (1), USA (9)	*C. colocynthis*
Citrullus	Water	524	Argentina (1), China (13), Denmark (3), Egypt (3), Germany (13), Holland (1), Iran (1), Russia (10), Taiwan (17), UAR (1), UK (1), USA (422), USSR (37), Uzbekistan (1)	*Citrullus lanatus* var. *caffer, Citrullus lanatus* var. *vulgaris, Citrullus lanatus* var. *citroides, Citrullus lanatus* var. *lanatus, Citrullus lanatus* ssp. *cordaphan*
Cucurbita	Buffalo/ Wild gourd	57	Lebanon (7), Mexico (1), USA (48), Unknown (1)	*C. foetidissima*
Cuphea spp.	Cuphea	267	USA (264), West Germany (3)	*C. aequipetala, C. carthagenensis, C. glutinosa, C. hookeriana, C. hybrid, C. laminulisers, C. lanceolata, C. lutea, C. painteri, C. procumbens, C. tolucana, C. viscosissima, C. wrightii*
Cyphomandra	Tree tomato	9.	Bulgaria (1), East Africa (1), France (1), Spain (2), UK (2), Venezuela (1), Unknown (1)	*C. betacea, C. crassifolia, C. letacea, C. naranjilla*
Diospyros	Persimmon	23	Australia (2), Romania (1), USA (12), USSR (4), Unknown (4)	*D. dignya, D. kaki, D. lotus, D. virginiana*
Durio	Durian	2	Malaysia (1), Srilanka (1)	*D. zibenthinus*
Elaeis	Oil palm	153	Belgium (25), Cameroon (18), Canada (2), Costa Rica (71), Malaysia (2), Nigeria (3), Philippines (1), Sierra Leone (1), Singapore (8), Tanzania (11), Zambia (9)	*E. guineensis*
Enterpe	Enterpe	1	UK (1)	*E. globosa*
Elymus	Russian wild rye grass	371	Australia (8), Canada (14), France (2), Germany (1), Japan (1), Sweden (5), USA (331),USSR (4), West Germany (3), Unknown (2)	*E. agropyroides, E. alatavicus, E. ametinii, E. angustus, E. antarcticus, E. antiquus,E. aolinii, E. arenarius, E. aristiglumis, E. atrtus, E. austromontanus, E. bakeri, E. barbicallus, E. batalinii, E. brachyaristatus, E. breviaristatus, E. breviaristatus subsp. Scabrifolius, E. canadensis,* var. *canadensis, E. caninus, E. caucasicus, E. ciliarisE. ciliaris* subsp. *amurensis, E. cinerens, E. confuses, E. curvatus, E. dahuricus, E. dahuricus* subsp. *excelsus, E. dentatus, E. drobovfi, E. elymoides, E. elymoides* subsp. *brevifolius, E. elymoides* subsp. *californicus, E. elymoides* subsp. *elymoides, E. europoens, E. fedtschenkoi, E. fibrosus, E. funceus, E. gigantens, E. glaucissimus, E. glaucus, E. gmelinii, E. grandighumis, E. haffmannii, E. hystrix, E. interruptus, E. junceus, E. kengii, E. kirkii, E. kokonoricus, E. lanceolatus, E. laxiflorus, E. longearistatus, E. macrourus, E. magellanicus, E. mallis, E. melantherus, E. millosus, E. mollis trin, E. multicaulis, E. multisetus, E. mutabilis, E. mutabilis oschensis, E. mutabilis* sub sp. *paecaespitosus, E. mutabilis* var. *oschensis, E. nevskii, E. nipponicus, E. nutans, E. panormitanus, E. parishfi-laeve, E. parishii, E. patagonicus, E. pendulinus, E. praeruptus, E. pseudonutans, E. purpuraristus, E. rectisetus, E. retusus, E. rigidulus, E. scaber, E. scaber* var. *parviflorus, E. scaber* var. *scaber, E. scabrifolius, E. scabriglumis, E. scabrous, E. scabrus* var. *scabrous, E. scribneri, E. semicostarus, E. semicostatus, E. sibiricus, E. nevski, E. sinicus, E. stenachyrus, E. stenostachyus, E. strictus, E. submuticus, E. subsecundus, E. tenuis, E. tilcarensis, E. trachycaulus, E. trachycaulus* subsp. *subsecundus, E. transhyrcanus, E. triticoides, E. tschimganicus, E. tsukushiensis, E. uganicus, E. uralensis, E. uralensis* subsp. *komarovii, E. vaillantianus, E. villosus, E. virginicus, E. virginicus submuticus, E. wawawaiensis, E. weigandii, E. yezoensfs, E. yezoensisus*

Genus	Common name	Total no. accs.	Sources	Species introduced
Elaeagnus	Rusian olive	9	Hungary (1), Philippines (1), Spain (2), Switzerland (1), USSR (4)	*E. angustifolia, E. multiflora, E. philippinensis E. pungens reflexa*
Eucalyptus	Eucalyptus	742	Australia (657), Brazil (60), Costa Rica (1), Cuba (1), Indonesia (2), Morocco (1), Papua New Guinea (1), UK (2), USSR (1), Zimbabwe (11), Unknown (5)	*E. albens, E. brockwayi, E. caleyi, E. camaldulensis, E. cambageana, E. conica, E. elata, E. erythrocorys, E. gracilaia, E. gracilis, E. grandis, E. intertexta, E. jacobsiana, E. microtheca, E. oblique, E. ochrophloia, E. orgadophila, E. pellita, E. populnea, E. regnans, E. salubris, E. sargentii, E. spathulata, E. tereticornis, E. terminalis, E. accidentalis, E. acmenioides, E. alba, E. annulata, E. argillacea; E. argophloia, E. baxteri, E. kondininensis, E. lesouefii, E. loxophleba* sub sp. *loxophl, E. mcintyrensis-bencoxylox, E. bigalerita, E. blakelyi, E. brassiana, E. brockwaiji, E. brockwayi E. buprestium, E. Caesia, E. calophylla, E. camabulensis, E. camadulensis, E. camaldulensei, E. camaldulensis, E. camaldulensis* sssp. *simulata, E. camaldulensis* v. *camaldulensis, E. camaldulensis* var. *obtusa, E. camaldulensis,* var. *obtuse, E. camaldulensis* var. *tereticornis, E. camaldulensisn, E. camaldutensis, E. cambageana, E. camldulensis* var. *obtus, E. campaspe, E. chamaldulensis, E. citndora, E. citriodora, E. cloeziana, E. cneorifolia, E. cneoriolia, E. conglobata, E. cooperana, E. cornuta, E. corrugata, E. cosmophylla, E. crepanophylla, E. deglupta, E. delegatensis, E. desmondensis, E. dichromophloia, E. diversicolor, E. diversifolia, E. doglupta,E. dumosa, E. dundasii, E. dunnii, E. exserta, E. ficifolia, E. foecunda, E. forrestiana, E. gardneri, E. globoidea, E. globulus,E. globulus* sub sp. *bicostata, E. globulus* sub sp. *globules, E. globulus* sup sp. *globulus, E. gomphocephala, E. gomphocephalor, E. gongylocarpos, E. goniantha, E. gracilis, E. grandis, E. gummifera, E. incrassata, E. intertexta, E. jacksonii, E. kondininesis, E. laesia, E. lansdowneana, E. laucoxylon, E. lehmannii, E. leucoxylon, E. longicornis, E. longifolia, E. macarthuri, E. macarthurii, E. macro rhyncha, E. macrocarpa, E. macrorhyncha, E. macrorhyncha* sub. sp. *macroply E. macrorphyncha, E. macrorrhyncha, E. maculata, E. marginata, E. megacarnuta, E. melanophlia, E. melliodora, E. microcorys, E. microtheca, E. miniata, E. moluccana, E. nintens, E. nitens, E. nutans, E. oaesia, E. oblique, E. obliqua. E. obtusiflora, E. occidentalia, E. occidentalis, E. oleosa, E. ovata, E. papuana, E. pargiflorens, E. parvifolia, E. pauciflora, E. pauciflora* ssp. *debeuzevillei, E. peeneri, E. pellita, E. phoenicea, E. pileata, E. platypus, E. platypus* var. *heterophylla, E. polybracta, E. polybractea, E. populnea, E. porosa, E. preissiana, E. propinqua, E. pruinosa, E. ptychocarpa, E. pyriformis, E. pyriformis* var. *youngiana, E. radiata, E. radiata* sub sp. *rad, E. radiata* var. *australiana, E. redunca, E. remote, E. robertsonii, E. robusta, E. rugosa, E. saligna, E. salmonophloia, E. salmonophora, E. sargentic, E. sessilis, E. seyphocalyx, E. sideroxylon, E. sieberi, E. socialis, E. spanthulute, E. spathulata, E. stoateri, E. striaticalyx, E. strichlandii, E. tenuipes, E. tereticormis, E. tereticormis* ssp. *tereticornis, E. tessellaris, E. tetragona, E. tetraptera, E. torelliana, E. torquata, E. transcontinentalis, E. umbrawarrensis, E. urophylla, E. uropylla x e. grandis, E. vesinfera, E. viminalis, E. viridis, E. wando, E. wandoo, E. woodwardii, E. yalatensis, E. youmanii, E. grandis, E. punctata.*
Eugenia	Jamun	10	Australia (2), Brazil (3), Philippines (1), Singapore (2), Spain (1), USA (1)	*E. cuminii, E. dysenterica, E. grandis, E. megacarpa, E. myrtifolia, E. stipitata, E. unifolora, E. uvalha, E. wilsonii*
Euphorbia	Petroleum plant	33	Cali Colombia (1), Germany (1), Mexico (3), Philippines (2), Spain (4), USA (16), USSR (2), Unknown (4)	*E. antisy philitica, E. canariensis, E. lashyrus, E. lathirus, E. marginata, E. prunifolia, E. pubescens, E. pulcherrima, E. regis jubae, E.* spp. *asclepias subulata dcne* (identified by Kew), *E. terracina, E. tirucalli*

Genus	Common name	Total no. accs.	Sources	Species introduced
Fagopyrum	Buckwheat	258	Canada (5), China (2), East Germany (14), France (4), Germany (4), Hungary (27), Italy (1), Japan (30), Nepal(42), Poland (8), Switzerland (1), Syria (1), UK (6), USSR (73), Unknown (2)	*F. cymosum, F. emarginartum, F. esculentum, F. macrocarpum F. safittatum, F. sagitatum, F. tataricum, F. vulgara, F. latancum*
Feijoa	Feijoa/ Pine apple guava	4	Australia (1), New Zealand (1), Spain (1), USSR (1)	*F. sellowiana*
Fortunella	Kumquat	9	Australia (2), France (4), UAR (1), USA (2)	*F. hirdsii, F. japonica, F. margarita*
Fragaria	Strawberry	185	Australia (3), Canada (13), Czekoslovakia (8), France (1), Holland (5), Italy (23), Nepal (2), Norway (1), South Africa (1), UK (10) Unknown (12), USA (96), USSR (8), Unknown (2)	*F. ananassa, F. chiloensis, F. vesca, F. virginiana*
Garcinia	Mangosteen	9	Indonesia (2), Nepal (1), Singapore (1), Sri Lanka (3), USA (2)	*G. dulicis, G. magostana, G. morella, G. venulosa, G. xanthochymus*
Haloxylon		10	Egypt (1), USSR (8), Unknown (1)	*H. aphyllum, H. persicum, H. salicornicum*
Humulus	Hops	149	Australia (36), Bulgaria (1), Czekoslovakia (10), Denmark (1), East Germany (3), France (1), Germany (3), Hungary (3), Italy (1), Japan (1), South Africa (9), Sweden (10), UK (6), USA (54), West Germany (9), Unknown (1)	*H. japonicus, H. lupulus, H. scandens*
Jatropha	Jatropha	9	Australia (2), Brazil (1), Ghana (4), Nepal (1), Nigeria (1)	*J.curcas, J.gossypiifolia, J. multifida, J. podarica*
Lesquerella	Lesquerella	32	USA (32)	*L. angustifolia, L. auriculata, L. densipila, L. engelmanii, L. fendleri, L. gordonii, L. lasiocarpa, L. lyrata, L. palmeri, L. perforata, L. stonensis*
Leucaena	Su-babool	864	Argentina (3), Australia (205), Cali Colombia (3), France (3), Malawi (5), Mexico (10), Nigeria (2), Philippines (20), South Africa (1), Sweden (2), UK (159), USA (449), Unknown (2)	*L. leucocephala, L. collinsii, L. collinsii zacapana, L. cuspidate, L. diversifolia, L. diversifolia* var. *diversi, L. diversifolia stenocarpa, L. esculenta, L. paniculata, L. glauca, L. greggii, L. insularum, L. lanceolata, L. leucocephala* cv. *cunningham, L. leucocephala* cv. *peru, L. leucocephala glabrata, L. macrophylla, L. macrophylla nelsoni, L. multicapitulata, L. nevoluta, L. pulueralenta, L. retusa, L. salvadorensis, L. shannoni, L. trichodes*
Macadamia	Queensland nut/macadamia nut	7	Australia (1), Spain (5), USA (1)	*M. integrifolia, M. ternifolia*
Momordica	Bittergourd	13	Bangladesh (1), China (6), Nigeria (5), USA(1)	*M. cochinchinensis, M. dioica*
Myrciaria	Myrciaria	8	Brazil(6), USA(2)	*M. cauliflora, M. cauliflora* cv *sabora, M. vexora, M. jaboticaba*
Nephelium	Rambutan	5	Indonesia (1), Sri Lanka (1), USA (3)	*N. lappaceum*
Parthenium	Guayule	33	Cali Colombia (1), Germany (1), Mexico (3), Philippines (2), Spain (4), USA (16), USSR (2), Unknown (4)	*P. argentatum*
Perilla	Perilla	138	Canada (2), France (3), Hungary (19), Italy (1), Japan (29), Nepal (22), Poland (3), Syria (1), UK (4), USA (34), USSR (18), Unknown (2)	*P. fruitescence*
Persea	Avocado	4	Australia (1), New Zealand (1), Spain (1), USSR (1)	*P. americana*

Genus	Common name	Total no. accs.	Sources	Species introduced
Phaseolus	Scarlet runner bean	19	Canada(1), France(1), USA(1), Unknown(16)	*P. multiflorus*
Psophocarpus	Winged bean	300	Australia (38), Costa Rica (1), Ghana (7), Indonesia (30), Nigeria (31), Papua New Guinea (35), Philippines (22), Puerto Rico (18), Sri Lanka (17), Thailand (80), USA (20), Unknown (1)	*P. tetragonolobus*
Pyrus	Pear	168	Australia (17), Bulgaria (5), Canada (3), Iran (3), Israel (4), Italy (3), Kenya (2), Korea (1), New Zealand (9), Philippines (1), Romania (3), Switzerland (4), USA (81), USSR (16), Unknown (16)	*P. communis*
Prunus	Peach	396	Argentina (1), Australia (39), Belgium (1), Brazil (7), Bulgaria (15), Canada (20), Chile (8), Czekoslovakia (4), France (24), Iran (2), Israel (5), Italy (36), Japan (3), Korea (6), Mauritius (2), Philippines (1), Romania (1), Sinkiang (1), South Africa (8), Taiwan (5), Turkey (1), USA (168), USSR (25), Unknown (11),	*P. persica*
Salsola spp.	Salsola	12	Canada (1), France (3), Germany (1), Italy (1), USSR (6)	*S. kali, S. orientalis, S. palezkiana, S. pestifer, S. richoteri, S. richteri, S. rigida, S. soda*
Simarouba	Paradise tree	5	El Salvador (2), Italy (1), UK (1), USA(1)	*S. glauca*
Simmondsia	Jojoba	183	Australia (1), Israel (2), Mexico (2), UK (1), USA (176), Unknown (1)	*S. chinensis*
Symphytum	Russian comfrey	1	USSR (1)	*S. peregrinum*
Triticale		820	Australia (17), Brazil (10), Bulgaria (1), Canada (3), Denmark (1), Germany (23), Greece (1), Hungary (9), Japan (4), Mexico (542), Norway (1), Poland (29), USA (149), USSR (29), Unknown (1)	*Triticale* sp.
Vaccinium	Black berry	90	Holland (1), Sweden (5), USA (84)	*V. acrobracteatum, V. amoenum, V. atrococcum, V. bracteatum, V. corymbosum, V. crenatum, V. erythrocarpum, V. uscatum, V. hirtum, V. macrocarpon, V. membranaceum, V. myrtillis* f. *epruinosum, V. myrtillus, V. myrtillus, V. neilgherrense, V. ovalifolium, V. ovatum, V. oxycoccus, V. padifolium, V. pallidum, V. parvifolium, V. stamineum, V. uliginosum, V. vitis idaea*
Vicia	Broad bean	1309	Afghanistan (1), Australia (2), Bulgaria (153), Canada (1), China (6), Cyprus (1), Czekoslovakia (6), Egypt (3), Eritrea (2), France (1), Germany (133), Holland (8), Hungary (14), Israel (48), Italy (120), Japan (1), Nepal (1), Netherlands (1), New Zealand (2), Poland (1), Portugal (1), Spain (6), Sweden (6), Syira (191), Syria (440), UAR (2), UK (11), USA (100), USSR (29), West Germany (1), Yugoslavia (1), Unknown (16)	*V. faba*

Genus	Common name	Total no. accs.	Sources	Species introduced
Vigna	Adzuki bean	160	Belgium (11), Cali Colombia (5), Germany (1), Japan (10), Thailand (2), USA (131)	*V. angularis*
Vigna	Rice bean	148	Belgium (39), Brazil (5), Cali Colombia (5), Costa Rica (1), Germany (2), Indonesia (8), Taiwan (4), UK (1), USA (82), Zaire (1)	*V. umbellata*

composition of other amino acids. Three domesticated species, namely, *A. hypochondriacus, A. caudatus* and *A. cruentus* are important for cultivation as grain crop in India, while *A. edulis* is mainly cultivated in Argentina. A total of 889 accessions of amaranth have been introduced from different countries including USA, Nigeria, Kenya, Germany, Taiwan, Netherlands, Poland, USSR/Russia, Chile, Hungary and Thailand. These have been evaluated alongwith about 2,000 indigenous germplasm accessions (Joshi and Rana, 1991), of which 72 promising accessions have been identified (Rathi *et al.*, 2005). Some of the promising amaranth introductions identified for different traits are given in Table 2. Variety Suvarna was selected from an American introduction (Rhodale Plus) released for cultivation in peninsular India. Presently, over 3,000 collections of amaranth are being maintained as active collections, representing 13 species, namely, *A. hypochondriacus, A. caudatus, A. cruentus, A. hybridus, A. retroflexus, A. lividus, A. viridis, A. graevizans, A. dubious, A. spinosus, A. tricolor, A. blitum* and *A. cannabinus* at NBPGR Regional Stations, Thrishur, Akola and Shimla. Some accessions are also being maintained as active collections at various Agricultural Universities and ICAR Institutes. The important gene AMA 1 isolated from amaranth for quality protein is being transferred in crops like potato and rice.

2. Buckwheat (*Fagopyrum* spp.)

Buckwheat is a crop with varied uses primarily as food grain with higher protein and balanced amino acid composition, also used as leafy vegetable, medicinal

Table 2. Promising introductions of amaranth

S. No.	Trait	Promising accession
1.	High grain yield	EC133859, EC13594, EC3828, EC10238, EC6646, EC 1493, EC289378, EC322033, EC328875, EC328889, EC322996, EC321557, EC321561, EC386315, EC386974, EC157415, EC269381
2.	Stem borer resistance	EC13594, EC133839
3.	Highly cross incompatible	EC13594
4.	Early maturing	EC13594, EC10238, EC198119, EC322043, EC333744, EC341799, EC321553, EC321556, EC328895, EC328884, EC387820, EC359459, EC359409, EC322882, EC328889, EC15441
5.	Vegetable type	EC147927, EC147969, EC149890, EC16512, EC328892, EC328882, EC386966, EC387821
6.	Dwarf type	EC322882, EC322032, EC32156, EC322994, EC322997
7.	Early flowering	EC322882, EC328889, EC321553, EC239336
8.	Leaves per plant	EC328889, EC223671, EC386987
9.	High protein	EC322032, EC170317, EC289386, EC289412
10.	Seed weight	EC322211, EC321557, EC387824, EC386988, EC386992, EC386984
11.	Number of spikelets	EC338958, EC222746, EC387025
12.	Long inflorescence	EC35563, EC35677, EC35727, EC321563, EC386970, EC354979, EC289386, EC170314, EC289408, EC359408, EC157415
13.	Biological yield	EC321553
14.	Harvest index	EC321553, EC321557
15.	Number of leaves	EC321556, EC321561, EC277972
16.	Plant height	EC321558, EC328887, EC386959, EC170314, EC38695, EC386987
17.	Field resistant (Pests)	EC321557, EC321561
18.	Stem thickness	EC354979, EC359437
19.	Leaf length	EC386959
20.	Tall type	EC35601
21.	Leaf width	EC3511567, EC359342
22.	High oil content	EC321558, EC328889, EC359442

plant (source of glucoside 'rutin') and a support crop for apiary. A total of 258 germplasm lines of buckwheat have been introduced from different countries, namely, USA, USSR, Sweden, Germany, Hungary, Poland, Nepal and Japan and evaluated along with over 400 indigenous accessions (Joshi and Paroda, 1991) and 30 promising lines were identified from the exotic introductions (Rathi *et al.*, 2005). Some of the promising buckwheat introductions identified for different traits are presented in Table 3. Presently, 568 accessions of buckwheat belonging to six species, viz. *F. tataricum, F. esculentum, F. emerginatum, F. gigantium, F. cymosum* and *F. himalayanum* are being maintained as active collections at NBPGR Regional Station, Shimla and three varieties have been identified and released for cultivation under AICRP on Underutilized Crops.

Table 3. Promising introductions of buckwheat

Trait	Promising accession
Early flowering	EC38954, EC218740, EC323724, EC323731, EC323729
High grain yield	EC161416, EC218737, EC216622, EC216628, EC218742, EC218753, EC218772, EC218738, EC323724, EC323731, EC323729, EC321798, EC386669, EC216634, EC286376, EC323723, EC131622, EC386671, EC218740
Number of internodes	EC218740, EC321798, EC216635, EC272738, EC131622
Seed weight	EC218740, EC321798, EC386667, EC386669, EC272734, EC18049, EC386671, EC218738, EC131620, EC97262, EC272734
Plant height	EC218738, EC386669
Early maturing	EC218738, EC321798, EC386667, EC386669, EC286396, EC386671, EC218784, EC323729, EC323731
Number of branches	EC321798, EC216634, EC272734
Field resistance (Pest)	EC386667
Leaf length	EC272734
Leaf width	EC321800

3. Chenopods (*Chenopodium* spp.)

Five species of *Chenopodium*, namely, *C. album, C. nuttaliae, C. pallidicaule C. publense* and *C. quinoa* are known to be cultivated but the former two are more popular. *C. album* is most widely distributed and is grown in Himalayas, generally consumed mixed with cereals and as leafy vegetable. 285 accessions of *Chenopodium*, mainly of *C. quinoa* have been introduced and tested for adaptability, of which 17 were observed to be promising for various traits. Some of the promising introductions identified for different traits are EC201678, EC359445, EC201618 for high grain yield; EC351912 for dwarf plant type; EC359447, EC359445, EC359449, EC338953, EC319184, EC329521 for tall plant type; EC359447 for number of branches; EC201678 for early flowering; EC180010 for early maturity; EC351912, EC201678, EC359447 for bold seed; EC338952, EC359451, EC359417 for inflorescence length; EC359448, EC359449 for leaves per plant; EC359445, EC359449, EC338953, EC359451 for leaf length and EC359447, EC359451 for leaf width. *C. quinoa* was adapted to Indo-gangetic plains and some CH/LKW lines have been developed. At present, 76 accessions of chenopodium, belonging to six species, namely, *C. album, C. amaranticolor, C. ambrisoides, C. botryas, C. murale* and *C. quinoa* are being maintained at NBPGR Regional Station, Shimla.

4. Adzuki bean (*Vigna angularis*)

Adzuki bean has varied uses as food, forage, medicine and cosmetics. One hundred and sixty accessions of adzuki bean have been introduced from USA, Nigeria, Belgium, Colombia and Japan, and characterized for agro-morphological traits, of which 92 have been found promising for different traits. Some of the promising introductions identified for different traits are given in Table 4. Two varieties of adzuki bean have been identified, one each by CSK HPKV, Palampur and VPKAS, Almora for cultivation in Himachal Pradesh and Uttaranchal, respectively. Presently, 142 accessions of adzuki bean are being maintained at NBPGR Regional Station, Shimla as active collections.

5. Rice bean (*Vigna umbellata*)

Rice bean is a promising multipurpose crop with good potential for use as food, fodder, green manure and a cover crop. In India, it is distributed in tribal regions of the north-east and the northern hills. Considerable variation is reported to exist between collections from different geographical areas. Seed size resembles cowpea to mung/urd bean and colour varies from dark brown to red, light brown, yellow, pale and light green.

Evaluation of 148 introduced accessions along with over 800 indigenous collections of rice bean at Shillong showed a wide range of variation for days to flowering (62-112), plant height (94-334 cm), branches per plant (3-12), pod length (7.3-14.0 cm), seeds per pod (5-10), pods per peduncle (2-11), 100 seed weight (4-25 g) and grain yield per plant (4.4-133.0 g).

Analysis of biochemical constituents of rice bean seeds showed considerable variation for crude protein

(17.8-25.2%), ash (3.8-4.1%), calcium (315-450 mg/ 100 g), phosphorus (197-393 mg/100 g) and iron (1-5 mg/100 g). A significant evaluation and selection work has been done under the AICRP and has resulted in the identification of 53 useful lines and development of 5 varieties. Some of the promising rice bean introductions identified for different traits are given in Table 5.

6. Faba bean (*Vicia faba*)

Faba bean is used as food and feed crop. It is cultivated as a vegetable and is used green or dried, fresh or canned. It has high protein content and is used as a substitute for meat or skimmed milk. It is grown in warm temperate and sub-tropical areas, in rich loamy soils and is more tolerant to acidic conditions, particularly sulphate ion, as compared to most of the legumes. In

Table 4. Promising introductions of adzuki bean

Trait	Promising accession
High seed yield	EC108080, EC108079, EC87897, EC87896, EC87899-1, EC108080, EC15257, EC120460, EC241041, EC120960, EC15057, EC240460, EC340245, EC340248, EC340275, EC340276, EC 81957, EC340280, EC15256, EC340246, EC340270, EC340273, EC340279, EC340258, EC340282, EC340283, EC340263, EC18151, EC290251, EC34625, EC340281, EC340255, EC387896, EC115820, EC144038, EC144039, EC28540
Early maturing	EC87896, EC87899, EC108080, EC87895, EC15257, EC120460, EC15256, EC340265, EC281186, EC390260, EC340272, EC8789, EC30256, EC18959, EC241187, E 340251, EC276
Number of primary branches	E 87896, E 108080, EC120460, EC340252, EC340252, EC340263, EC340285, EC8789, EC30256
Pods per plant	EC87896, EC108080, EC120460, EC340280, EC340277, EC181168, EC340285, EC290251, EC34625, EC5949, EC340260, EC187896, EC340255, EC36070
Seed weight	EC87896, EC108080, EC340280, EC390285, EC340283, EC340263, EC340277, EC346258, EC18151, EC34625, EC8707, EC12045, EC348258, EC340264, EC263, EC24523, EC34027, EC390296, EC57169, EC87898, EC108070, EC120460
Pod length	EC87899-1, EC120460, EC241041, EC340280, EC340285, EC8789
Number of clusters	EC87899, EC108080
Plant height	EC108080, EC15257, EC340258, EC340263, EC340227, EC340256, EC340285, EC34625, EC30250, EC30256, EC340255, EC387896, EC30270, EC34025, EC340261
Early flowering	EC108080, EC108070, EC87895, EC120460, EC241041, EC340280, EC340263, EC34258, EC12045, EC340255, EC387896, EC18959, EC346263, EC340278
Dwarf type	EC108074, EC100877, EC15257, EC89957
Large pod size	EC101080, EC15257
Petiole length	EC 15257, EC 120460, EC 340280, EC 340258, EC 340265, EC 87071, EC 340264
Leaf width	EC15257, EC120460, EC340280, EC340265, EC340263, EC281186, EC340256, EC340281, EC5949, EC30256
Seeds per pod	EC15257, EC120460, EC340265, EC340263, EC293, EC30256, EC264, EC340260, EC252, EC340251, EC340269, EC370269, EC24523, EC120480
Pods per cluster	EC120460, EC340285, EC30256, EC348258, EC720460
Leaf length	EC120460, EC340280, EC281186, EC340227, EC290251, EC34625, EC8789, EC340260, EC340251, EC340278
Tolerant to *Cercospora* and *Uromyces* disease	EC108080

Table 5. Promising introductions of rice bean

Trait	Promising accession
High seed yield	EC18113, EC18181, EC18171, EC16167, EC12136, EC12416, EC18114, EC18114-2, EC18229, EC18566, EC18567, EC18565, EC97882, EC11476, EC12436, EC18184, EC18183-A, EC18183-B, EC18230, EC18113-A, EC18136, EC37242, EC37244, EC7244-C, EC161887, EC37221-1, EC37242-2, EC18183, EC97882-A, EC26365, EC18562, EC18153, PI 194787, PI 24786
Early flowering	EC12463, EC16167
Early maturing	EC12463, EC18171, EC16167, EC101887, EC114123, EC15115, EC98452, EC30931, EC247821, EC98453, EC182228, EC90453, PI 247687, PI 247643
Long pod	EC18565
Dwarf type	EC18583-3
Prolific pod bearing	EC18113-A, EC37240, EC97882-A, EC97882-C, EC16167-A, E 242723
Field tolerance to disease	EC8113-A, EC97882-C, EC16167-A
Vegetable type	EC37225-D

India, its cultivation is confined to Himalayan hills, northern and north-eastern plains. A total of 1,309 accessions of faba bean have been introduced and evaluated at Hisar and Delhi. The accessions have shown a wide range of variation for days to flowering (68-94), maturity period (121-188 days), plant height (44-100 cm), branches per plant (1-6), internode length (1.4-4.0 cm), clusters per plant (4.0-46.3), pods per plant (4.7-73.6), seeds per pod (2-3), 100 seed weight (18.3-78.9 g) and seed yield per plant (24.0-49.8 g). Considerable variation for seed protein and also an anti-metabolite factor, viz., vicine-convicine has been reported and lines showing upto 27 per cent protein earmarked. Thirty six promising accessions have been identified for various traits and one variety (Vikrant) has been released for cultivation. Some of the promising faba bean introductions identified for different traits are given in Table 6.

7. Winged bean (*Psophocarpus tetragonolobus*)

Winged bean is rich in protein and oil and holds promise as a multipurpose crop. Its pods, seeds and roots are edible and the plant is used as fodder. It is also used as green manure and a cover crop. In India, its cultivation is confined to humid sub-tropics (Bengal, Bihar, North-eastern region, Deccan plateau and Western ghats). Characterization of 300 exotic and 160 indigenous accessions of winged bean for 25 descriptors revealed considerable variability for various yield attributes. Pod length was observed to vary from 8.4 to 35.7 cm, with both small and large poded types belonging to Indonesia. Flowering ranged from 74-145 days with the earliest flowering types represented from Papua New Guinea and late flowering types from Indonesia. The range of variation in seeds per pod was 4-18, with the highest occurrence in the Indonesian material. The indigenous germplasm included high tuber yielding types. Eighty eight promising accessions have been identified from the introduced germplasm. Some of the promising winged bean introductions identified for different traits are given in Table 7. A dual-purpose variety (AKWB 1) of winged bean has been released for cultivation and around 250 accessions of winged bean are being maintained at NBPGR Regional Station, Akola as active collections.

8. Horse tail tree (*Casuarina* spp.)

Casuarina is a fast growing tree with potential for fuel wood, which can be successfully grown under saline conditions. Twenty five accessions of three species, viz., *C. equisetifolia, C. cunninghamia* and *C. cristata* were introduced and evaluated at Tamil Nadu Agricultural University, Mettupalayam. A wide range of variation was observed for plant height (1.50-5.05 m), basal diameter (2.50-5.97 cm) and diameter at breast height (0.80-3.47 cm). Studies at the Central Soil Salinity Research Institute, Karnal, revealed that *C. equisetifolia* showed 90-95 per cent survival, both in surface planting and channel planting methods under higher salinity levels. The plant is now being researched under the project on Agro-forestry.

9. Salt bush (*Atriplex* spp.)

Salt bushes are perennial fodder shrubs, which can be grown successfully on highly saline soils under low rainfall conditions. Thirty six accessions of nine species of *Atriplex*, namely, *A. amnicola, A. bunburyana, A. cinerae, A. lentiformis, A. paludosa, A. undulata, A. nummularia, A. canescens* and *A. halimus* were evaluated at NBPGR Regional Station, Jodhpur. Considerable variation was observed for different growth traits. Three species viz., *A. nummularia, A. canescens* and *A. halimus*, were observed to perform well in the arid regions of Rajasthan.

Table 6. Promising introductions of faba bean

S. No.	Trait	Promising accession
1.	Early maturing	EC117748, EC117787, EC243746, EC273859, EC117724, EC354985
2.	Pods per plant	EC329584, EC329585, EC329591, EC117817, EC117810
3.	Seeds per pod	EC329640, EC329642, EC329644
4.	High seed yield	EC329649, EC329729, EC329720, EC243629, EC243707, EC243743, EC243763, EC243823
5.	Early flowering	EC329720, EC325185, EC329625, EC329662, EC329717, EC329680
6.	Tall type	EC329720, EC325185, EC29625, EC329662, EC329717
7.	Low susceptibility to aphids	EC329717, EC243763, EC243743, EC243890, EC116634, EC117727, EC117745, EC117757, EC243761, EC243883, EC329604, EC329645, EC117810

10. Guayule (*Parthenium argentatum*)

This desert shrub, native of north-central Mexico and south-western United States, is drought hardy, well-suited to arid lands with 250–300 mm rainfall and is a good source of rubber. Twenty-eight accessions were evaluated at NBPGR, New Delhi, and a wide range of variation was observed for stem girth (9.1-17.6 cm), plant circumference (203.4-237.7 cm), fresh biomass yield per plant (690-873 g), dry biomass yield per plant (360-432 g), rubber content (4.7-7.4%) and resin content (4.2-6.2%). The germplasm is now being maintained at Gujarat Agricultural University, S.K. Nagar and CCS Haryana Agricultural University, Hisar. Two varieties, namely, Arizona 2 and HG 8 have been identified as high yielding.

11. Jojoba (*Simmondsia chinensis*)

This hardy shrub, native to northern Mexico and south-western United States, is valued for its seed oil, which is a substitute for sperm whale oil and is used as lubricant and fuel when mixed with alcohol, and also in pharmaceuticals and cosmetics. This species has been tried at several sites in India with variable edapho-climatic conditions and has been found successful on arid lands and coastal wastelands. Evaluation of germplasm, comprising 183 accessions, at 60 month stage at NBPGR Regional Station, Jodhpur, revealed a wide range of variation for plant height (33-123 cm), plant canopy (36 x 24 cm-142 x 142 cm) and internode length (2.0-4.0 cm). One accession as variety (EC33198) has been released for cultivation. The species is being promoted by the Department of Agriculture, Rajasthan for large scale cultivation.

12. *Cuphea* spp.

These species adapted to temperate climate are good sources for industrial oils. Germplasm evaluation of 30 accessions of different *Cuphea* species, viz., *C. wrightii, C. lutea, C. painteri, C. procumbens* and *C. carthegenensis*, at NBPGR Regional Station, Shimla, revealed a wide range of variation for different traits. The range of variation observed was 61.2-69.9 cm for plant height, 11.3-13.0 for branches per plant, 48.5-59.5 for number of leaves, 38.6-44.9 for number of capsules, 1.7-2.4 cm for capsule length, 89-94 days to flowering, 129-138 days to maturity, 2.03-2.08 g for 1000 seed weight and 13.6-67.0 for seed yield per plant.

13. Paradise tree (*Simarouba glauca*)

This tree species, introduced from El Salvador in 1968, has a very high potential. Its seeds contain 55-60 per cent edible oil comparable to ground nut in quality. The press-cake contains 60–69 per cent protein and is a good source of organic manure (N 7.7 to 8.1%,

Table 7. Promising introductions of winged bean

Trait	Promising accession
Frost resistant	EC11073, EC11074
High tuber yield	EC111205, EC114073, EC27855, EC27884, EC116886, EC38959, EC128269, EC142600-1, EC251020
Fodder type	EC114073, EC27884, EC111074
High seed yield	EC36942, EC37885, EC38825, EC27885, EC27884, EC38821, EC27886-A, EC38957, EC116886, EC38959, EC38955-A, EC38957-A, EC38824, EC27886, EC38955, EC116885, EC27886-A-1, EC116884, EC121918, EC118345, EC27886-A-2, EC116889, EC27006, EC38821-P-1, EC38956, EC38825-1, EC38831-3, EC38855-1, EC38955-B, EC38957-1, EC142666, EC178268, EC178319, EC178322, EC178337, EC26170, EC34865-1, EC49558, EC11885, EC121919, EC142653, EC178306, EC38823, EC114273-B, EC178313, E 178271, EC178331, EC142665
Green pod yield	EC38825-P-3, EC27885, EC8821, EC38957, EC38959, EC38955-A, EC38957-A, EC38824, EC38955, EC116884, EC118345, EC121906, EC121907, EC121908
Seeds per pod	EC38821, EC116885
Forage yield	EC111074, EC114273-1
Early flowering	EC27886-A, EC38821-P-2, EC38821-P-4, EC27886-A-2
Early maturing	EC38955-A, EC38821-P-2, EC38956
Pod yield	EC38824, EC38954, EC38825-1, EC38955-B, EC114273-B, EC116884, EC118645, EC121906, EC21907, EC121908
Long pod	EC116885, EC121920, EC121918
Late type	EC1301813, EC130182, EC130186, EC130184, EC130185
Pod quality	EC116884, EC118645, EC121906
Suitable for North India	EC116884, EC118345, EC121906, EC121907, EC121908
Photosensitive strain	EC130184, EC130185, EC121921, EC130283
Pod length	EC118345, EC26942, EC26945, EC178279, EC178331
Tuber length	EC112417, EC178302, EC26904, EC26944, EC26949-1, EC34865-2, EC38821-B, E 41979, EC45225, EC95238
Number of tubers/ plant	EC178279, EC178333, EC178340-1

Table 8. Distribution of less known cultivated food plants in different regions of diversity

Regions/ Food Plants	1	2	3	4	5	6	7	8	9	10	11	12*	Total
Tuber/ root types	26	22	1	7	–	4	8	28	9	26	5	5	141
Vegetables	56	31	1	11	–	4	24	36	29	18	6	2	218
Flowers	2	2	1	2	–	–	2	–	–	–	1	–	10
Fruits	50	61	2	17	19	13	5	13	14	69	36	38	337
Seeds/ nuts	18	14	3	11	1	10	7	21	6	12	8	4	115
Miscellaneous	20	36	–	8	1	2	24	29	20	19	5	7	171
Total diversity	172	166	8	56	21	33	70	127	78	144	61	56	992

* The 12 regions of diversity of crop plants are: 1. Chinese-Japanese, 2. Indo-Chinese-Indonesian, 3. Australian, 4. Hindustani, 5. Central Asian, 6. Near Eastern, 7. Mediterranean, 8. African, 9. European-Siberian, 10. South-American, 11. Central American and Mexican, 12. North American.

P 1.07% and potash 1.24%). The bitter (toxic) element extracted from press-cake of *S. glauca* kernels has been used as amoebicide (Glaumeba). The shells (endocarp) can be used in hard-board industry. The mesocarp of the fruit, which constitutes 62 per cent of fruit weight is used in the preparation of squash, beverage and jam. The leaves, bark and wood of *Simarouba* have a long history of usage as a natural medicine by the natives in tropical Americas. Also the wood is light and less preferred by insects and hence useful in making yoke and light furniture. *Simarouba* has adapted well in peninsular India and National Oil Seeds and Vegetable Oils Development Board (NOVOD) is promoting its large scale propagation in Karnataka, Tamil Nadu and Orissa, each of which has around one thousand hectares area under *Simarouba* plantation. Trials are being conducted to identify/ develop suitable location specific genotypes under AICRP (UC).

14. Purging Nut (*Jatropha curcas*)

This industrial oil yielding species is adapted to marginal lands e.g. sandy, clayey, gravel and eroded lands, and produces a semi-drying oil that can be used in fuel mixtures, as an illuminant and/or making soaps and candles. Evaluation of Jatropha was carried out at GAU, S.K. Nagar. The range of variation observed was 217-409 cm for plant height, 30-45 for branches per plant, 10-25 for clusters per plant, 69-817 for 1000 seed weight and 25-95 g for seed yield per plant. The growth of *Jatropha curcas* was observed to be better than that of *J. gossipifolia*. One accession of *J. multifida*, introduced from Australia, has also been established well.

Opportunities for Introduction of Underutilized and New Crops in South Asia

The underutilized species are primarily grown in their centres of origin or centres of diversity where they are still important for the subsistence of local communities. Distribution of such less-known cultivated food plants in different regions of diversity is given in Table 8 (Arora, 1985) which shows that enormous diversity

Table 9. Some important underutilized and neglected crops/ plant species in Asia-Pacific region

Category	Crops/species diversity
Pseudocereals	*Amaranthus* spp., *Chenopodium* spp., buckwheat (*Fagopyrum esculentum*, *F. tataricum*)
Small Millets	*Digitaria* spp., *Echinochloa* spp., finger millet (*Eleusine coracana*), proso millet (*Panicum miliaceum*), pearl millet (*Pennisetum americanum*), little millet (*Panicum sumatrense*), kodo millet (*Paspalum scrobiculatum*), foxtail millet (*Setaria italica*); others - *Brachiaria* spp., *Coix lachryma-jobi*
Pulses	Sword bean (*Canavalia* spp.), hyacinth bean (*Lablab purpureus*), grasspea (*Lathyrus sativus*), horse gram (*Macrotyloma uniflorum*), velvet bean (*Mucuna* spp.), winged bean (*Psophocarpus tetragonolobus*), faba bean (*Vicia faba*), moth bean (*Vigna aconitifolia*), adzuki bean (*Vigna angularis*), rice bean (*Vigna umbellala*), others - pilipasara, *Vigna trilobata*, *Parkia roxburghii* (multipurpose)
Roots and Tubers	Elephant foot yam (*Amorphophallus paeoniifolius*), taro (*Colocasia esculenta*), yams (*Dioscorea* spp.), *Vigna vexillata*
Vegetables	Cucurbitaceae (*Benincasa*, *Luffa*, *Momordica*, *Trichosanthes* spp.), aibika (*Abelmoschus manihot*), leafy amaranth (*Amaranthus* spp.), *Brassica* spp., Kangkong (*Ipomoea aquatica*)
Fruits and Nuts	Jackfruit (*Artocarpus heterophyllus*), breadfruit (*A. allitis*), carambola (*Averrhoa carambola*), longan (*Dimocarpus longan*), pilinut (*Canarium ovatum*), durio (*Durian zibethinus*), Indian gooseberry (*Emblica officinalis*), mangosteen (*Garcinia mangostena*), duku (*Lansium domesticum*), litchi (*Litchi chinensis*), *Manilkara* spp., rambutan (*Nephelium lappaceum*), pistachio (*Pistachia vera*), jamun (*Syzygium cumini*), tamarind (*Tamarindus indica*), Indian jujube/ber (*Ziziphus mauritiana*), Chinese jujube (*Ziziphus jujube*)
Oil plants	Safflower (*Carthamus tinctorius*), colocynth (*Citrullus colocynthis*), niger (*Guizotia abyssinica*), physic nut (*Jatropha curcas*), sesame (*Sesamum indicum*)
Fibres and Pulp	Ramie (*Boehmeria nivea*), sunn hemp (*Crotalaria juncea*), kenaf (*Hibiscus cannabinus*), flax (*Linum usititissimum*), dhaincha (*Sesbania bispinosa*)
Others	Sago palm (*Metroxylon sago*), bamboo

exists world wide for the underutilized plants and thus, there is an ample scope of introducing exotic material from diverse geographic regions of the world.

Eco-regional approach and inter-institutional collaboration are needed to promote the use of underutilized species e.g. there exists a strong inter-regional interest in south, south-east and east Asia for crops like amaranth, buckwheat, rice bean, faba bean, minor millets, sesame, Lathyrus, safflower, taro, minor tropical vegetables and fruits. Inter-institutional collaboration at international, regional and national level can be helpful in promoting the use of underutilized species.

Information compiled by Bioversity International, International Centre for Underutilized Crops (ICUC) and National Academy of Sciences (NAS/USA) (Eyzaguirre *et. al.*, 1999) provides a list of about 200 such underutilized priority species which include millets – 29 species, oil plants – 10, pulses – 27, root and tubers – 25, spices – 2, fruits and nuts – 52, minor fruits – 24, vegetables – 39 and fibre and pulp yielding plants – 5. Out of these, the species listed species in Table 9 are more important to the Asia-Pacific region.

References

Arora RK (1985) Ethnobotanical studies in plant genetic resources: National efforts and concern. *Ethnobotany* **7:** 125-136.

Arora RK (2002) Biodiversity in underutilized plants – A genetic resources perspective. Lecture delivered on the occasion of the foundation day of National Academy of Agricultural Sciences, New Delhi. June 5, 2002.

Eyzaguirre PB, S Padulosi and T Hodgkin (1999) IPGRI's strategy for neglected and underutilized species and the human dimension of agro-biodiversity. Pp. 1-19. In: Priority Setting for Underutilized and Neglected Plant Species of the Mediterrean Region (S. Padulosi, ed.). International Plant Genetic Resources Institute, Rome, Italy.

Joshi BD and RS Rana (1991) Buckwheat in India. National Bureau of Plant Genetic Resources, Shimla, *Sci. Monogr.* **2:** 117p.

Joshi BD and RS Paroda (1991) Grain Amaranth: The Future Food Crop. National Bureau of Plant Genetic Resources, Shimla, India.

Ramachandran K, K Kashyapa and Ramesh Chand (1986) The Useful Plants of India. CSIR, New Delhi.

Rathi RS, HL Raiger, BS Phogat and RP Dua (2005) Evaluating Germplasm Introductions of Underutilized Plants. Poster presentation in International Symposium on Plant Introduction: Achievements and Opportunities in South Asia. February 15-17, 2005, New Delhi.

International Crop Germplasm Exchange at ICRISAT

CL Laxmipathi Gowda* and HD Upadhyaya
ICRISAT, Patancheru, Andhra Pradesh-502324, India

Plant genetic resources are essential for sustainable development of agriculture and food security. Rapid loss of plant biodiversity and realization of its importance during twentieth century led to collection, conservation and exchange of large number of germplasm in genebanks across the planet, resulting in the conservation of more than 6.1 million accessions in over 1,300 genebanks. Eleven International Agricultural Research Centers (IARC) maintain over 6,00,000 accessions and supply seed samples freely to scientists globally. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has the global responsibility of collection, conservation, evaluation, improvement, and distribution of sorghum, pearl millet, chickpea, pigeonpea, groundnut, and six small millets (finger millet, foxtail millet, proso millet, little millet, kodo millet, barnyard millet) germplasm. ICRISAT holds in trust 1,16,799 accessions from 142 countries. To support the research of national programs ICRISAT supplied over 1.22 million seed samples in 172 countries. A total of 583 varieties were released in 76 countries from the ICRISAT supplied germplasm and breeding material. Germplasm accessions at ICRISAT were evaluated for morpho-agronomic, biotic, abiotic, and quality traits in batches as and when they were acquired. Core collections of sorghum, pearl millet, chickpea, pigeonpea, groundnut, and finger millet and mini core collection of chickpea, pigeonpea, and groundnut were developed to enhance the utilization of germplasm. Genetically diverse, new sources of early-maturity, large seed size, drought tolerance and chilling tolerance at germination were identified using core/mini core collection approach.

Key words: ICRISAT, Germplasm, Collection, Exchange, Utilization, Diversity, Core collection, Mini core collection

Plants have formed the basis of agriculture for more than 10,000 years and they continue to provide food security globally. Success of crop improvement depends on the availability of diverse germplasm resources. Collection and assembly of germplasm at some locations and easy access to those germplasm has facilitated crop improvement progress globally. Historically, there have been several exchanges and introductions of crop germplasm, across the globe. However, purposeful efforts to explore, collect, exchange, and conserve the germplasm resources started in the 1920s. Over the years, gene banks have been established in a number of countries and the number of accessions conserved in genebanks now exceeds six million (FAO, 1998).

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has world mandate for the germplasm collection, characterization, conservation, and distribution of sorghum, pearl millet, chickpea, pigeonpea and groundnut, and the genetic enhancements of these crops. In addition, it also has mandate for collection, characterization, conservation, and exchange of germplasm of six small millets, namely, finger millet, foxtail millet, kodo millet, little millet, proso millet, and barnyard millet. This has necessitated exchange of the germplasm among the number of countries and ICRISAT.

* E-mail: icrisat@cgiar.org

Germplasm Assembly in the ICRISAT Genebank

Soon after the establishment of ICRISAT in 1972, efforts were initiated to assemble and collect the germplasm. The Rockfeller Foundation working with the Indian national program during 1960s, had assembled over 16,000 sorghum germplasm accessions from major sorghum areas, and ICRISAT acquired 11,961 accessions of this collection in 1974 that existed in India and USA. Initially, ICRISAT also acquired over 2,000 pearl millet germplasm accessions assembled by the Rockfeller Foundation in India, and another 2,000 accessions collected by the Institut Francais de Recherché Scientifique pour le Development en Cooperation (ORSTOM) in Francophone, West Africa.

The chickpea and pigeonpea germplasm initially acquired by ICRISAT consisted of the material originally collected and assembled by the former Regional Pulse Improvement Project (RPIP), a joint project of the Indian Agricultural Research Institute (IARI), the United States Department of Agriculture (USDA), and Karaj Agricultural University in Iran. Sets of this germplasm placed in several agricultural research institutes in India and Iran, and at the USDA were donated to ICRISAT in 1973. ICRISAT also acquired over 1,200 chickpea accessions from the Arid Lands Agricultural Development (ALAD) program in Lebanon. Similarly, much of the groundnut germplasm was received from the Indian groundnut research programme, now the National Research Center for Groundnut (NRCG-Junagadh, India), and USDA (USA).

ICRISAT also initiated programmes to add new germplasm of the five mandate crops. Special efforts were made to collect or assemble landraces and wild relatives from areas threatened by genetic erosion. During 1974 and 1997, ICRISAT launched 212 joint collection missions in areas of diversity in 61 countries and collected 8,957 sorghum; 10,802 pearl millet; 4,228 chickpea; 3,870 pigeonpea, and 2,666 groundnut accessions. Apart from ICRISAT's own collection efforts, the donations from the national programmes of countries namely Ethiopia, Sudan, and India contributed to enrich the germplasm collections at ICRISAT. Presently, ICRISAT genebank (named as Rajendra S. Paroda Genebank in 2002) is holding 1,16,799 accessions from 142 countries (Table 1).

Table 1. Germplasm holdings in the R S Paroda Genebank, ICRISAT, Patancheru (upto July 2006)

Crop	Active collection	Base collection	In-trust
Sorghum	36,774	33,039	36,771
Pearl millet	21,594	18,870	21,563
Chickpea	19,187	16,977	17,117
Pigeonpea	13,632	11,547	13,389
Groundnut	15,419	10,709	14,803
Finger millet	5,949	4,620	5,949
Foxtail millet	1,535	1,054	1,535
Proso millet	842	576	835
Little millet	466	384	462
Kodo millet	658	630	656
Barnyard millet	743	487	743
Total	**1,16,799**	**98,893**	**1,13,823**

Germplasm Characterization and Evaluation

Agronomic and morphological characterization is necessary to facilitate the utilization of germplasm. Evaluation of germplasm accessions for traits of agronomic importance enhances its utility by the research workers. Therefore, the germplasm accessions of all the crops were sown in batches over the years and characterized for morphological and agronomic traits. Germplasm accessions were also screened against stresses in collaboration with various disciplinary scientists. Grains were tested for nutritional value such as starch, protein, oil content, cooking time, etc. Germplasm sets were evaluated over locations jointly with NARS in India, Nepal, Thailand, Indonesia, Ethiopia, Kenya, and a few countries in West Africa to enhance the value of characterization, and at the same time-share the germplasm with partners. A total of 96% accessions have been characterized for all morpho-agronomic traits upto July 2006. Following is the crop-wise progress in brief on germplasm characterization at ICRISAT.

Sorghum

Germplasm characterization was initiated in 1973 by sowing the germplasm accessions in batches over the years. During 1997, the status of characterization work was reviewed and the gaps were identified. To fill these gaps, a set of 781 new germplasm accessions was sown for characterization. In addition, data were recorded on 2,000 accessions for grain characteristics. Also characterized and classified 498 germplasm accessions received earlier from South Africa and 348 accessions of converted zera-zera sorghums. Protein content of 364 accessions analyzed during 2002 ranged between 8.3 to 17.7%. Out of 122 accessions of wild relatives of sorghum screened for shoot fly resistance, 11 accessions were identified as resistant in addition to the two accessions of cultivated sorghum (IS 2146 and IS 18551).

Pearl Millet

During 1973-96, most of the germplasm accessions of pearl millet had been characterized. Work done was reviewed in 1997 and as result 197 germplasm accessions were characterized for traits that were missing from earlier years. In subsequent seasons, 1,815 and 1,394 accessions were sown to record the data on days to flowering, plant height, spike length, and spike thickness.

Chickpea

Chickpea germplasm characterization work was almost fully achieved by 1996. However, data on some traits on part of the germplasm were missing and the additional data were recorded during 1997/98. Forty-nine accessions of wild *Cicer* were characterized in the field, and another 100 accessions received from ICARDA were sown under extended day length conditions in the glasshouse and characterized for 22 traits. Preliminary screenings of the chickpea collections of Asian origin indicated the presence of good levels of genetic resistance, particularly to collar rot and botrytis gray mold disease.

Pigeonpea

In continuing the work of germplasm characterization of pigeonpea, 388 accessions received from USA were sown during 1997 crop season for characterization and seed increase. Information on photoperiod reaction on 11,000 pigeonpea accessions was added to the database. A very diverse set of 28 accessions of pigeonpea and 12 related wild species were tested for tolerance to damage by pod fly (*Melanagromyza obtusa* Malloch) and pod wasp (*Tanaostigmodes cajaninae* La Salle). Accessions ICPW 141, 278, and 280 (*Cajanus scarabaeoides*); ICPW 14 (*C. albicans*); ICPW 214 (*Rhynchosia bracteata*); and ICPW 202 (*Flemingia stricta*) showed resistance to both pod fly and pod wasp damage (Sharma *et al.*, 2003).

Groundnut

Almost all the germplasm accessions had been characterized by 1996 for most of the traits. However, missing data for one or more traits were recorded in 1997. Also characterized 158 accessions of wild *Arachis* species using 70 descriptors. Rosette and early leaf spot (ELS) are the most destructive diseases of groundnut in the West and Central Africa (WCA) and southern and eastern Africa (SEA) regions. Out of 4,420 groundnut germplasm accessions and 80 accessions of wild species evaluated, 20 genotypes in 1997/ 98 and 28 genotypes in 1998/ 99 showed low (<20%) disease incidence. Identified 35 additional sources of resistance to ELS. Of these, 30 are from South America (mostly from Peru and Bolivia) and are Valencia types. Eleven accessions of wild *Arachis* species (ICGs 8131, 13211, 13222, 14855, 14856, 14888, 14875, 14907, 14924, 14939, and 14946) were highly resistant and 15 others were resistant to ELS. We identified seven wild species accessions (ICG 8131, 8193, 8904, 11560, 13212, 13261 and 15875) with low *Aspergillus flavus* colonization and aflatoxin contamination. In West Africa, 500 accessions were screened over two years for tolerance to *A. flavus* invasion and aflatoxin contamination. Thirty-one lines were consistently tolerant to seed invasion and aflatoxin production. Against late leaf spot disease, 24 promising sources of resistance were identified from several wild species accessions. Out of 48 accessions of wild *Arachis* species screened against peanut bud necrosis disease (PBND), ICG 8131, ICG 8144, ICG 8944 were identified as disease free and ICG 11551 with <5% disease incidence. A number of germplasm accessions were identified for resistance. This included six accessions for resistance to jassids (*Empoasca kerri* Pruthi), 11 for thrips (*Thrips palmi* Karny.), one for aphids (*Aphis craccivora* Koch.), 10 for termites (*Odontotermes* spp.), and two for leaf miner (*Aproaerema modicella* Deventer) (Ranga Rao and Wightman, 1999).

Geographical Pattern of Diversity

Chickpea

Data on 16,820 accessions of chickpea germplasm for seven morphological and 13 agronomic traits, and reaction to fusarium wilt was analyzed to determine phenotypic variation in the accessions from different geographical regions. The means for different agronomic traits differed significantly between regions. The variances for all the traits among regions were heterogeneous. South Asia contained maximum range of variation for all the traits. Seed color and days to 50% flowering showed the highest pooled diversity index. Principal component analysis using 13 agronomic traits and clustering of the first three principal component scores delineated two regional clusters consisting Africa, South Asia, and Southeast Asia in the first cluster and Americas, Europe, West Asia, Mediterranean region, and East Asia in the second cluster (Upadhyaya, 2003) (Fig. 1).

Groundnut

The data on groundnut germplasm (13,342 accessions) for 16 morphological and 10 agronomic traits in two seasons were analyzed to study geographical patterns of variation. Phenotypic variation was found for most traits in all the regions, and means for different agronomic traits differed significantly among regions. The variances for all the traits among regions were heterogeneous. Principal component analysis using 36 traits and clustering on first seven principal component scores delineated three regional clusters, consisting of North America, Middle East, and East Asia in the first cluster; South America in the second cluster; and West Africa, Europe, Central Africa, South

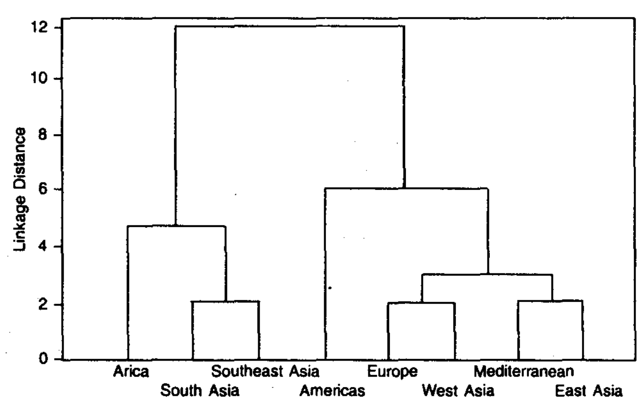


Fig. 1: Dendogram of eight regions in the entire chickpea germplasm based on first three principal components

Asia, Oceania, South Africa, East Africa, Southeast Asia, Central Asia and the Caribbean Islands in the third cluster (Upadhyaya *et al.*, 2002a) (Fig. 2). Similarly, geographic regions differed significantly for morpho-agronomic traits in pigeonpea (Upadhyaya *et al.*, 2005).

Forming Subsets of Germplasm to Enhance its Utilization

With increased emphasis on germplasm assembly and explorations during the last four decades, most genebanks have now huge collections. However, the germplasm accessions could not be characterized effectively and the documentation was not achieved as desired. This resulted in under utilization of the germplasm resources. One of the means to enhance utilization is developing a subset of core collection (Frankel, 1984). A core collection contains a subset of accessions (about 10%) from entire collection that captures most of the available genetic diversity of species (Brown, 1989). The core subset can be evaluated extensively and the information derived will provide a targeted entry point for more efficient utilization of the entire collection. At ICRISAT, we have accomplished this by making subsets at three levels: (i) Global core-, (ii) Mini core- and (iii) Regional core collections.

Global Core Collection

Using the sampling theory of selectively neutral alleles, Brown (1989) argued that the entries in a core subset should be about 10% of total collection, with a ceiling of 3,000 per species. This level of sampling is effective in retaining 70% alleles of the entire collection. At ICRISAT, we have developed core collections for all the five mandate crops and finger millet. The core collections provide an effective mechanism for the proper exploitation of germplasm resources for the genetic improvement and simplifies the genebank management.

Mini Core Collection

In many crops, the number of accessions in genebanks are several thousands, and a core subset consisting of 10% of entire accessions would again be large and unwieldy to identify useful parents for traits of economic importance. Thus, there is a need to reduce the size of the subset further without losing species diversity. Upadhyaya and Ortiz (2001) suggested the strategy for sampling the entire and core collections for developing a 'mini-core' collection, which contains about 1% of the entire collection but captures most of the useful variation of the crop. ICRISAT scientists have already developed mini-core collections of chickpea (Upadhyaya and Ortiz, 2001), groundnut (Upadhyaya *et al.*, 2002b) and pegeonpea with 211, 184 and 146 accessions, respectively.

Regional Core Collection

To enhance the utilization of crop genetic resources in a particular region, regional core collection could also be developed. At ICRISAT, an Asian core collection of groundnut consisting of 504 (10.6% of entire collection) accessions was developed (Upadhyaya *et al.*, 2001a).

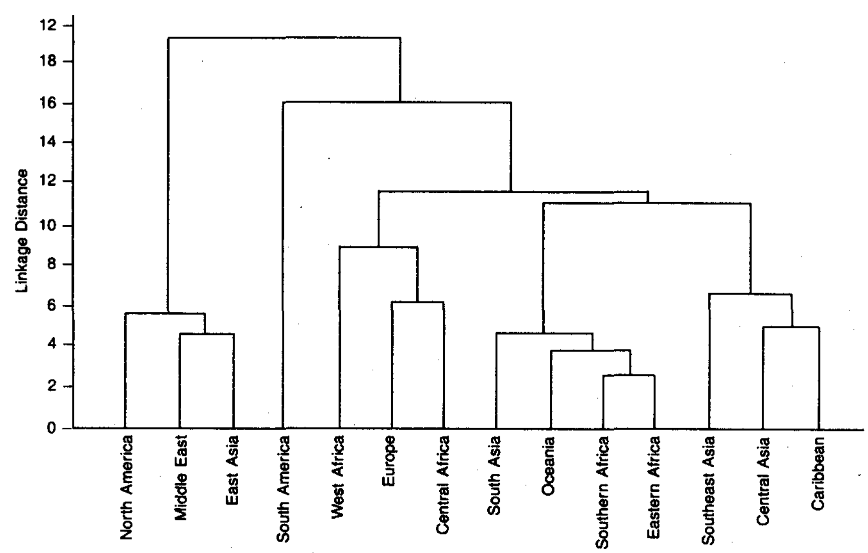


***Fig. 2:** Dendogram of 14 regions in entire groundnut germplasm based on scores of first seven principal components (Upadhyaya et al. 2003)*

Uses of Core Collections in Crop Improvement

In most groundnut breeding programs globally, Chico has been predominantly used (Gangapuri and JL 24 also) as a source of earliness. This has resulted in the narrow genetic base of short-duration cultivars. We used groundnut core collection consisting of 1,704 accessions (Upadhyaya *et al.*, 2003) to identify new sources of early maturity. We selected 21 early maturing landraces (similar to Chico in maturity) and evaluated them at 1240° Cd [(equivalent to 75 days after sowing (DAS)] and 1470° Cd (equivalent to 90 DAS) in rainy season at Patancheru, India along with Chico. ICGs 4558, 4729 and 9930 (1.97-2.15 t ha^{-1}) produced 25-36% more pod yield than the early maturing Indian cultivar JL 24 at 1240° Cd in the 2001/02 post rainy season. Diversity studies indicated that the new germplasm lines are diverse from widely used source of early maturity, Chico and Gangapuri.

We have been able to select promising accessions for low temperature tolerance using core collection of groundnut. The set of 1,704 core accessions was screened for low temperature tolerance at germination under laboratory conditions, and 343 accessions were found promising. Of this, 164 landraces were further characterized for yield and related traits and 24 accessions were found most promising (Upadhyaya *et al.*, 2001b).

In USA, the peanut core collection of 831 accessions (Holbrook *et al.*, 1993) was tested against various stresses and a number of resistant sources were identified. They included 36 core accessions resistant to root knot nematode (Holbrook *et al.*, 1997), 14 tolerant to pre-harvest aflatoxin contamination (Holbrook *et al.*, 1998), and six with high level of resistance to *Rhizoctonia* limb rot (Frankel *et al.*, 1999).

The 184 mini-core accessions of groundnut (Upadhyaya *et al.*, 2002) were evaluated for traits related to drought tolerance, specific leaf area (SLA) and soil plant analysis development (SPAD) chlorophyll meter reading (SCMR), and 18 accessions were identified with high water use efficiency (WUE) at ICRISAT-Patancheru (Upadhyaya, 2005). The chickpea mini-core developed at ICRISAT (211 accessions) was evaluated at IIPR, Kanpur during 2003-04 season and 12 accessions were selected for use in the crop improvement program. Five accessions, namely ICCs 14199, 12034, 14194, 14196, and EC381882 have already been involved in hybridization to develop large seeded kabuli types. This will help to broaden the genetic base of the cultivars.

Germplasm Distribution from ICRISAT

Supply of Breeding Material and the Basic Germplasm

Supply of healthy, viable, and genetically representative seeds of germplasm accessions to the research workers is one of the major objectives of the ICRISAT Genebank. During 1973 to 1996, 5,93,388 seed samples were supplied to users in 134 countries. During the recent years (1997 to 2006), we have distributed 85,869 samples to the users (Table 2). Additionally, we provided 1,22,338 seed samples within ICRISAT for utilization in research and screening against various stresses. The number of samples exchanged from ICRISAT, including supply from the genebank as well as the breeding materials or nurseries sent by the crop improvement scientists is over 1.22 million samples exported and 0.16 million samples imported (Tables 3 and 4).

Insight into the Germplasm Supplied to Users

One of the main areas of research is to assess the patterns of demand for germplasm accessions to guide future

Table 2. ICRISAT germplasm distributed during 1997-July 2006

Crop	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total
Sorghum	3,900	4,022	1,144	1,523	3,857	1,783	778	822	327	599	18,755
Pearimillet	915	1,330	366	1,080	394	2,063	621	284	339	1,194	8,586
Chickpea	1,414	1,632	2,833	848	3,715	1,344	1,233	2,139	1,511	56	16,725
Pigeonpea	837	856	693	1,297	2,147	2,470	845	591	98	1,001	10,835
Groundnut	4,657	2,039	3,011	3,002	1,350	546	1,358	1,631	339	1,035	18,968
Finger millet	394	71	342	41	5,115	293	167	193	1,609	1,010	9,235
Foxtail millet	38	21	16	3	1,233	134	10	47	40	1,542	
Proso millet	–	21	29	3	19	121	6	45	–	–	244
Little millet	–	6	11	5	463	104	2	45	10	–	646
Kodo millet	30	1	15	1	–	–	2	14	–	–	63
Barnyard millet	–	1	39	–	9	105	52	44	20	–	270
Total	**12,185**	**10,000**	**8,499**	**7,803**	**18,302**	**8,963**	**5,074**	**5,855**	**4,293**	**4,895**	**85,869**

Table 3. Import of germplasm (no. of samples) to ICRISAT during 1974-2006

Continent/ Region	No. of countries	Sorghum	Pearl millet	Chickpea	Pigeonpea	Groundnut	Small millets	Total
ASIA								
East	11	6,632	1,098	102	267	1,443	3,426	12,968
South	4	115	241	585	333	53	824	2,151
West	7	14,172	3,723	21,966	0	0	926	40,787
AFRICA								
North	3	1,332	975	131	0	46	0	2,484
East	7	7,004	629	436	805	495	298	9,667
West & Central	16	5,572	10,215	113	217	1,925	26	18,068
South	8	5,382	3,855	40	436	2,305	2,969	14,987
AMERICAS								
North	2	22,203	2,689	3,596	1,906	7,299	449	38,142
Central	4	1,344	12	173	38	0	151	1,718
Caribbean Is.	11	2,060	0	0	2,464	15	0	4,539
South	7	781	2	156	127	478	0	1,544
Europe	14	4,716	2,222	978	113	6,076	1,649	15,754
Oceania	2	1,086	4	623	813	98	0	2,624
Total	**96**	**72,399**	**25,665**	**28,899**	**7,519**	**20,233**	**10,718**	**1,65,433**

Table 4. Export of germplasm (no.of samples) from ICRISAT during 1974-2006

Continent/ Region	No. of countries	Sorghum	Pearl millet	Chickpea	Pigeonpea	Groundnut	Minor millets	Total
ASIA								
East	17	57,003	2,981	28,403	14,260	41,511	1,824	1,45,982
West	17	20,715	3,404	70,645	2,430	1,854	90	99,138
South	6	21,988	10,785	89,280	14,750	7,048	2,261	1,46,112
AFRICA								
North	5	8,773	756	14,607	148	521		24,805
East	9	84,875	8,030	28,920	15,708	3,930	6,429	1,47,892
West & Central	26	1,50,832	1,14,050	5,946	7,988	16,709	702	2,96,227
South	12	68,610	20,284	3,966	8,911	30,982	3,155	1,35,908
AMERICAS								
North	3	25,213	4,354	18,433	4,294	2,991	776	56,061
Central	8	32,310	1,952	12,802	2,571	998	283	50,916
Caribbean Is.	16	1,817	79	168	4,144	829		7,037
South	12	22,491	4,933	13,241	4,844	1,673	937	48,119
Europe	30	12,521	12,134	13,450	1,863	5,340	3,168	48,476
Oceania	11	4,249	1,114	6,889	3,741	1,371	129	17,493
Total	**172**	**5,11,397**	**1,84,856**	**3,06,750**	**85,652**	**1,15,757**	**19,754**	**12,24,166**

strategies for germplasm regeneration and management. The germplasm distribution data of sorghum, pearl millet, chickpea, groundnut, and pigeonpea till 1998 were analyzed, and the following patterns emerged.

***Sorghum*:** Of the 36,727 germplasm accessions held in the genebank, 30,570 (83.2%) accessions were distributed at least once. Of this, about 83% were landraces, 16% breeding material and 1% wild sorghums. Twelve accessions, including three zera-zera accessions were dispatched more than 99 times.

***Pearl Millet*:** Of the 21,392 accessions, 15,366 (71.8%) accessions were distributed at least once during 1973 to 1998. The diversity in the distributed material was almost same as in the entire collection. A total of 1,769 accessions were distributed more than 10 times. IP 4021, an earliest flowering accession from Gujarat, India was distributed 94 times.

***Chickpea*:** 16,311 accessions of chickpea accessions were supplied to scientists in 81 countries. A maximum of 302 requests were received for ICC 4973 (L 550), a kabuli cultivar from India. Shannon-Weaver diversity index (H') of the accessions distributed was similar to the accessions contained in the global collection, indicating that the diversity available in the entire collection has been distributed.

***Groundnut*:** All assembled accessions except 794 (5.3% of the entire collection), have been distributed. Countries in Africa have received the maximum number of accessions (92.3%) followed by countries in Asia (76.6%), Europe (5.6%), Americas (5.3%), and Oceania (2.2%). ICG 799 (Kadiri 3), *A. hypogaea* cultivar from India, was supplied to 292 requestors globally.

Pigeonpea: The summary of germplasm distributed from 1974 to 2003 revealed that 65,749 germplasm seed samples were supplied to users. These samples represented only 10,648 unique accessions, indicating that only 78.1% of the accessions held in the genebank have been distributed. The scientists from India were the major recipients of the seeds (68.7% of the total). The pigeonpea accessions requested most frequently were: ICP 7035 (DSLR-55), a germplasm collection from Madhya Pradesh (distributed 305 times), ICP 26 (T 21, distributed 267 times), and ICP 7182 (BDN 1, distributed 253 times).

Restoration of the Basic Germplasm to National Programmes

The global collections held at ICRISAT serve an important purpose in restoration of germplasm to the source countries when national collections were lost due to lack of adequate storage facilities, natural calamities, civil unrest, etc. For example, we supplied 362 sorghum accessions to Botswana; 1,827 sorghum and 922 pearl millet to Cameroon; 1,723 sorghum and 931 chickpea to Ethiopia; 838 sorghum and 332 pigeonpea to Kenya; 1,436 and 445 sorghum accessions respectively to Nigeria and Somalia, and 71 pigeonpea accessions to Sri Lanka as part of restoring the lost germplasm that originated from these countries. The germplasm collections maintained in the Rajendra S Paroda Genebank include 44, 822 accessions received from or jointly collected with the Indian National Programs. The National Bureau of Plant Genetic Resources (NBPGR), India requested ICRISAT for restoration of this entire germplasm in 1998. As part of ICAR-ICRISAT Partnership Projects, the ICRISAT genebank has already repatriated the entire set of accessions by July 2004. This included sorghum (14,637), pearl millet (7,189), chickpea (7,488), pigeonpea (5, 988), groundnut (6,060), and six small millets (3,460) accessions.

Impact Realized by the NARS

From the materials supplied by ICRISAT, 583 varieties and hybrids (sorghum: 200; chickpea: 100; pearl millet: 129; groundnut: 105; and pigeonpea: 49) have been released in 76 countries spread over all the five continents (Fig. 3). This includes some of the basic germplasm accessions supplied from the ICRISAT genebank. Sixty-six varieties selected directly from the germplasm have been released in 44 countries, world over (Fig. 4).

Gaps in Germplasm Collections

In the initial years, we concentrated on assembling the germplasm from various R & D institutes across the world.

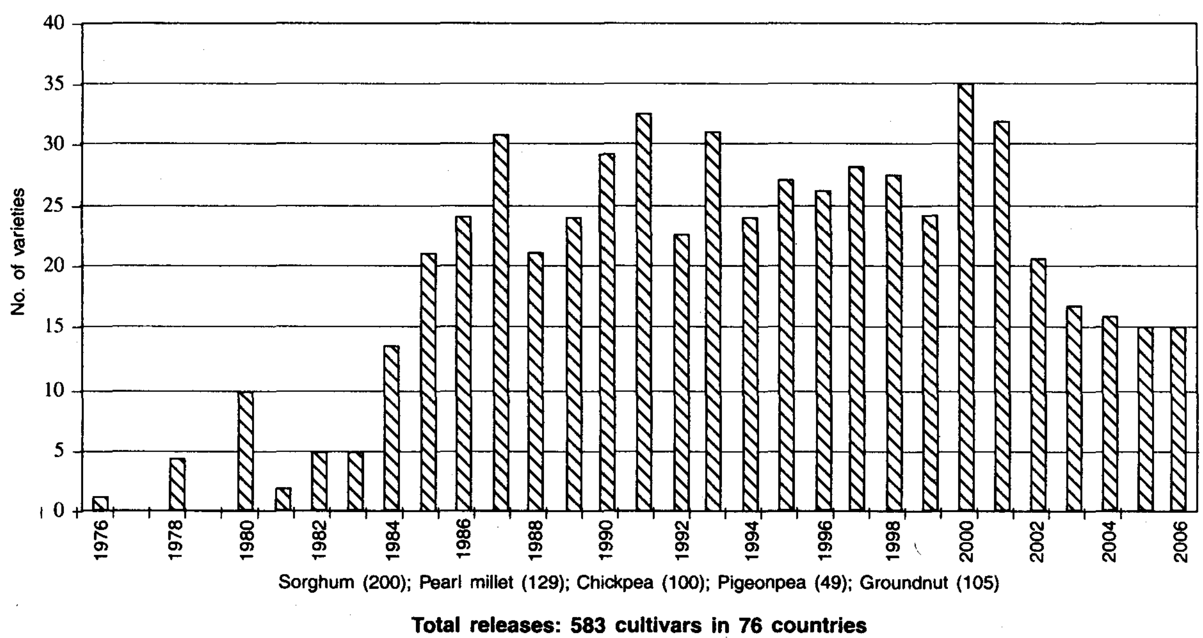


Fig. 3: Number of cultivars released worldwide from the ICRISAT supplied germplasm materials, 1975-2006

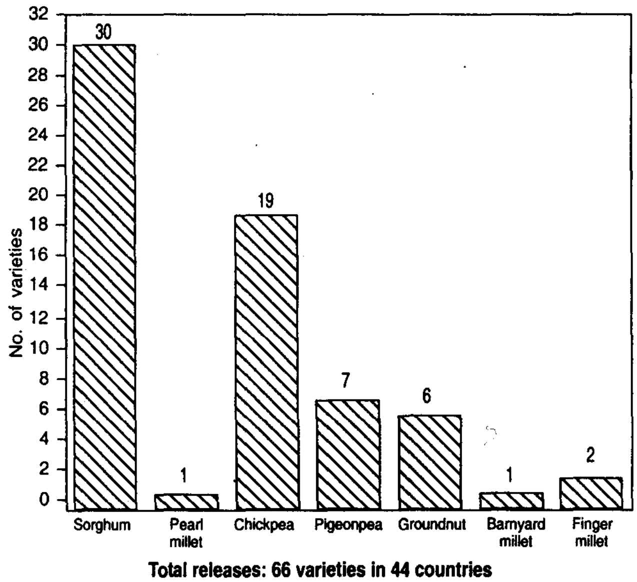


Fig. 4: Number of cultivars released worldwide from the basic germplasm supplied from ICRISAT genebank 1976-2003

Subsequently, germplasm collecting missions were launched in areas that were poorly represented. With availability of passport and characterization data and their summarization, we have arrived at specific germplasm types that are not adequately represented in the genebank (genetic gaps) and also the regions hitherto less represented. Such gaps for germplasm are listed in Table 5, and need attention for future collections.

Protocol for Germplasm Exchange

Starting in 1999, germplasm is supplied under the 'Material Transfer Agreement' (MTA) whereby the recipient agrees not to claim ownership over the material, nor to seek Intellectual Property Rights (IPRs) over that material, or its genetic parts or components, in the form received. The recipient also agrees not to seek IPRs over related information received, and to ensure that any subsequent person or institution to whom he/she may make samples of the material available, is bound by the same provisions and undertakes to pass on the same obligations to future recipients of the material.

Acquisition of the Germplasm from outside India

Import of crop germplasm from out side India needs approval from the National Bureau of Plant Genetic Resources (NBPGR) through issuing for Germplasm Import Permit (IP). This IP is sent to the institute from where germplasm material is to be imported. The sender prepares the germplasm under the guidelines given in the IP and sends the consignment along with IP and Phytosanitary Certificate to the NBPGR. After the germplasm consignment is found pest-free by the NBPGR scientists, the material is planted in the Post Entry Quarantine Isolation Area (PEQIA) at ICRISAT research farm at Patancheru under the joint supervision of NBPGR and ICRISAT researchers. The PEQIA is situated in one corner of the farm, surrounded by 45 ha uncultivated land (mostly covered with thick population of trees and shrubs) and it is more than 200 m away from any cultivated field.

The NBPGR and ICRISAT researchers jointly inspect the germplasm raised in PEQIA, regularly throughout the growing period until harvest. Any unhealthy or diseased plants are promptly rouged and burnt as and when detected. Every effort is made to grow disease and insect-pest free plants in the PEQIA, and seeds only from healthy plants are harvested. These seeds are then released to ICRISAT for subsequent use in research and or for conservation in the genebank.

Germplasm Supply outside ICRISAT

ICRISAT is committed to the strict plant quarantine guidelines for export of seeds to other countries. The crop areas from which seeds are collected for export are inspected regularly by the scientists to monitor incidence of any peculiar disease or insect-pests and suggest the control measures. This helps us to meet the plant quarantine requirements, if any, of the germplasm importing country.

Table 5. Need for further procuring germplasm of ICRISAT mandate crops

Crop	Genetic gap	Geographic gap
Sorghum		Algeria, Angola, Congo, Cota de Ivory, Guinea, Libya, Morocco, Syria and Tunisia
Pearl millet	Sources for yellow endosperm, white seeds	Botswana, Central Africa Republic, Ghana, Kenya, Malawi, Sierra Leone, Tchad, Togo, Uganda
Chickpea	Kabuli type	Ethiopia, Mediterranean countries
Pigeonpea		Eastern and Western Ghats (India)
Groundnut	Bot. Var. *hirsuta* and *aequotoriana*	Angola, China, Ecuador Laos, Namibia, Paraguay, Peru, South Africa, and Urugay

The export of germplasm from ICRISAT started in 1974. The requirements as laid down by the FAO/ Plant Protection Convention 1951 for the issue of a Phytosanitary Certificate for export of seeds are strictly followed. The Government of India has established an export certification laboratory at ICRISAT-Patancheru, which is supervised by the NBPGR scientists. ICRISAT provides the laboratory facilities and support staff to carry out the initial operations for preparing the seeds for export. The following inspection and testing procedures are followed while processing the seed consignment for export:

X-ray and other Examination: Seed samples for export are X-rayed for detection of latent infestation by insect-pests. Apparently healthy looking seeds showing internal infestation are detained and destroyed and only the healthy seed samples are cleared for further processing.

Plating: Each seed sample is plated according to the international standards for seed testing for observation on seed-borne diseases. After seven days, seeds are examined for germination percentage and seen under the microscope for the presence of pathogens. Seeds samples showing poor germination or infection by the pathogen of quarantine importance to the concerned country are not exported.

ELISA Test: ICRISAT has facility to detect peanut mottle virus (PMV) reported in India, which can be transmitted by seeds (0.1 - 3.5%). Enzyme-linked Immunosorbent Assay (ELISA) tests are carried out to ensure freedom from PMV before export.

Treatment: The seeds ready for export (after all the tests) are finally inspected by the NBPGR scientists, and only after their approval, the seeds are treated with insecticide or fungicide or fumigated as mentioned in the import permit of the indenting country. Seeds intended for specific research and requested not to dress them with any chemical, are exported without treatment.

Additional Declaration: Special care is exercised to meet any additional declaration or requirement of the importing country while processing the seed material for export.

Issue of Phytosanitary Certificate (PSC): The certificate is signed and issued by the authorized official of the NBPGR in the form prescribed by the FAO International Plant Quarantine Convention, 1951, which is also called the "Rome Certificate." It contains details of seed health and all treatments given to the seeds, and mention of additional declaration, if any. The original PSC is put in an envelope affixed to the seed consignment.

Issues for Future

- Endangered germplasm from threatened areas of diversity to be salvaged and conserved for future use.
- Morphological and molecular characterization of germplasm to enhance their utilization in crop improvement.
- Multi location evaluation of core and mini core subsets to identify useful parents.
- Safety duplication of germplasm at other locations.
- Development of quick and reliable nucleic acid based detection and identification techniques for pathogens, particularly bacteria and viruses for quarantine purposes.
- Information generation on Pest Risk Analyses (PRA) of important pests of quarantine importance in ICRISAT-mandate crops.
- Conserve germplasm and provide samples to bonafide users.

References

Brown AHD (1989) Core collections: a practical approach to genetic resources management. *Genome* **31:** 818-824.

FAO (1998) The state of ex-situ conservation. P. 90. In *The state of the world's plant genetic resources for food and agriculture.* FAO, Rome.

Frankel OH (1984) Genetic perspectives of germplasm conservation In: W. Arber *et al.* (eds) *Genetic Manipulations: Impact of Man and Society.* Cambridge Univ. Press, Cambridge, England, pp 161-170.

Frankel MD, TB Brenneman and CC Holbrook (1999) Identification of resistance to *Rhizoctonia* limb rot in a core collection of peanut germplasm. *Plant Dis.* **83:** 944-948.

Holbrook CC, WF Anderson and RN Pittman (1993) Selection of a core collection from the U.S. germplasm collection of peanut. *Crop Science* **33:** 859-861.

Holbrook CC, MG Stephenson and AW Johnson (1997) Level and geographical distribution of resistance to *Meloidogyne arenaria* in the germplasm collection of peanut. *Agron. Abstr.* 157.

Holbrook CC, DW Wilson and ME Matheron (1998) Sources of resistance to preharvest aflatoxin contamination in peanut. *Proc. Am. Peanut Res. & Educ. Soc.* **30:** 21.

Ranga Rao GV and JA Wightman (1999) Status of the integrated management of groundnut pests in India. In: Upadhyaya RK, KG Mukerji and RL Rajak (eds.) *IPM System in Agriculture.* Aditya Books Pvt. Ltd., New Delhi, pp 435-459.

Sharma HC, G Pampapathy and LJ Reddy (2003) Wild relatives of pigeonpea as source of resistance to pod fly (*Melanagromyza* *obtusa* Malloch) and pod wasp (*Tanaostigmodes cajaniae* La Salle). *Genetic Resources and Crop Evolution* **50**: 817-824.

Upadhyaya HD (2003) Geographical patterns of variation for morphological and agronomic characteristics in the chickpea germplasm collection. *Euphytica* **132**: 343-352.

Upadhyaya HD (2005) Variability for drought resistance related traits in mini core collection of peanut. *Crop Science* **45:** 1432-1440.

Upadhyaya HD, PJ Bramel, R. Ortiz and Sube Singh (2002a) Geographical patterns of diversity for morphological and agronomic traits in the groundnut germplasm collection. *Euphytica* **128:** 191-204.

Upadhyaya HD, PJ Bramel, R Ortiz and Sube Singh (2002b) Developing a mini core of peanut for utilization of genetic resources. *Crop Science* **42**: 2150-2156.

Upadhyaya HD, SN Nigam and Sube Singh (2001b) Evaluation of groundnut core collection to identify sources of tolerance to low temperature at germination. *Indian J. Plant Genet. Resour.* **14:** 165-167.

Upadhyaya HD and R Ortiz (2001) A mini core subset for capturing diversity and promoting utilization of chickpea genetic resources. *Theoretical and Applied Genetics* **102:** 1292-1298.

Upadhyaya HD, R Ortiz, PJ Bramel and Sube Singh (2001a.) Development of core collection for Asia region.In: Kharkwal, M.C., and R.B. Mehra (eds.). *Hundred years of post-Mendelian genetics and plant breeding - Retrospect and prospect.* Diamond Jubilee Symposium of Indian Society of Genetics and Plant Breeding IARI, New Delhi, India, pp 43.

Upadhyaya HD, R Ortiz, PJ Bramel and Sube Singh (2003) Development of a groundnut core collection using taxonomical, geographical, and morphological descriptors. *Genetic Resources and Crop Evolution* **50:** 139-148.

Upadhyaya HD, RPS Pundir, CLL Gowda, KN Reddy and Sube Singh (2005) Geographical patterns of diversity for qualitative traits in the pigeonpea germplasm collection. *Plant Genetic Resources* **3(3):** 331-352.

Plant Introductions in the Maldives: Achievements and Opportunities in South Asia

KL Mehra
Former Director, National Bureau of Plant Genetic Resources, New Delhi-110012, India

Several United Nations agencies deputed consultants to assist the Republic of Maldives for selecting agri-horticultural plants for imports. Major findings of seventies, eighties and till recent times are reviewed. Plant introductions suited for northern, central and southern atolls were listed for growing in the fields, household plots, community farming, and those suited to specific islands/atolls. The findings showed that efforts related to plant introductions mostly confined to the introduction and comparative analysis of productivity of individual species rather than variety performance within specific target species.

Integrated Agri-horticultural Development Systems for islands/atolls and uninhabited islands were recommended for continued supply of vegetables, fruits and other economic plant/plant products. The scope for floriculture, agro-forestry, fodder plants, export crops is discussed. The need for the use of exotic species for afforestation, firewood, timber, boat- making is elaborated. With a view to obviate the need for imports, the use of hydroponics system is discussed to produce vegetables and fruits for the consumption of tourists.

Key words: Maldives, Plant introductions, Island plants, Agri-horticultural plants, Community farming

Several agencies of the United Nations system, especially the United Nations Development Programme (UNDP), Food and Agriculture Organization (FAO), have been helping the Republic of Maldives for the last several years through the services of several experts/ consultants, aimed at planning and development of Republic for its economic prosperity. In the context of agricultural (agriculture, horticulture, forestry, etc.) development of the Republic, several U.N. experts/ consultants visited the country for short terms or worked on specific projects for few months or years. They submitted their respective reports from time to time. The Republic does not have any programme on plant improvement and plant introductions which has a prominent role to play in the sustainable development of the Republic. While several experts visited the Republic to make recommendations for the development of agri-horticulture and forestry, only a few experts conducted field trials of selected introduced plant species to assess their suitability to agro-climatic conditions of selected islands of the Republic. It was unfortunate that follow up action with respect to suggested recommendations for plant introductions of target species was not taken up. There has always been a high shortage of trained personnel to carry out the recommendations of the expert. Being a least developed country, requests made by the Republic to different funding agencies were mostly accepted. Sometimes the international agencies International Board of Plant Genetic Resources (IBPGR) / International Plant Genetic Resources Institute (IPGRI-now Bioversity International) undertook genetic resources surveys, collection, evaluation and seed multiplication; Convention on Biological Diversity (CBD) for country report on bio-diversity; the International Union for the Conservation of Native and Natural Resources (IUCN) for report on the status of climatic change and on rare species, etc.). The limited staff of the Republic was attached with the consultant, but again due to staff shortage, the continuity of various programmes was not maintained.

Major Findings of Seventies

To start the programme on adaptive research and agricultural development, the UNDP/ FAO appointed an agronomist (1967-1973), Mr. W.T. Butany, to undertake agricultural surveys and crop production trials. During this period 172 islands (115 inhabited and 57 uninhabited) from 18 atolls, were surveyed. Test crop trials were carried out at five important agricultural islands to identify suitable crop species for maximizing agricultural production. An excellent report was prepared (Butany, 1974). It has been cited as a reference by several subsequent experts, as a source of information about the country-its physical characteristics, population,

Residence: 38, Munirka Enclave, New Delhi-110067
E-mail: klmehra@gmail.com

administration, economy, physical features of islands, cultivable area and land leasing, natural vegetation, wild life, soils, water resources, agricultural and fishing activities, subsidiary occupations, etc. Since this report introduces the reader to the status of agricultural development in different islands of the Republic, major findings of this report are presented below. Finger millet (*Eleusine coracana*) and Italian foxtail millet (*Setaria italica*) were two main crops grown widely throughout the Maldives during the southwest monsoon season. Sweet potato was grown mostly in the South and only in some parts of the North. Cassava was grown on a field scale in many parts of the South and in a limited area in the North, all under upland conditions. Other tuber crops, like *Dioscorea*, yams, *Alocasia* and some wild tubers were cultivated in household compounds. In the low-lying swampy areas, taro was grown mostly in the South, throughout the year, wherever suitable conditions existed.

The cultivation of maize, which occupied a fairly large area in the South between 1966 to 1970, went down to negligible levels in 1971, because people began to prefer rice. The people in the North and South also grew sorghum.

Green chili (*Capsicum annum* var. *grossum*) and small red onion (*Allium cepa)* were grown on a large scale. The cultivation of these crops spread after the government provided the incentive in the form of a cash price of Rf. 5,000 to the highest producer of each of the two crops. While green chili was grown only in the Southwest monsoon season, small onion was grown throughout the year on several islands in the North.

The cultivation of watermelon, especially in Thoddoo Island, provided ready cash. The crop was grown widely in the North, but on a limited scale in the South.

Breadfruit, banana, pine apple, mango, lemon, pomegranate, *jamrol*, passion fruit, custard apple, screw-pine, sapota, wood apple, papaya, bullock's heart, jack-fruit, guava, jujube, bael fruit were some of the fruits grown in household compounds/ backyards. Area under banana cultivation was increasing. Breadfruits grown in each household compound were consumed in the household.

Maldivians were not fond of vegetables and they did not practice vegetable cultivation. Cucurbits, beans and cabbage were grown mostly for the use of visiting foreigners. Pumpkin (*Cucurbita maxima*), because of its keeping quality, was grown widely. Cucumber was grown on a field scale in many islands. Ridge-gourd, bitter gourd, brinjal (egg plant), snake-gourd and drumstick, were grown here and there.

Coconut and arecanut were the only two crops taken as plantation crops. Arecanut was grown widely within the households only, while coconut was grown in the houses and outside.

The report mentions that in those days government used to decide whether people should do fishing, or agriculture, or both, in a specific year, depending on the amount of fish catch. Thus, at times, practically no land was taken up for community plantings.

All land preparations were done manually. The rainfall in the North during the northeast monsoon being meager, crops were grown in one season only, whereas in the South two crops could be taken up in a year. The report dealt with the cultivation practices of millets, maize, sorghum, tuber crops, onions and green pepper; pests and diseases; local storage practices; productivity and production of several crop and local uses of several crops. It referred to annual changes in the areas under each crop and incidence of diseases and pests, rodent damage, etc. It mentioned that millets and root/ tuber crops were mostly consumed in the islands. However, banana, coconuts, green and red chilli, small onions, watermelon were transported to Male for sale. Due to the lack of mechanized-motorized boats, several fresh fruits and vegetables used to get damaged in transit, the loss being 50-70% due to long delay and unfavorable weather. It mentioned several industrial products, viz., the agro-industries, handicrafts, mats, baskets, rope making etc.

Field trials of introduced food, cash, commercial, export-oriented, and vegetable crops, as well as of crops raised under the late sowing, in the second season, under low and large scale mechanized conditions, were conducted at different locations (Five islands-Guraidoo, Hithadoo, Kela, Vaikaradoo and Hithadoo). For each crop, the fertilizer dosage, time of sowing, yield, diseases and pests control and suitable varieties, were recommended. Economics of cultivation and income with or without the use of fertilizer was worked out. Such data were presented for rice, maize, millets, sorghum, pearl millet, small millets, finger millet, several legumes (greengram, blackgram, pigeonpea, cowpea), oil seed crops (groundnut, sesame), green pepper, small red onion, big-Bombay onion, fennel, methi, mustard, sweet potato, taro, cotton and other crops (tobacco, etc.). Trials on green manure crops were also undertaken. Information on double cropping, effect on yield under irrigated conditions, crop rotation recommendations, were also presented. Information, based on trials, using spade digging versus tractor ploughing, was also presented. The need for further research was pointed out. In conclusion, the report emphasized that agriculture in the Maldives was in a primitive condition. Mainly minor millets and some tuber crops were sown by hand labour and without any fertilizer application. Soils were poor. Agriculture was at a subsistence level. It was, however, established that several warm weather crops could be grown and that the response to fertilizer and pesticides was excellent, leading to a considerable increase in yields. The southern region was considered more suitable for the cultivation of tuber crops during the southwest monsoon season and cereal crops and pulses in the northeast monsoon season. In the North, all crops could be grown only in the southwest monsoon season. For double cropping in the north, supplementary irrigation was considered necessary.

The report provided information, on the cultivated areas (upland-lowland), topography, soils, physiological grade, water table, pH and salinity of several islands and on the economic analysis of crop trials.

This report provided much needed basic information about the country and the status of agricultural economy and development.

Major Findings of the Eighties and Nineties

In the eighties and nineties, several consultants visited the republic and some experts worked for long-term assignments, mainly for the agricultural extension and development works. Some of the major findings are given below:

Several reports deal with the description of vegetation and plant species found in several islands/ atolls of the Maldives (Willis and Gardiner, 1901; Fosberg, 1957; Fonseka and Balasubramanian, 1984; Adams, 1983; Anon, 1992). Truly native or naturalized species are around 260, of which about 100 were present before human settlement. Adams (1983) listed 583 plant species, of which 55% were cultivated. The number of species varies in an island/ atoll based on the land area and human disturbance. Anon (1992) listed 686 species (cultivated and wild) including recent imports (including their economic plant parts) in the Maldives. Five species of *Pandanus* occur in the Maldives of which four are endemic (St. John, 1961). Dense stands of *Pandanus* occurred in Hittadoo Island.

Arora (1984) surveyed the genetic diversity of several plant species occurring in several islands of the Maldives. Mehra (1986a, b; 1989) and Mehra and Ibrahim (1988) collected 628 samples of cultivated plants and their wild relatives from 86 islands located in 18 atolls. Mehra (1988, 1989) evaluated at Feridoo Island the genetic diversity of samples collected in the Maldives. Rich diversity was observed in several crop species including vegetables.

Tobacco Production

Prospects of tobacco production in the Maldives exist for growing *Bidi*-type and dark Air-sun cured Tobacco. Thuddo Island was not found suitable for the cultivation of tobacco. The crop can also be grown successfully in Feridoo Island. High yielding, disease resistant cultivars were listed (Hamid, 1980).

Spice Cultivation and Processing

Ginger, turmeric and curry leaf plant have high potential for production in the Maldives. Cinnamon and cloves could also be tried. Varieties of these plant species considered suitable for cultivation were listed (Jacob, 1984). Adaptive research, feasibility trials and demonstration trials were recommended. Methods of cultivation and processing/drying of different spices were demonstrated. At present the farmers do not use scientific ways of drying and processing the produce. Since there is a problem of transport and marketing, the plants/plant products may be scientifically dried and processed. Since the farmers are familiar with the cultivation of betel leaf, there should be no difficulty in cultivating black pepper in the Maldives. Booklets on the cultivation, agronomic practices and processing procedures, were prepared for ginger, turmeric, curry leaf, black/ white pepper, cinnamon and cloves (Jacob, 1984).

Jackfruit Production

Jackfruit can be successfully grown in several islands (Ito, 1984). The existing jackfruit trees in Kandumafushi, Ariadhoo, Aidafushi and Dharandoo were highly productive. It was recommended that the seeds/ planting materials from these trees should be used for planting more trees. A booklet was prepared, describing the procedure for air layering and growing of jackfruit.

Citrus Disease Control and Rehabilitation

Two strains of *Xanthomonas citri* pv. *citri,* called Asian strain – A and the Maldives strain, were responsible for citrus canker damage in the Maldives (Roistacher, 1987). The condition of heavy rainfall, ideal temperature and strong winds make the Maldives islands an ideal place for the development and distribution of citrus canker. The expert provided suggestions for its control, including (i) a detailed survey; (ii) legalized regulations for quarantine and eradication; and (iii) programmes for education, research, nursery operations and the training of personnel. Only disease free, fresh stocks of *Citrus* were recommended for introduction in future.

Horticulture – Production of Fruits and Vegetables

Several experts visited the Maldives from time to time and presented their impressions about the status of horticulture and the manner in which the horticultural development, using the elite plant introductions, should be taken up. Some important findings/suggestions are as follows:

Information on general growth, fruit bearing capacity and the reasons for low production, was presented, based on experimental study of 19 introduced tropical fruits species. Also information on seed germination, establishment and days to harvest, of several introduced vegetable crops based on experimental work in the Maldives was presented (Belien, 1984).

Based on the information dealing with the seed rate, depth of sowing, manner of spacing, yield capacity and pH values of 25 species of elite introduced vegetable crops, including leafy vegetables (Tropical-sub-tropical materials), species suitable for growing in the country were recommended. Suitability of 16 tropical and sub-tropical introduced fruit species for growing under Maldivian conditions was analyzed based on small-scale adaptability trials (Belien, 1984).

List of planting materials likely to suit the agro-climatic conditions of the country, along with their sources was prepared . Most of the materials are available in Sri Lanka, India, USA and Europe. No varieties from atoll countries of South Pacific/Fiji were recommended. Most of the recommended varieties of fruits and vegetables are presently doing well in the tropical/sub-tropical field environments of India, Sri-Lanka, Pakistan, (Philippe, 1980; Choudhri, 1984; Herath, 1986). No varieties were listed, which have shown adaptation to high pH levels, low fertility and drought conditions. No varieties have been recommended that are being produced by International Crop Research Centers, Asian Vegetable Research and Development Centre (AVRDC), CIAT, International Institute for Tropical Agriculture (IITA) etc. Evaluation trials of such elite cultivars need to be undertaken.

Species used as local, leafy vegetables were identified (Herath, 1986).

Several cropping patterns and related technological packages were recommended for annual, biennial, and long-range systems, using mixed cropping of two or more species (Herath, 1986). Similarly, cropping patterns were recommended for home gardens, community plantings and for growing in the uninhabited islands. Several experts recommended species of vegetables and fruits for use in the sequential cropping system, alley cropping system and integrated atoll/ island development systems (Mehra, 1993).

Several reports deal with packages of agronomic practices to be followed for several vegetable/fruit crops. Experts have presented their views about the manner through which the results of adaptive research could be taken up for implementation with the growers. Several reports deal with different aspects of extension and training methods, accountability, technological packages, staff training, training of growers, and woman participation.

Several extension bulletins have been published in the local language on vegetables, fruits and wood lots and on the diseases and pests of crops, vegetables and fruits.

An excellent, well-illustrated booklet, entitled – "Pests of crops and their control in the Maldives", has been published in English. It deals with the description of insects, symptoms of damage on plants, chemical control measures, and procedures for the biological control.

Besides these reports on the agricultural/ horticultural development, several economists of the UN system visited the country and offered their suggestions for planning agricultural research and development (Saini, 1987).

General Remarks

The perusal of available reports of various experts on the status of cultivation and production of specific economic plant species and their recommendation for problem oriented assignments (diseases and pests, scope for the cultivation of specific plant species) had revealed both constraints and possibilities of solving specific problems. Major constraints were the difficult agro-climatic conditions of the islands, irrigation facilities, lack of technical know how of modern agronomic practices, plant protection, transport and marketing of the produce, pricing policy of the agricultural products and protectionist measures to increase the production and use of crops known to be suitable for growing in the islands (Mehra, 1993). Several crops were produced in large quantities in the country in different years, e.g. coconut (1977), finger millet (1975), arecanut (1976), maize (1975), sorghum (1974), Italian millet (1975), cassava (1975), *Colocasia* (1976), *Alocasia* (1976), sweet potato (1975), onion (1975) and chilies (1976). Although to some extent high production may be due to more area under a specific crop in a particular year, yet it does show the potential of the country to produce economically high yields and even more so through the use of better crop varieties and management practices (Mehra, 1993).

The study of several reports has further revealed that the factors mainly responsible for increased production are, choice of suitable varieties, proper management practices, transfer of technology, peoples' participation and extension activities.

Several experts have discussed in detail how to grow the planting materials and to look after plants, using appropriate agronomic practices. Manuals have been prepared. The project on agricultural extension has done a commendable job in several islands to improve the plant protection measures. The major constraint has been the choice of varieties of specific crops. Several reports on horticulture have listed plant materials to be imported from specific countries. The varieties recommended are mostly standard, popular varieties of specific plant species. No serious attempt has been made to go through pertinent literature to select specific elite cultivars of different plant species suited to the coral island environment. This has been the major limitation in increasing the production levels of several species. This limitation is more important for tree species (fruits, timber trees) because one would know about the wrong choice of the material only when the trees begin to bear fruits or produce timber. Therefore, selection and introduction of suitable material of different species is very important to increase the production of most of the target plant species.

Household Farming

Islanders generally grow a few trees of coconut, breadfruit, drumstick and other tropical fruits, curry leaf, betel leaf, leafy vegetables, root crops, sometimes areca nut, chillies, bell pepper, egg plant etc. Mostly traditional varieties are sown from last year's seed stocks. The Ministry of Fisheries and Agriculture (MOFA) annually prepares suitable plans, providing information on crops and their introduced varieties to be grown, cultural practices to be followed and from where to get seeds and planting materials. In each island, where atoll chief lives, a demonstration plot may be laid with suitable choice of elite introduced species. The concept of nutritional gardens may be developed. When people come to atoll offices, they may see such demonstration plots. Regional hospitals are located in some islands. Such demonstration plots can also be laid there (Mehra, 1993).

Community Farming

In several islands, non-forest land is allotted to islanders for cultivating vegetables and watermelon. Since plots are adjacent and the farmers are interested to grow crops, timely guidance for cultural practices to be followed would highly increase crop production. Women committees of the islands should be involved in this endeavor. A list of crops to be sown may be provided to the islanders.

Introduced Varieties for Crop-Island Concept

A few islands have specialized in the cultivation of specific crops, e.g., Kela – cassava, banana and sweet potato; Nolhivaram – betel leaves; Feevah – banana; Kaashidhoo – papaya; Thoddoo – watermelon; Isdhoo – cassava and taro; Hoadedhdhoo – chilli; Gadhdhoo – taro; Foa Mulah – taro and sweet potato and Hithadhoo – banana. Improved introduced varieties of crops may be supplied to the farmers to obtain increased production. Marketing facilities and pricing policies should encourage the cultivators. In fact, additional strategy should be to develop southern atolls for the production of root crops; central atolls for the production of onion, chili, water melon and other crops, which can be sold easily in Male; whereas northern atolls should be developed for the production of cereals and millets (Mehra, 1993).

Development of Uninhabited Islands

Leasing of the uninhabited islands are expected to develop them. Before a lease agreement is signed, the MOFA may prepare a programme of rehabilitation and development of the island in collaboration with the leassee. The development plan may be included in the lease agreement. The MOFA may supply improved introduced cultivars of crop plants, coconut and tree species. There should be a separate plan for the planting of tree species. Technical inputs may be provided by the MOFA. The development of uninhabited islands under the guidance of the MOFA would be one of the best ways of extension of research findings. Leassees could also be advised to record data on production levels. When a tree is cut with the permission of the government, the indenter is required to plant another sapling or a few seeds of tree species. Even such plantation programmes should fall under uninhabited island development plan. A suitable plan providing details of species to be sown, spacing between plants and information on how to raise the planting materials should be provided by the MOFA. Some economically rich commercial enterprises may be persuaded to take up planned development work in the uninhabited islands (Mehra, 1993).

Integrated Agri-horticultural Development

Multi-crop, agri-horticultural development of islands/ atolls should receive priority. The farming systems should be developed to have a continuous supply of vegetables and fruits (Mehra, 1993). This is easily possible at least in the southern atolls since they receive good rainfall in both seasons. Species diversification is also possible.

Ornamental Horticulture

Maldivian people are very fond of ornamental horticulture. Most of the households in Male have ornamental plants in the front yards of their homes. There is a good scope to develop ornamental horticultural enterprises to generate more income (Mehra, 1993).

Development of Agro-industry

In several islands, agricultural products are produced in plenty to generate surplus. However, due to the lack of marketing facilities and transportation problems to take the produce to Male for sale, farmers feel reluctant to grow several crops. If spices could be dried, breadfruit could be made into chips, and root crops (cassava – sweet potatoes) could be processed, more income could be generated.

Similarly, several tropical fruits grown in the far off islands could be processed. Agro-based industries may be developed around islands, which specialize in crops amenable for long-term preservation (Mehra, 1993).

Cultivation of Plants for Fodder

Goat production has been taken up in several islands without undertaking a plan for fodder production. This enterprise being new to the islanders, they are not aware about what plant species to use as fodder. Several tropical forage plant species are suitable for growing in the islands. Species of *Pueraria, Centrosema, Desmodium, Macroptilium* and *Leucaena* may be tried. All are legumes and can also enrich the soils, being capable of nitrogen fixation. *Vigna marina* and *Desmodium umbellatum* already grow in several islands. *Desmodium umbellatum* is also amenable to several cuttings. Similarly, several grasses, i.e., species of *Cenchrus, Setaria, Pennisetum, Cynodon,* etc. should be evaluated for growing in the islands. The coastal Bermuda grass (from U.S.A) is especially suitable for the coastal areas (Mehra, 1993).

Crops with Export Potential

Catharanthus roseus (Periwinkle) grows wild in several islands. It is grown and exported by India and some Latin American countries to USA and Europe for use in the pharmaceutical industry. Two alkaloids extracted from this plant are used for curing certain forms of leukemia. The cultivation of crops like periwinkle, betel and Chinese ginger with export market in USA/Europe/ Pakistan/India and Japan, respectively may be encouraged (Mehra, 1993).

Hydroponics

Since the tourist industry started in 1972-73, the number of visitors to the Maldives have increased with an amazing growth rate, reaching a total of 180,000 registered tourists in 1991.This figure practically exceeds the existing domestic population, when seen in the light of the effective purchasing power. There is a demand generated by European and Japanese tourists who consume several species of vegetables. In 1991, the country imported 4,890 tons of fresh vegetables, amounting to Rf 3.19 million and another Rf 4.5 million of potato, sweet potato, yams and cassava. Strong possibility exists of meeting this high demand by producing fruits and vegetables through hydroponics in the Maldives. A comparison of the landed prices of vegetables and fruits presently being imported and distributed to the resort islands, with the cost of producing those by hydroponics seem not only much advantageous but also reasonable since it would provide employment to the local people besides saving the foreign exchange. One experimental station, located in Biyaadoo, produced tomato at the cost of $ 1.25/kg, which is a little higher than the whole sale import cost, but lower than the retail price. In fact, the tourists consume 39% of the imported vegetables, but if we take potato and onions out, the tourists consume 53% of the rest of the vegetables. Thus, the hydroponics is a promising agro-industrial enterprise, which deserves much attention and encouragement (Mehra, 1993).

Afforestation Using Exotic Species

With a view to meet its daily energy requirements for cooking food and for the production of lime from corals, wood is cut or collected from the native trees or shrub species. Over exploitation of tree cover of the terrestrial eco-systems has led to a rapid loss of natural (plant) resources. One of the ways to cater to the need of firewood is to plant exotic, quick growing tree species.

Bamboo and its products are used in the Maldives for fishing poles, scaffolding, furniture and handicraft. During 1987 to 1991, bamboo and its products (baskets, curtains, canned shoot, skewers, handicrafts and pies, etc.) were imported worth Rf 1,845,538, and in 1991 over ten thousand pieces of fishing roads worth Rf 495 thousand were imported. Therefore, to make the country self-sufficient, bamboo plantation may be taken up in selected islands.

Exotic Species for Fire-Wood

Existing bamboo stands adapted to the soil-climatic conditions of the Maldives may be evaluated in other islands. Other species viz. *Bambusa arundinacea, B.atra, Dendrocalamus strictus, Melocanna baccifera, Ochalandra scriptoria, Schizostachyum lima, S. lumampao, Thyrsostachys siamensis and Dinochloa pubiramea* have also been recommended for trials and use in the Maldives (Virtucio, 1993).

Present Afforestation Programmes

Casuarina trees were planted in 5 islands each in Haa Alifu, Lhaviyani, Alifu and Dhaalu atolls; all the inhabited islands in Meemu atoll; and some selected islands in Lammu atoll. *Eucalyptus* was also planted in 4 islands. Plantations of bamboo were taken up in Raa and Alifu atolls. The technique for raising the seedlings and propagation of cuttings had been standardized and the staff of the MOFA explained such procedures to several growers of these atolls.

Wood is generally getting scarce and imported timbers are now used for many purposes, suggesting extensive modification of the natural vegetation (Brune, 1984). Considerable ecological damage has already been done to the ecology as a result of fuel-wood and timber exploitation (Saini, 1987).

With a view to promote the use of locally grown plant species for use as timber handicraft and fire wood and to save much needed foreign exchange, detailed instructions for raising nurseries were prepared and those were now being followed by the staff of the MOFA. Methods of propagation and raising seedlings have continued to be demonstrated to the local people. Several exotic species, which could be grown in the Maldives, were recommended, for use as fire-wood (Brune, 1984).

The total cultivable area is given as 46,766 acres (Anon, 1987) most of which is used for subsistence production. Agricultural production in 1984 involved more than 10% of the country's labor, but accounted for 11.44 % of the Gross Domestic Product (GDP), having declined from around 18% in 1981. In 1985, however, despite a 4.83% increase in GDP from Agriculture, this sector share of total GDP had fallen to 10.48 % (Saini, 1987). The contribution of agricultural sector to the total GDP has continued to decline. Thus, this sector accounted for 9% (1990), 3.6% (1995) and 2.8% (2000) of the total GDP. The growth rate of agriculture has been 0.74 (1981-1985), 4.1 (1985-90) and 2.6 (1990 onwards) per cents, respectively (Mehra, 1993).

The future opportunities pointed out in this presentation, and the programmes presently being taken up by the MOFA, especially coconut rehabilitation; timber tree plantation; vegetable and fruit tree growing, including the use of improved varieties; increased production of poultry and eggs; integrated island/atoll development; better transport and marketing facilities for the agricultural produce; rural credit; etc., are expected to start paying off.

References

Adams CD (1983) Report to the government of Maldives of Flora identification. FAO 9 RAS79/123).

Anon (1992) Ministry of Fisheries and Agriculture. Catalogue of Plants. Male, Republic of Maldives.

Arora RK (1984) Plant genetic resources of the Maldives: An eco-geographical survey. FAO (AGPG: IBPGR 184/5).

Belian J (1984) Agricultural Development, Maldives: The suitability of horticultural crops in Maldives. End of assignment report, FAO (MDV/80/0033), Field document number 4, 3 volumes.

Brune A (1984) Report to the government of Maldives on tropical wood lots. FAO (MDV/80/003).

Butany WT (1974) Report to the government of the republic of Maldives on agricultural survey and crop production. TA 3270 FAO. Rome, Italy.

Chaudhri SA (1984) Assistance to planting programme. FAO (TCP/MDV/2305).

Fonseka RN de and S Balasubramanian (1984) An index of Maldivian names to the plants and vegetable products of Male and some of the other islands in north Male atoll.

Fosberg FR (1957) The Maldive Islands, Indian Ocean. Atoll *Res. Bull.* **58:** 1-37.

Hamid IFA (1980) Report to the government of Maldives on prospects of tobacco production in Maldives islands. FAO (TCP/MDV/8904).

Herath HME (1986) Report on status of agriculture and proposals for agricultural development. FAO (MDV/80/003).

Ito PJ (1984) Agricultural development, Interim report on jackfruit consultancy, FAO (MDV/80/003).

Jacob VJ (1984) Spice cultivation and processing. Republic of Maldives. FAO (TCP/MDV/ 4401).

Mehra KL (1986a) Plant genetic resources collecting in the Maldives. AGPG: IBPGR/86/ 119.

Mehra KL (1986b) Plant Genetic Resources collecting in the Maldives. 2nd mission report, AGPG: IBPGR/87/13.

Mehra KL and AH Ibrahim (1988) Genetic resources in the Maldives. FAO/IBPGR *Plant Genetic Resources Newsletter,* **75/76:** 42-43.

Mehra KL (1988) First evaluation mission report .FAO/ IBPGR, Rome, Italy.

Mehra KL (1989) Second evaluation mission report. FAO/ IBPGR 89/52. Rome, Italy.

Mehra KL (1993) The study of agriculture sector's contribution to GDP and proposal for afforestation programme. UNDP, Male, Maldives.

Philippe JM (1980) Assistance to the demonstration farm / training center. Thoddhu island. First visit report. TCP/MDV/ 8904.

Roistacher CN (1987) Citrus disease control and rehabilitation. FAO (TCP/MDV/6752).

Saini GR (1987) Medium term sector plan: 1988-1991 for agricultural development of Maldives. Consultant's report (MDV/80/003).

St John (1961) Revision of the genus *Pandanus* Stickman Part 5, *Pandanus* of the Maldives Islands and the Seychelles Islands, Indian Ocean. *Pac. Sci.* **15**: 328-346.

Virtucio FD (1993) Bamboo introduction and management in the Maldives. FAO, Rome, Italy.

Willis JC and JS Gardiner (1901) The botany of the Maldives islands. *Ann. Roy. Bot. Gard.,* Peradeniya. **1**: 45-164.

Plant Introduction in India During Pre- and Post-CBD Periods - An Analysis

Vandana Tyagi, AK Singh, Nidhi Verma, Deep Chand, RV Singh and BS Dhillon
National Bureau of Plant Genetic Resources, New Delhi-110012, India

An analysis of the germplasm import into India before and after the adoption of Convention on Biological Diversity (CBD) was undertaken with the objective of finding the impact of signing this legally binding instrument by contracting countries. Plant Genetic Resources are at NBPGR for research purpose, quarantine examination and onward transmission to the users. The records of such imports five years prior to the signing CBD (1988-92) and five years after CBD (1997-2001), with a gap of 1993-1996 as transit phase were analysed. The impact was studied separately for CGIAR centres national gene banks in different group of crops. An overall decrease of about 14.5% in introduction of germplasm was observed during post-CBD period. This decline has, however, not affected imports from CG centres. The decrease in introduction from National Gene Banks in different countries suggest a cautious approach for sharing of germplasm. Countries like USA, Germany, Canada, UK and Italy still remain the main supplier of germplasm to India.

Key words: Convention on Biological Diversity (CBD), Plant introduction, Pre- and Post-CBD analysis

Plant Genetic Resources (PGR) are a prerequisite to any crop improvement programme. They are the heritage to be conserved for current and future generations and for the food and nutritional security of the ever-increasing world population. Crop improvement is therefore the axle of the wheel of human life. The plant breeders need diverse germplasm to develop better varieties. Hence, the acquisition of diverse and superior germplasm from exotic sources is of prime importance. Introduction of exotic germplasm has enriched Indian agriculture since times immemorial. Introduction has resulted in establishment of large number of crops and development of high yielding varieties. Not only India, almost all countries are interdependent with respect to genetic resources required for their crop improvement programs.

Enforcement of Convention on Biological Diversity (CBD), 1992 and provisions of Trade Related Aspects of Intellectual Property Rights (TRIPS) in 1990's led to the apprehension that exchange of germplasm would get restricted (Brahmi *et al.*, 2004). Developing countries have been and continue to receive large amount of germplasm from Interanational Agricultural Research Centres (IARCs) supported by Consultative Group on International Agricultural Research (CGIAR) Centres. Hence, an analysis has been carried on introduction of germplasm from CGIAR Centres hereinafter referred as CG centres and other national genebanks of different countries hereinafter referred as NGB. This is based on the records of the Germplasm Exchange Division of NBPGR, published quarterly in the form of Plant Introduction Reporters [NBPGR (1990-91, 91-92, 1997, 1998, 1999, 2000; Kumar *et al.*, 1988(a-d); Kumar *et al.*, 1989(a-d); Kazim *et al.*, 1990 (a-d); Singh *et al.*, 2001 (a-d)] The study has been categorized into two parts pre-CBD period (1988-1992) and post-CBD period of (1997-2001) to get the comparative idea on how the import was affected after CBD came into force. For this study years 1993 to 1996 were not included to avoid the effect of transit phase. The germplasm introduced in the form of international nurseries/ trials for multilocation testing from CG centres were also not included. Various cases were considered for the study- i) Crops dealt by CG centres; ii) Crops dealt by Asian Vegetable Research and Development Centre (AVRDC), Taiwan and iii) Crops not dealt by IARCs.

Crops dealt by CG Centres

India has been receiving germplasm collections of rice from International Rice Research Institute (IRRI), Philippines; maize, wheat, triticale as well as barley from International Centre for Maize and Wheat Improvement (CIMMYT), Mexico; barley, lentil, fababean, wheat, chickpea and forages from International Center for Agricultural Research in Dry Areas (ICARDA), Syria; potato, sweet potato, Andean root and tuber crops from International Potato Centre (CIP), Lima, Peru; beans, cassava, forage grasses and legumes from Central Institute for Tropical Agriculture (CIAT), Columbia; food legumes (cowpea, lima beans, soybean), root and tuber crops (sweet potato, cassava, yams), maize and rice from International Institute for Tropical Agriculture (IITA), Nigeria and sorghum, pearl millet, chickpea, pigeonpea and groundnut from International Crop

Research Institute for the Semi Arid Tropics (ICRISAT), India. The data on number of accessions introduced in different crop groups is discussed below

Cereals and Millets

In cereals and millets group, where large number of accessions have been introduced, are rice, wheat, maize, barley and sorghum. The germplasm of these crops are mainly received from IRRI, Philippines (Rice); CIMMYT, Mexico (Wheat, barley, triticale); and ICARDA, Syria (wheat, barley, triticale). During pre-CBD, the germplasm introduced from CG centres and NGB were 66.54 percent and 33.46 percent respectively. During post CBD a decline of about 1 percent was observed, 65.25 percent and 34.74 percent respectively. As regard the breeding material in the form of international nurseries/ trials introduced every year from IRRI, CIMMYT and ICARDA for multilocational testing in paddy, wheat, maize, barley, triticale, lentil, chickpea, fababean, pea, about 10,000-15,000 entries were introduced with 3-4 replications and 5-10 sets of each nurseries ranging from 1.5 lakhs to 2.5 lakhs samples. Thus, if these breeding materials are included in this study, appears to be dependence of 75 per cent on CG centres for germplasm of cereals and millets (Table 1).

Table 1. Germplasm introduced in cereals and millets from CG centres and NGB

Crop	Accessions (no.) CG centres		Accessions (no.) NGB	
	Pre-CBD	Post -CBD	Pre-CBD	Post -CBD
Rice	16,384	16,199	755	3,462
Wheat	11,968	3,492	5,209	4,546
Maize	3,939	9,584	1,332	5,414
Barley	103	83	334	69
Sorghum	2,164	2,559	3,952	1,752
Others	2,284	1,254	6,948	2,988
Total	**36,842**	**33,171**	**18,530**	**18,242**

In introductions made through CG centres, germplasm accessions contributed the largest share being 94.3 per cent and 93.4 per cent pre- and post-CBD respectively; on the other hand wild species contributed 2.7 and 2.3 per cent pre- and post-CBD respectively. The share of introduction of improved varieties from CG centres was 2.9 per cent and 4.4. per cent pre- and post-CBD respectively. In case of NGB, germplasm comprised 95.3 per cent and 96.5 per cent pre- and post-CBD respectively; wild 1.2 and 0.5per cent and varieties 3.5 and 4.4 per cent respectively. It can be concluded that during post- CBD an increase of 1.5 percent was observed in case of varieties while a decrease of 1.3 percent in is seen in case of germplasm (Table 2).

Grain legumes

Grain legumes are introduced from ICARDA, Syria; CIAT, Columbia and IITA, Nigeria. In grain legumes the ratio of germplasm introduced through CG centres and NGB is almost equal. Study exhibited that a total of 4,000 to 9,000 accessions were introduced in grain legumes and the CG centres contributed 42.2 per cent and 55.0 per cent during pre- and post-CBD respectively and NGB contributing 57.7 per cent and 45 per cent respectively. Though during post CBD the number of accessions has shown a significant increase in case of both CG centres and NGB. There is a significant increase of 12.8 per cent in post-CBD introductions from CG centres while a significant decline of 12.7 percent in post-CBD introductions from NGB (Table 3).

Oilseeds

In case of oilseeds groundnut is received from ICRISAT and import has been 41.3 percent and 64.1 percent during pre- and post-CBD respectively. From NGB of 58.7 and 35.9 per cent have been introduced pre- and post-CBD respectively (Table 4).

Table 2. Introduction of germplasm (GP), varieties (VR) and wild species from CG centres and NGB

Crop	Pre- CBD (1988-1992) No. of accessions						Post -CBD (1997-2001) No. of accessions					
	CG centres			NGB			CG centres			NGB		
	GP	VR	Wild	GP	VR	Wild	GP	VR	Wild	GP	VR	Wild
Rice	14,947	430	1,007	736	19	–	15,096	591	476	3,173	261	31
Wheat	11,932	37	–	4,907	249	62	3,033	360	99	4,369	177	–
Maize	3,805	134	–	1,015	317	–	9,062	522	–	5,408	6	–
Barley	103		–	250	12	72	83	–	–	53	16	–
Sorghum	1,682	482	–	3,891	53	10	2,559	–	–	1,686	66	–
Others	2,284		–	6,867	4	77	1,057	23	174	2,817	8	63
Total	34,753	1,083	1,007	17,666	654	221	31,817	1496	749	17,506	534	94
Percent	**94.3**	**2.9**	**2.7**	**95.3**	**3.5**	**1.2**	**93.4**	**4.4**	**2.3**	**96.5**	**2.2**	**0.5**

Table 3. Germplasm introduced in grain legumes from CG centres and NGB

Crop	Accessions (no.) CG centres		Accessions (no.) NGB	
	Pre-CBD	Post -CBD	Pre-CBD	Post- CBD
Chickpea	1,073	2,130	439	1,558
Cowpea	962	129	290	264
Lentil	509	3,882	198	102
Mungbean	114	–	238	7
Pea	117	930	1,076	1,054
Pigeonpea	64	1,596	482	264
Soybean	686	51	931	3,595
Others	506	115	1,852	337
Total	**4,028**	**8,833**	**5,506**	**7,125**

Table 4. Germplasm introduced in groundnut from CG centres and NGB

Crop	Accessions (no.) CG centres		Accessions (no.) NGB	
	Pre-CBD	Post -CBD	Pre-CBD	Post -CBD
Chickpea	1,073	2,130	439	1,558
Groundnut	508	1,582	722	887
Total	**1,581**	**3,712**	**1,161**	**2,445**

Tubers

Potato, sweet potato are introduced from CIP, Lima, Peru. This CG centre has contributed 56.8 percent and 46.2 percent of total introductions during pre- and post-CBD respectively (Table 5).

Table 5. Germplasm introduced in tubers (potato, sweet potato) from CG centres and NGB

Crop	Accessions (no.) CG centres		Accessions (no.) NGB	
	Pre-CBD	Post-CBD	Pre-CBD	Post-CBD
Tubers	381	341	290	396

Crops dealt by Asian Vegetable Research and Development Centre (AVRDC), Taiwan

The vegetable crops (*Allium* sp., tomato, pepper, eggplant, okra, cucumis, leafy brassica, cucurbits) and grain legumes (cowpea, mungbean, urdbean, pea and soybean) introduced from AVRDC, Taiwan is discussed below

Vegetables

In vegetables, NGB contributed 85.2 per cent and 97.4 per cent of introductions during pre- and post-CBD respectively. Significant increase of 12.2 per cent is observed in post-CBD introductions from NGB. This may be a result of special emphasis for procuring the vegetable germplasm by NBPGR (Table 6).

Table 6. Germplasm introduced in vegetables from AVRDC Taiwan and other countries

Crop	Accessions (no.) CG centres		Accessions (no.) NGB	
	Pre-CBD	Post -CBD	Pre-CBD	Post -CBD
Brinjal	–	–	416	106
Chilli	270	24	1,267	569
Cucumis	–	93	252	1,684
Okra	–	–	567	40
Onion	11	–	172	301
Tomato	725	–	1,899	1,068
Others	–	–	1,230	684
Total	**1,006**	**117**	**5,803**	**4,452**

Grain legumes

The germplasm introduced from AVRDC, Taiwan comprised 37.1 per cent and 13.9 per cent respectively during pre- and post- CBD respectively. From NGB 62.9 percent and 86.1 per cent germplasm of grain legumes was received during pre- and post-CBD period respectively (Table 7).

Table 7. Germplasm introduced in grain legumes from AVRDC Taiwan and NGB

Crop	Accessions (no.) CG centres		Accessions (no.) NGB	
	Pre-CBD	Post -CBD	Pre-CBD	Post -CBD
Cowpea	90	39	200	224
Mungbean	74	–	164	7
Pea	–	32	1,076	1,022
Soybean	377	613	554	2,982
Total	**541**	**684**	**1,994**	**4,235**

Crops not dealt by IARCs

The other crops not being maintained by CG centres such as oilseeds and fruit crops are introduced from NGB. The quantum of germplasm introduced from different countries is presented in Table 8.

Oilseeds

In oilseeds the introduced germplasm is mainly from NGB. During pre-CBD the total germplasm accessions introduced were 7,355, which decreased to 3,811 accessions in post-CBD.

Table 8. Germplasm introduced in Oilseeds from NGB

Crop	Accessions (no.) NGB	
	Pre-CBD	Post- CBD
Brassica sp.	1,758	892
Castor	47	16
Linseed	363	–
Others	963	518
Safflower	1,765	334
Sunflower	2,459	2,051
Total	**7,355**	**3,811**

Fruits

In fruits, the import has increased during post CBD. A significant increase of 3.6 percent is observed in post CBD introductions from NGB as a result of special efforts for procuring the fruit germplasm by NBPGR (Table 9).

Table 9. Germplasm introduced in fruits from NGB

Crop	Accessions (no.) NGB Pre-CBD	Post -CBD
Apple	14	18
Citrus	128	64
Mango	7	–
Papaya	27	1
Peach	75	–
Prunus sp.	27	14
Others	405	1109
Total	**683**	**1,206**

The germplasm introduced in different crop groups viz. forages, fibers, medicinal and aromatic plants, spices and condiments, narcotics, beverages, ornamentals, under utilized crops, sugar yielding crops is presented in Table 10. The total introductions has increased to about 2.6 per cent during post-CBD from IARCs while a decline of 14.5 per cent is observed in total introductions made from NGB during post-CBD.

Table 10. Germplasm introduced in different crop groups from IARCs and NGB pre-CBD and post-CBD

Crop	Accessions (no.) CG		Accessions (no.) NGB	
	Pre-CBD	Post -CBD	Pre-CBD	Post- CBD
Chick pea	1,073	2,130	439	1,558
Cereals	36,842	33,171	18,530	18,242
Forages	13	0	3,290	1,645
Grain legumes	4,028	8,833	5,506	7,125
Oilseeds	508	1,582	7,714	4,698
Fibres	0	0	2,743	61
Vegetables	1,006	117	5,803	4,452
Tubers	381	341	290	396
Fruits	27	4	656	1,222
UUP*	106	0	398	314
Others	0	0	1720	1,750
Total	**43,984**	**46,178**	**47,089**	**41,463**

*Underutilized Plants

Overall a decline of 14.5 per cent was observed in the germplasm introduced during post-CBD. A total of 89,561 accessions in various crops were introduced during pre-CBD and the number of accessions of germplasm introduced in various crops decreased to 83,682 during post-CBD.

One of the interesting findings of the study is that 81 per cent of the total germplasm introduced was imported from countries which were not the centre of origin of that particular crop i.e. these materials were introduced from countries other than their centre of origin: whereas only 19 percent of the total germplasm introduced was received directly from the countries or the centres of origin of that particular crop. In other words, a large amount of germplasm have been collected by various nations from the place of origin and conserved at their genebanks from where regular exchange of material is taking place (Table 12).

Table 11. Total germplasm introduced during Pre and Post-CBD

Crop	Accessions (no.) NGB Pre CBD	Post CBD
Cereals	55,372	51,413
Forages	3,302	1,645
Grain legumes	9,534	15,992
Oilseeds	8,222	6,280
Fibres	2,743	61
Vegetables	6,809	4,569
Tubers	671	737
Fruits	683	1,226
UUP*	106	323
Others	1,720	1,436
Total	**89,162**	**83,682**

* Underutilized Plants

Conclusions

The analysis revealed that for the food crops mainly cereals there is 75 percent dependence on CG centres introductions, while grain legumes and oilseeds are more or less equally shared from both CG and NGB. In vegetables and fruit crops the situation is reverse, the major introductions being from NGB. Results indicate an overall decline of 6.6 percent in the introduction of accessions during post-CBD period. Despite overall decrease, there was an increase in import of accessions from CG centres. This decline was confined to the supplies from NGBs, which suggest of cautious approach adopted by the different countries in sharing of germplasm. During Post-CBD there was an overall decline of 14.5 percent in introduction. The trend may however change after the International Treaty on Plant Genetic Resources for Food and Agriculture (IT-PGRFA), a legally binding treaty came into force (FAO 2002), which envisages a facilitated access to plant genetic resources for food and agriculture held by countries through multilateral system (MS) of exchange. Also, the results indicated that 81percent of the germplasm introduced from NGB or other countries did not originate there or they are not the centres of diversity of the respective crops. This

Table 12. Total germplasm introduced (origin different or same from the supplier country)

Crop group	CG centres				NGB			
	Pre-CBD		Post-CBD		Pre-CBD		Post-CBD	
	Origin different from the supplier country	Origin same from the supplier country	Origin different from the supplier country	Origin same from the country	Origin different from the country	Origin same from the country	Origin different from the supplier country	Origin same from the country country
Cereals and millets	32,880	3,962	23,510	9,625	15,395	3,135	17,216	926
Oilseeds	508	–	1,582	–	5,643	290	3148	1,550
Grain legumes	2,306	1,722	8,833	–	4,818	688	4,809	2,416
Forages	13	–	–	–	2,439	851	1,352	293
Fibres		–	–	–	915	1,364	44	17
Tubers	381	–	141	200	227	63	380	16
Vegetables	1,006	–	99	18	3,703	2,096	4,274	178
Fruits	27	–	–	–	571	92	1,043	151
UU and UEP*	106	–	–	–	398	–	175	139
M and AP		–	–	–	922	161	396	22
Ornamentals		–	–	–	70	–	47	4
Narcotics &Beverages		–	–	–	105	104	324	123
Spices and Condiments		–	–	–	114	80	163	–
Sugar yielding		–	–	–	184	–	317	40
Total	**37,227**	**5,684**	**34,165**	**9,784**	**35,504**	**8,942**	**33,688**	**5,875**

* Under utilized and underexploited Plants

might be because of early realization of the importance of plant genetic resources in these countries, leading to collection and conservation from world over. Amongst the NGB, USDA was the main supplier of germplasm to India. Significant number of accessions were also introduced from Australia, UK, Italy, Germany and Canada.

References

Brahmi P, S Saxena and BS Dhillon (2004) The Protection of Plant Varieties and Farmers' Rights Act of India. *Current Science*, **86**: 392-398 pp.

CBD (1992) http:/www.biodiv.org. The Secretariat, Convention on Biological Diversity, Montreal, Canada.

FAO (2002) The International Treaty on Plant Genetic Resources for Food and Agriculture. FAO. Rome, Italy.

Kumar Basant, M Kazim and Deep Chand (1988a) Plant Introduction Reporter Jan.-March 1988 (1), NBPGR Publication. 265 pp.

Kumar Basant, M Kazim and Deep Chand (1988b) Plant Introduction Reporter April-June 1988 (2), NBPGR Publication. 228 pp.

Kumar Basant, M Kazim, Deep Chand and Ranjana Nagpal (1988c) Plant Introduction Reporter July-August 1988 (3), NBPGR Publication. 118 pp.

Kumar Basant, M Kazim, Deep Chand and RL Sapra (1988d) Plant Introduction Reporter Sept-Dec.1988 (4), NBPGR Publication. 211 pp.

Kumar Basant, M Kazim, Deep Chand and RL Sapra (1989a) Plant Introduction Reporter Jan.-March 1989 (1), NBPGR Publication. 101 pp.

Kumar Basant, M Kazim, Deep Chand and RL Sapra (1989b) Plant Introduction Reporter Reporter April-June 1989 (2), NBPGR Publication. 871 pp.

Kumar Basant, M Kazim, Deep Chand and RL Sapra (1989c) Plant Introduction Reporter Reporter July-August 1989 (3), NBPGR Publication. 82 pp.

Kumar Basant, M. Kazim, Deep Chand and RL Sapra (1989d) Plant Introduction Reporter Reporter Sept-Dec. 1989 (4), NBPGR Publication. 130 pp.

Kazim M, BP Singh, RV Singh, Deep Chand and Pratibha Brahmi (1990a) Plant Introduction Reporter Jan.-March 1990 (1), NBPGR Publication 148 pp.

Kazim M, B.P. Singh, RV Singh, Deep Chand and Pratibha Brahmi (1990b) Plant Introduction Reporter April-June 1990 (2), NBPGR Publication. 117 pp.

Kazim M, BP Singh, RV Singh, Deep Chand and Pratibha Brahmi (1990c) Plant Introduction Reporter July-August 1990 (3), NBPGR Publication. 57 pp.

Kazim M, BP Singh, RV Singh, Deep Chand and Pratibha Brahmi (1990d) Plant Introduction Reporter Sept.-Dec. 1990 (4), NBPGR Publication. 81 pp.

NBPGR (1990-91) Annual Report, National Bureau of Plant Genetic Resources, New Delhi, 172 pp.

NBPGR (1991-92) Annual Report, National Bureau of Plant Genetic Resources, New Delhi, 163 pp.

NBPGR (1997) Annual Report, National Bureau of Plant Genetic Resources, New Delhi, 145 pp.

NBPGR (1998) Annual Report, National Bureau of Plant Genetic Resources, New Delhi, 148 pp.

NBPGR (1999) Annual Report, National Bureau of Plant Genetic Resources, New Delhi, 152 pp.

NBPGR (2000) Annual Report, National Bureau of Plant Genetic Resources, New Delhi, 154 pp.

Singh RV, Deep Chand, Pratibha Brahmi, Vandana Tyagi, Nidhi Verma and SP Singh (2001a) Plant Germplasm Reporter January-March 2001, NBPGR Publication 210 pp.

Singh RV, Deep Chand, Pratibha Brahmi, Vandana Tyagi, Nidhi Verma and SP Singh (2001b) Plant Germplasm Reporter April-June 2001, NBPGR Publication 175 pp.

Singh RV, Deep Chand, Pratibha Brahmi, Vandana Tyagi, Nidhi Verma and SP Singh (2001c) Plant Germplasm Reporter July-August 2001, NBPGR Publication 251 pp.

Singh RV, Deep Chand, Pratibha Brahmi, Vandana Tyagi, Nidhi Verma and SP Singh (2001d) Plant Germplasm Reporter September-December 2001, NBPGR Publication 420 pp.

Plant Quarantine Issues for Germplasm Exchange and Scope for Networking in South Asia

RK Khetarpal[1]*, Kavita Gupta[1] and KS Varaprasad[2]
[1] *National Bureau of Plant Genetic Resources, New Delhi-110012, India*
[2] *National Bureau of Plant Genetic Resources Regional Station, Rajendra Nagar, Hyderabad-500030, India*

Exchange of plant genetic resources (PGR) has contributed significantly towards crop improvement and increased crop production in the South Asian countries. For safe exchange of germplasm the quarantine related issues which are either legislative or technical need to be addressed. The legislative issues are country specific while those of quarantine processing and methodology are applicable to all. Taking the case of India, the Plant Quarantine (Regulation of Import into India) Order, 2003 is more for facilitating bulk imports than for exchange of germplasm with pest risk analysis (PRA) made mandatory prior to issue of import permit. But in case of germplasm, a large number of species of cultivated crops (and their wild relatives/ land races) with useful traits are imported and doing PRA for them becomes difficult as their pest profile is not available. The technical issues include deployment of non-destructive methods for detection of pests in small samples, delay in release of samples due to post entry quarantine requirements, availability of diagnostic reagents such as antisera for viruses/bacteria and the need for reference collection of insect pests. Besides, research also needs to be intensified and databases developed. There is a need for a regional plant quarantine network in South Asia on the lines of the European and Mediterranean Plant Protection Organization to facilitate smooth flow of planting material/ plant products within and outside the region. It would also facilitate PRA and help in preventing use of non-tariff barriers in international trade. In view of scarcity of resources in the region capacity building under multidisciplinary collaborative research projects need to be taken up with the help of international organizations for safe exchange and quarantine of germplasm.

Key words: Germplasm, Quarantine, South Asia

Plant quarantine plays an important role in preventing introduction of pests along with the exchange of germplasm material in a new geographical area. Almost all countries regulate the importation of germplasm because of the pest risk posed by such imports. It is motivated by the philosophy that it is better to endure some inconvenience and expense in an effort to exclude the exotic pests, rather than submit to losses involved following their entry and establishment (Khetarpal and Ram Nath, 1998). However, the risks are not fully realized by many and this has led to circumvention of quarantine procedures and policies developed as safeguards. Circumvention of safeguards implies a negative image of plant quarantine believed to be too conservative and/ or plant introduction specialists or plant breeders being too liberal towards risks associated with the entry of germplasm (Kahn, 1989). This chapter discusses the issues related to plant quarantine in relation to international exchange/ introduction of plant genetic resources (PGR) and also the scope of collaboration and networking in the South Asian region.

PGR Exchange and Quarantine in the Region

The South Asia region, also referred to as the Hindustani Region of Cultivated Plant Biodiversity, is rich in genetic diversity. In case of agricultural crops this plant diversity is exhibited in the form of variable landraces and primitive types belonging to cereals, millets, legumes, vegetables, fruits, oilseeds, fibres, forages and sugar yielding plants, spices, condiments, medicinal and aromatic plants and many others. In addition, India is also a rich source of wild PGR.

The countries in the region have a lot of commonalities with respect to agro-ecological conditions, cropping systems and crop spectra. Most of them have contiguous land borders without any natural barriers. For instance, except for the island nations i.e. Sri Lanka and Maldives of the region, India has conjoined borders with Pakistan, Nepal, Bangladesh and Bhutan. The region is highly rich in plant biodiversity being the center of origin for a number of important crops like rice, mango, brinjal etc. The land races and wild relatives of many crops are distributed across national boundaries. Besides, all are developing countries with several common problems and have agriculture-based economy.

Over the years, exchange of PGR has contributed significantly towards crop improvement and crop production in the region. However, a number of pests have also moved across the countries along with planting material (Khetarpal *et al.*, 2001b, Gupta *et al.*, 2005).

* *E-mail: ravi@nbpgr.ernet.in*

Indian J. Plant Genet. Resour. 19(3): 442-448 (2006)

For example, *Hemileia vastatrix* causing coffee rust, bunchy top of banana and coffee berry borer, *Hypothenemus hampei* have moved from Sri Lanka to India in 1876, 1943 and 1990, respectively.

- In 1875, Coffee rust (*Hemileia vastatrix)* in Sri Lanka was so severe that the production went down from 400 million pounds in 1870 to just 5 million pounds in 1889. The disease entered India in 1876 from Sri Lanka and within a decade, the coffee industry of South India was badly affected.
- Bunchy top of banana entered India from Sri Lanka and now causes loss to banana of over Rs 4 crores annually. Bunchy top was reported for the first time in 1943 in Kottayam area of Travancore (Verghese, 1945).
- Coffee berry (*Hypothenemus hampei*) borer was first reported in India in 1990 from the Nilgiris in south India and has spread to adjoining coffee growing areas seriously affecting the coffee industry which is primarily export-oriented (Ramaiah and Krishnamurthy Bhat, 1992).

Now, with the liberalization of trade under World Trade Organization (WTO), the quarantine set-up including legislation and infrastructure of all the countries in the region needs to be reviewed. As far as legislation is concerned in the South Asian countries, the Destructive Insects and Pests (DIP) Act was legislated by the British government ruling the undivided India in 1914 which covered three nations of the present day world-India, Pakistan and Bangladesh. After partition, India retained the DIP Act, 1914 under its original name revising it as per requirements over the years through various amendments. Recently, in 2003 it has revised the Plants, Fruits and Seeds (Regulation of Import into India) Order 1984 (further revised in 1989) and brought out as the Plant Quarantine (Regulation of Import into India) Order, which came into force from April 1, 2004. Pakistan adopted the DIP Act, 1914 in the year 1949, which was later replaced by the Plant Quarantine Act in 1976. Bangladesh after attaining independence in 1966 legislated the Destructive Insects and Pests rules on Plant Quarantine. Myanmar had earlier adopted the Insect Pests Act in 1914, but later found it inapplicable because of its outdated clauses and under Food and Agriculture Organisation (FAO) programme drafted a plant quarantine legislation, which was finally enacted as a Plant Pest Quarantine Law in 1993 (Table1). Nepal enacted the Plant Protection Act in the year 1972 and the Plant Protection Rules were enforced throughout the Kingdom of Nepal in 1974. The legal authority for the movement of agricultural commodities is covered by the regulations under the Plant Protection Ordinance No. 10 of 1924 in case of Sri Lanka and the Plant Protection Act was certified in 1999.

Table 1. Chronological Development of Regulations on Plant Quarantine in South Asia

Country	Regulations on Plant Quarantine	Year
Bangladesh	Destructive Insects and Pests Act	1914
	Destructive Insects and Pests rules	1966
Bhutan	Plant Quarantine Act	1993
	Bhutan Package Commodities Rules and Regulations	1995
India	Destructive Insects and Pests Act	1914
	Plants Fruits and Seeds (Regulation of Import into India) Order	1984, 1989
	Plant Quarantine (Regulation of Import into India) Order	2003
Maldives	Not available	–
Myanmar	Insects and Pests Act	1944
	Notification No- 61, 405, 406, 288	1946
	Plant Pest Quarantine Law	1993
Nepal	Plant Protection Act 2029	1972
	Plant Protection Rules	1974
Pakistan	Destructive Insects and Pests Act	1914
	The Pakistani Plant Quarantine Act	1976
Sri Lanka	Plant Protection Ordinance No-10	1924
	Plant Protection Act	1999

In India, the National Bureau of Plant Genetic Resources (NBPGR) is the nodal agency for exchange of all germplasm and trial material meant for research including transgenics. For import of germplasm, import permit from the country of import and phytosanitary certificate from country of origin are essential. NBPGR, has been authorized to issue import permit and undertake quarantine processing of germplasm material under the DIP Act and its amendments and subsequently under the PFS order 1984, 1989 and the same is being continued under the Plant Quarantine Order 2003. NBPGR is well equipped with most modern quarantine laboratories including transmission electron micro-scope and a containment facility. It is thus well equipped also for quarantine processing of transgenic germplasm in a risk-free manner (Khetarpal and Pandey, 2002; Khetarpal *et al.,* 2000).

Issues Related to Quarantine in Exchange of Germplasm

There are number of issues related to quarantine in exchange of plant germplasm. The legislative issues are country specific whereas those of quarantine processing and methodology are applicable to all. The following legislative issues pertain to India alone:

The national quarantine legislation needs to be in harmony with the international norms laid down by International Plant Protection Convention (IPPC) and the countries in the region are trying to gear up their activities to comply with it. India has attempted to do so by bringing out the new Plant Quarantine (Regulation of Import into India) Order 2003, henceforth referred to as the PQ Order. Under this the imports have been classified as

a) Prohibited plant species (Schedule IV)
b) Restricted plant species where import is permitted only by authorized institutions (Schedule V)
c) Restricted plant species permitted only with additional declarations of freedom from quarantine/ regulated pests and subject to specified treatment certifications (Schedule VI) and
d) Plant material imported for consumption/ industrial processing permitted with normal Phytosanitary Certificate (Schedule VII).

Under the PQ Order, a pest risk analysis (PRA) has been made mandatory for all material being imported into the country other than those mentioned in Schedules V, VI and VII. However, the legislation has been drafted more for facilitating bulk imports than for exchange of germplasm (Khetarpal and Gupta, 2006). Issues specific to germplasm exchange are as follows:

The various schedules V, VI and VII of the Order give lists of crops for which a generic PRA is given and detailed PRA is not required. In case of germplasm, a large number of species of cultivated crops (and their wild relatives/land races) with useful traits are imported but do not find mention in any of the schedules. Hence, a detailed PRA becomes obligatory for them which, in fact, is elaborate and modalities of its preparation are being developed by NBPGR in consultation with the Deaprtment of Agriculture and Cooperation, Ministry of Agriculture. There is an effort to decentralize the power to waive off the requirement of having a detailed PRA in specific case of germplasm of species not mentioned in any of the aforesaid schedules. This is more relevant in the present context when access to germplasm is becoming more and more difficult under the Convention on Biological Diversity, 1992.

Another difficulty, which is faced during import of certain material, is the additional declarations being sought under the Schedule VI (Species permitted only with additional declarations of freedom from quarantine/ regulated pests and subjected to specified treatment certifications). Many countries from where a pest is not reported find it difficult to certify in the phytosanitary certificate the freedom from those pests. To solve this problem, provision needs to be there in the PQ order to waive off the requirements for the declaration of pests not reported from that country. This would greatly help the indentors in procuring germplasm of their interest from varied sources.

The technical issues that include issues pertaining to quarantine processing i.e. methodology for detection and salvaging of pests are enumerated as follows:

- The amount/ size of the germplasm sample is very crucial from quarantine processing point of view, as sampling procedures meant for bulk material cannot be adopted here. Also, the technique applied should enable detection of miniscule amounts of pest in the samples and be non-destructive at the same time. The sample size may not be enough for direct testing of seed through the various techniques being applied to detect different types of pests. Hence, in case of small but precious samples of germplasm extreme precaution is needed to ensure that the result obtained in the tested part is not a false positive or a false negative (Khetarpal, 2004). A minimum size of the sample to be imported has to be made mandatory.
- The seed samples of leguminous crops known to carry seed-transmitted viruses (Kumar *et al.*, 1994) are grown in post-entry quarantine glasshouses and the seedlings showing symptoms are tested for viruses by biological and serological tests, and only the harvest from the virus-free plants is released to the indentors (Khetarpal *et al.*, 2001a; Chalam *et al.*, 2004). Also, chemically treated material of international trials, which cannot be subjected to laboratory testing, are also subjected to post-entry quarantine growing in isolation (Dev *et al.*, 2003). Thus, post-entry quarantine testing and release from indexed disease free plants may take one crop season, delaying the use of material.
- For detection, often the diagnostic reagents such as antisera for viruses/ bacteria are not easily available for exotic pests for which a repository of antisera needs to be established, as one has to deal with exotic pests in quarantine. In quarantine

the detection of exotic pests is the prime concern and for specialized detection and identification of viruses of exotic origin, it becomes mandatory to have the corresponding antisera for carrying out serological assays. Similarly, for detection by Polymerase Chain Reaction (PCR) it is necessary to know the sequence of the exotic virus or a part of its genome in order to synthesize the corresponding primers for their detection. This requires an antisera bank of exotic viruses, a database on sequences of virus specific primers, and also a repository of seeds of indicator hosts for easy access to quarantine officials as they often have to work under time pressure. Expertise is also required in the field of taxonomy and biosystematics as there is a continuous need to identify new pathogens or strains unknown to a region.

- The identity of the species, when intercepted in quarantine, needs to be established speedily to determine the quarantine risk posed by the pest and the suitable disinfestation procedures to be applied. Identification of quarantine insect-pests is difficult because few institutions have an insect reference collection. Also, reference collection for exotic insect pests and identification keys are not readily available. Moreover, even if information on the species is available, it is scattered in various journals and quick retrieval is a problem. Therefore, attempts need to be made to consolidate the taxonomic information with the preparation of digitized keys for quick and reliable identification of various genera and species.
- Research prioritization in quarantine would involve
  - ▾ development of sensitive and non-destructive detection and salvaging techniques to detect low levels of infections as the quarantine samples need to be subjected to various techniques for detection of a variety of pests namely; fungi, bacteria, viruses, nematodes, insects, mites, etc. This becomes very challenging as in case of small samples of germplasm often there are not enough seeds available to subject the seed lot to various tests. Hence, more attention needs to be given to non-destructive techniques wherever possible. Also, such methods to salvage the germplasm for making pest-free material available to the indenters especially as access to germplasm has presently become more difficult in the post-CBD era.
  - ▾ development of suitable alternatives to methyl bromide (MB), a widely used quarantine fumigant being phased out due to its adverse environmental impacts (Kapur *et al.*, 2004). MB, an ideal quarantine fumigant, has been facilitating safe movement of commodities/ germplasm in the past has been designated as ozone-depleting substance and a potential health hazard to various organisms in the Montreal Protocol (1987) under WHO/ UNEP and is to be eventually phased out. Ozone depletion is a global concern as it guards the earth against harmful UV-B radiations. India ratified Montreal Protocol and is legally committed to phase out the use of MB except for pre-shipment and quarantine purposes by 2015. Hence, there is an urgent need to intensify research to develop/ standardize alternatives to MB to meet the international phytosanitary requirements.
  - ▾ development of molecular techniques for detection of races/ biotypes/ strains also needs to be intensified as they are also considered as pests under the IPPC definition of pest, which should be sensitive enough to detect even low levels/ concentrations of pests. However, their use should be made to detect specified pests of potential quarantine importance.
  - ▾ studies on factors affecting likelihood of survival of pest under different conditions of transport, sensitive methods for detection of pest at entry, mode of dispersal, distribution of hosts/ alternate hosts at destination, potential for establishment, reproductive strategy and method of pest survival, potential vectors and natural enemies of the pest in the area etc. need to be urgently undertaken to authentically prepare a PRA during exchange.
- Availability of databases on quarantine pests and endemic pests would simplify the job of the quarantine personnel. Such lists of potential quarantine and endemic pests of different crop species would act as a ready reckoner.

Scope of Developing a Regional Quarantine Network

As the South Asian region has a nearly similar crop spectra and pest problems, it has a number of common challenges in relation to quarantine considerations and pest risk. Therefore, there is an urgent need as well as scope for collaboration and networking in the region on the lines of Association of South East Asian Nations (ASEAN) or European Union to act at the regional level for enforcement of quarantine regulations keeping in mind the unknown potential hazard of germplasm exchange and new technologies like genetically modified crops (Khetarpal and Gupta, 2004).

Some of the areas for collaboration in the region are:

1. There is a need to establish a regional plant quarantine network through harmonization of plant quarantine regulations in South Asia on the lines of the ASEAN and the European and Mediterranean Plant Protection Organization (Dhillon *et al.*, 2004). This would not only help in preventing introduction of exotic pests of quarantine significance into the Region but also facilitate the flow of planting material/ plant products within the region based on harmonized plant health related standards. The first step in this direction would be compilation of status of pests present in different countries of the region.
2. Common quarantine regulations can be envisaged according to the norms prescribed by the IPPC wherein common pests present in all the countries could be listed to enable the waiver of additional declarations in the issue of import permit during exchange within the region. This would imply a compilation of information on pests present or absent all over the region, or a part of the region (Table 2 and 3). Such a data would also facilitate development of PRA for crops/ pests and trade related plant safety standards of common interest to prevent their use as non-tariff barriers in international trade. Countries which have an expertise for doing quarantine of special crops/ pests could take up that task on behalf of other member countries.

Table 2. Few Pests not Reported in South Asian Region Based on Published Records

Pest	Distribution Status
South American fruit fly *Anastrepha fraterculus*	Mexico, Central and South America
Mexican cotton boll weevil *Anthonomus grandis*	West Indies, Mexico, Central America, Venezuela and USA
Colorado potato beetle *Leptinotarsa decemlineata*	North America and Europe
Groundnut scab *Sphaceloma arachidis*	Brazil
South American leaf blight *Dothidella ulei*	Mexico, Central America, West Indies and South America
Ergot of maize *Claviceps gigantea*	South America and Mexico
Citrus burrowing nematode *Rhodopholus citrophilus*	USA
Rice yellow mottle virus	Africa
Maize streak virus	Africa, USA and South America

3. Collaboration can be developed to conduct combined PRA for crops/ pests of plant quarantine significance common to the region. For this purpose, each country would be required to take up survey for the occurrence and distribution of pests of the common crops of the region and share the information. Preparation of a computerized database of pests and pathogens present and if localized then particular area identified to review the records of new pests detected and outbreaks also needs to be taken up. For instance, movement of plant pests recently introduced in any of the South Asian countries such as *Bemisia tabaci* (B biotype) introduced in India which is a polyphagous pest with a wide host range of > 600 plant species requires immediate attention. Monitoring the movement and spread of established plant pests of concern to the countries also needs immediate

Table 3. Few Pests with Limited Distribution in the Region Based on Published Records

Pest	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
San Jose scale	–	–	+	–	–	+	–
Banana bunchy top disease	+	–	+	–	–	–	+
Potato cyst nematode	–	–	+	–	–	+	+
Tea stem canker	–	–	+	–	–	–	+
Sunflower downy mildew	–	–	+	–	–	+	+
Coffee berry borer	–	–	+	–	–	–	+
Phloem necrosis virus in tea	–	–	–	–	–	–	+
Pine wilt nematode	–	+	–	–	+	–	–

+ reported as present, - not reported

attention. Pests like sunflower downy mildew introduced into India and which have yet not spread to other sunflower growing countries like Bangladesh in the region, needs to be carefully monitored especially since both the countries have contiguous land borders.

4. Human resource development needs attention to overcome the major constraint of lack of trained personnel in developing an effective networking system. Regular training programmes to strengthen both the research capabilities and the training of trainers in national programmes should be conducted at the regional level.
5. Quarantine and PGR management is a developing multidisciplinary field in which many researchable issues are emerging. These researchable issues could be identified and collaborative efforts made to tackle these issues, particularly in view of paucity of scientific and financial resources in the region.

Perspectives

International Plant Genetic Resources Institute (IPGRI-now Bioversity International), South Asian Network on PGR (SANPGR), Asia and Pacific Plant Protection Commission (APPPC) and Committee on Sanitary and Phytosanitary Measures of SAARC need to enhance their efforts in developing a strategy at regional level to identify areas of collaboration, streamline the technical and policy issues and network for safe exchange and quarantine. The partner countries should decide to develop a consensus on working out the modalities on development of database, exchange of information, harmonization of regulations and human resource development.

References

Chalam VC, DB Parakh, AK Maurya, A Jain, S Singh, and RK Khetarpal (2004) Interception of plant viruses in exotic germplasm imported during 2002-2004. In Souvenir & Abstracts of Symposium on Crop Surveillance: Disease Forecasting and Management, February 19-21, 2004, Indian Agricultural Research Institute, New Delhi, 48 pp.

Destructive Insects and Pests (DIP) Act, 1914 and the Plants, Fruits and Seeds (Regulation of Import into India) Order, 1989 of Government of India.

Dev U, B Singh, PC Agarwal, S Singh, AK Maurya, D Chand, KD Joshi and RK Khetarpal (2003) Quarantine processing of chemically treated wheat (*Triticum* species), barley (*Hordeum vulgare*) and Triticale germplasm imported during 1992-2001. *Indian Journal of Agricultural Sciences* **73:** 462-465.

Dhillon BS, AK Singh and Kavita Gupta (2004) Collaborative plant genetic resources research activities. In: Proceedings of the VI meeting of South Asia Network on Plant Genetic Resources (SANPGR) (eds. Bhag Mal, PN Mathur, V Ramanatha Rao and AHM Jayasuriya) IPGRI South Asia Office, New Delhi, India, pp 81-85.

Gupta Kavita, Ashok Gaur and RK Khetarpal (2005) Role of regulatory measures in controlling spread of plant pests. In: Integrated Pest Management: Principles and Application **Vol. I** (eds. America Singh, OP Sharma and DK Garg) CBS Publishers and Distributors, New Delhi. pp. 48-69.

Kahn RP (1989) *Plant Protection and Quarantine: Selected Pests and Pathogens of Quarantine Significance.* Vol II. CRC Press Inc., Florida, 265 pp.

Kapur Manju Lata, Kavita Gupta, Shashi Bhalla and RK Khetarpal (2004) Potential alternatives to methyl bromide for safe movement of horticultural material. In: First Indian Horticultural Congress 2004 on Improving Productivity, Quality, Post-harvest Management and Trade in Horeticultural Crops organized by the Horticultural Society of India, New Delhi, November 6-9, 2004. pp 68-69.

Khetarpal RK (2004) A critical appraisal of seed health certification and transboundary movement of seeds under WTO regime. *Indian Phytopathology* **58(4):** 408-421.

Khetarpal RK and BM Pandey (2002) Plant Quarantine and safe exchange of transgenics. In *Transgenic Crops and Biosafety Concerns* (eds. GJ Randhava, RK Khetarpal and BS Dhillon) National Bureau of Plant Genetic Resources, New Delhi. pp. 101-109.

Khetarpal RK and Kavita Gupta. (2004) Plant quarantine in South Asian countries: Need and scope for collaboration. In XV International Plant Protection Congress from May 11-16, 2004, Beijing, China, 754 pp.

Khetarpal RK and Kavita Gupta (2006) Policy issues in plant protection. In: *One hundred years of Plant Pathology in India – An Overview* (eds. SS Chalal, RK Khetrapal and TS Thind) Indian Society of Mycology and Plant Pathology. Scietific Publishers, Jodhpur, India. pp. 381-401.

Khetarpal RK and Ram Nath (1998) Evolving national plant quarantine system: harmonization of current quarantine regulations with sanitary and phytosanitary (SPS) agreement. In National Dialogue (ISPGR Dialogue 1998): Issues on Plant Genetic Resources, December 1-2, 1998, National Bureau of Plant Genetic Resources, New Delhi, 47 pp.

Khetarpal RK, S Singh, DB Parakh and VC Chalam (2001a) Viruses intercepted in exotic germplasm during 1991-2000 in quarantine. *Indian Journal of Plant Genetic Resources* **14:** 127.

Khetarpal RK, KS Varaprasad, A Lal, PC Agarwal, and B Lal (2001b) Plant quarantine of germplasm under exchange. In *National Bureau of Plant Genetic Resources: A Compendium of Achievements* (Eds. BS Dhillon, KS Varaprasad, K Srinivasan, M Singh, S Archak, U Srivastava and GD Sharma). National Bureau of Plant Genetic Resources, New Delhi, 90-115 pp.

Kumar CA, RK Khetarpal, DB Parakh, S Singh, and Ram Nath (1994) *Check-list of Seed-transmitted Viruses: Leguminous*

Hosts. Technical Bulletin, National Bureau of Plant Genetic Resources, New Delhi, 14 pp.

Mathur VK and A Lal (Eds) (1999) *Plant Quarantine Activities at NBPGR. NBPGR Scientific Monograph* **No. 6:** 96 pp.

Plant Quarantine (Regulation of Import into India) Order (2003) The Gazette of India Extraordinary, Part II Section 3 Sub-section (ii) No. 1037 Published by Authority. p 105.

Ramaiah PK and PK Krishnamurthy Bhat (1992) Coffee berry borer in India. *Indian Coffee* **56(1):** 33-35.

Verghese MK (1945) Bunchy top disease of plantains. *Indian Farming* **6:** 239-240.

Cost of Plant Introduction -The Expanding Horizons of Crop Diseases

Satvinder K Mann
Department of Plant Pathology, Punjab Agricultural University, Ludhiana-141004, Punjab, India

Inadvertent movement of plant pathogens into new ecological regions from their original home creates an alarming signal by causing threat to plant biodiversity. All the historical evidences indicate that the introduction of invasive alien species (IAS) is the major driver behind the appearance of new disease, resurgence and spread of indigenous pathogens and pathotype strain selection which ultimately adds cost to the plant introduction. This calls for designing a suitable policy which can restrain the ingress of pathogens into a new ecological niche through plant introductions. But, considering the enormity of the ecological regimes in India and the dynamics of the international agri-trade policy, plant quarantine regulations would be constrained due to the increased possibilities of the spread of pathogens. Preventive domestic quarantine needs to be considered along with strict Pest Risk Analysis (PRA), so that aggravated risk to ecological biodiversity and cost of plant introduction could be reduced.

Key words: Invasive pathogens, Quarantine, Plant introduction

The invasive alien species (IAS), many of which are plant pests and pathogens, assume significance as threat to biodiversity (Khetarpal and Gupta, 2004a). Several thousand of species have moved globally and out of every 7 species, atleast one becomes invasive. Biological invasions due to plant pathogens have a long history and devastating effect (Kiss, 2005). Food security of the nations depend upon agriculture and sustainability has been affected by plant pathogens, because crops are vulnerable to diseases. Frequently indigenous or introduced pests and pathogens have jeopardized production in many parts of the world, with serious economic consequences in terms of increased cost of sustained management and loss of export markets (Ambrose, 1996).

The number of diseases which moved inadvertently in to new ecological regions from their original habitats have increased over the years due to the increased mobility of men and materials. Probability of plant pathogens becoming invasive on plant introduction increases in intensive agro-ecosystems, which has gradually become a reality from 19th century onwards (Fig. 1). In the augment trade regime, probability of inadvertent introductions of pathogens can also increase and plant quarantine as crop protection strategy thus faces an enormous challenge in future.

Recent example is the introduction of Karnal bunt of wheat in USA in spite of the stringent regulations and considerable investments to prevent the entry of the pathogen (*Tilletia indica*). The Karnal bunt pathogen was detected in USA in 1996 (Ykema, 1996), after about 25 years of its detection in Mexico in 1972 (Duran,

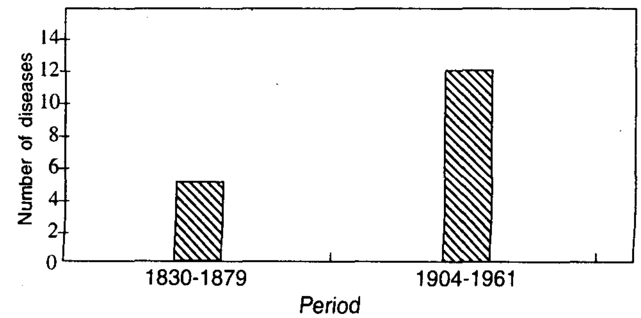


Fig. 1: Number of diseases of crop plants which moved into new locations from 1830-1961

1972) indicating "inadequacy of the quarantine efforts to prevent entry of pathogens in to new locations" with the methods used. This calls for introspection because "the expanding horizons of plant pathogens remains a reality" (Table 1).

With this continued introduction of pathogens, the critical aspects of which need to be re-examined are that the legislative measures of the Plant Quarantine as tools to prevent entry of pathogens in to new ecological niches, because

A. The Plant Quarantine Regulations emphasize the movement of disease free planting material but till date non-indigenous pathogens have remained an important issue.
B. The ability of the "endemic low profile pathogens becoming severe on the introduction of exotic plant material" has not been considered.
C. Now with World Trade Organization having legalized farm trading under various treaties, and in the current global scenario the international quarantine

Table 1. Some important diseases inadvertently introduced in to new locations

Disease	Organism	Introduced in	From	Year
Leaf blight of potato	*Phytophthora infestans*	Latin America	Europe	1830
		India	Europe	1883
Powdery mildew of grapes	*Uncinula necator*	England, Europe	USA	1845
Downy mildew of vines	*Plasmopara viticola*	France	USA	1845
Leaf rust of coffee	*Hemelia vastatrix*	India	Sri Lanka	1879
Chestnut blight	*Endothia parasitica*	USA	Asia	1904
Flag smut of wheat	*Urocystis tritici*	India	Australia	1906
Citrus canker	*Xanthomonas citri*	USA	Asia	1907
Blister rust of pine	*Cronartium ribicola*	USA	Europe	1910
Downy mildew of grapes	*Plasmopara viticola*	India	Europe	1912
Potato scab	*Streptomyces scabies*	Korea	Japan	1913
Downy mildew of maize	*Sclerospora phillipinesis*	India	S-E Asia	1918
Onion smut	*Urocyctis cepulae*	Switzerland	France	1924
		India	Europe	1958
Tobacco black shank	*Phytophthora nicotianae*	India	South east	1938
Bunchy top of banana	Viral	India	Sri Lanka	1940
Bacterial canker of tomato	*C. michiganesis*	England	USA	1942
Golden nematode of potato	*Heterodera rostochinesis*	India	Europe	1961
Downy mildew of sunflower	*Plasmopara helstedii*	India (hybrids seeds)	Russia	1985
Karnal bunt of wheat	*Tilletia indica*	USA	Mexico	1996
Strawberry leaf spot	*Xanthomonas fragariae*	Netherlands, France	Belgium	1998

restrictions on the movement of agricultural commodities have to be justified as per the "potential impact", which must be based upon the bionomics and epidemiology of the pathogens, so as to facilitate free trade in farm produce.

International Plant Protection Convention (IPPC), entrusted for developing international phytosanitary regulations bases it decisions on pest risk analysis (PRA) and information on pest free areas, PFA (Khetarpal and Gupta, 2002; Gupta *et al.*, 2002). Similarly the certification for seed borne pathogens was also based upon the impact on yields (Khetarpal, 2004b).

But the Sanitary and Phytosanitary (SPS) measures in future are likely to remain under increased compulsions to facilitate farm produce trade. Hence at this stage, there is an urgent need to look at the phenomena of plant introduction (intentional or inadvertent) as form of biological invasions and its consequences more objectively on a long term basis. When plant introductions are made in the new environment, the plants are released from the indigenous pathogen pressures and:

i) if the environment was favourable, the plant it self may assume an invasive role, or succumb to the endemic pathogens; or
ii) select strains of minor pathogens, changing the pest and disease scenario of the colonized environment.

When plant introductions are made through germplasm exchange, the materials, which are infected, are likely to get eliminated or salvaged, but when a virgin disease free planting material, unchallenged with local pathogens is considered for planting, at times it may become more susceptible due to absence of resistance against indigenous pathogens.

Recent resurgence and emergence of minor pathogens on the cereal crops in India was because of the extensive plant introductions made during the initial stages, which usherd in the onset, later accelerated and finally to sustained the green revolution. As a consequences, minor pathogens have assumed significance and the situation was well illustrated with cereals and cotton in India, where number of "minor diseases and pests emerged and resurged in last 40 years. Like Karnal bunt and leaf blights in wheat and bacterial leaf blight (BLB), sheath rot, sheath blight, false smut and brown spot in rice and grain discolorations due to facultative pathogens in both have assumed significance", after the new dwarf varieties were released for cultivation in the farmers field since 1960's (Table 2). Although data on the virulence changes with respect to most of the obligate pathogens affecting the grain crops was available, nothing much was known about the virulence spectrum or mating types prevalent or introduced in case of the facultative pathogens which became major problems during this phase.

Karnal bunt of wheat and kernel smut of rice are endemic to northern India. Sheath blight was first reported from Japan in 1910 and was important in the Philippines, BLB was originally important in Maharashtra since 1951.

Table 2. Minor diseases of wheat and rice which became major in India

Disease	Crop/Variety	Pathogen	Severe in
Karnal bunt of wheat	Dwarf wheat	*Tilletia indica*	1976
Leaf blight of wheat	High yielding var	*Bipolaris sorokinana*	1996
Sheath blight	IR 8 rice	*Rhizoctonia solani*	1968
Bacterial leaf blight in Punjab	Taichung native 1 (Formosan var)	*Xanthomonas campestris*	1966
	PR 114	New pathotype of *X. campestris*	1999
Kernel smut of rice	PR 112, PR 113	*T. barclayana*	1997

The domains of endemic diseases mentioned above have increased, further aggravating the situation, with the introduction of new varieties and crops. The pathogens like *T. indica,* which were endemic to the foot hills of north India, colonized all the niches in the north western plain zone. Spatial domain increased and resurgence in case of Karnal bunt of wheat was due to the susceptibility of the dwarf wheat or introduction of the new pathotype, which was never investigated. But the disease did create an economic impasse for wheat exports from north western India when production started increasing from early nineties and the disease had yet not entered USA. Only after it was detected in USA in 1996, need for reasonable quarantine against *T. indica* was suggested on IPPC recommendations. Embargo on Indian wheat due to the presence of this pathogen remains till date even in the neighbouring countries, where the disease is prevalent.

Phytophthora infestans, which caused late blight of potato, remained under control in USA till 1970, with the help of fungicides and use of resistant genotypes, after its emergence in 1880's. But it resurged due to the introduction of the complementary mating type in indigenous population, the pathogen had earlier migrated from Mexico and thrived clonally and all of a sudden the disease resurged in USA in 1980s. By 1990, it became berserk and profitability went down rapidly. The new pathotype of *P. infestans* from Mexico, helped in generating new genotypes of the pathogen, due to sexual recombination which had the ability to adapt to the fungicides and resistance deployed (Deahl *et al.*, 1993).

Invasive nature of powdery mildews was well illustrated with *Erysiphe necator* invasions into Europe from USA in the 19th century, *Podosphera morus-uvae* in the early 20th century and later two species *E. flexusa* and *E. elevata* which spread from country to country in Europe are serious concerns (Kiss, 2005).

All the historical evidence indicates that plant pathogen invasions have a devastating effect. Appearance of new diseases, resurgence and spread of indigenous pathogens due to increased susceptibility of the exotic materials, introduction of new pathotypes and minor pathogens becoming severe with specific pathotype strain selection and the consequences there after on the agro-ecology and its management, all add to cost of plant introduction. Chestnut blight, caused by *Endothia parasitica* was introduced on nursery stocks into USA in 1906 and in 25 years exterminated forest chestnuts causing 1000 million dollar loss. Eradication of citrus canker in Florida has costed more than 200 million dollars to date. Annihilation of grape wine industry in France by powdery mildew and downy mildew, coffee plantation in Sri Lanka by *Hemelia vastatrix* are some of the landmark examples of how the pathogens can assume devastating proportions.

In India, considering the vastness of the ecological niches, keeping pace with the dynamics of the international farm trade policy will be a tedious challenge. The free seed trade of the exotic introductions in the domestic market and indiscriminate retailing and their movement into unscheduled regions will be major biotic drivers for the environmentally diverse countries like India, causing an aggravated risk. From 1991 to 1999, four introductions are recorded for India viz., direct introduction of sunflower hybrids, resulted in the introduction of downy mildew, caused by *Plasmopara halstedii*, which became severe. The other recent introductions in India included American serpentine leaf minor, *Liriomyza trifoli*, in 1991, spiralling white fly, *Aleurodicus disperses* in 1993 and white fly biotype B, *Bemisia tabaci* in 1999 (Khetarpal, 2004). The situation is not much different in other countries where many virus and nematode diseases are being reported and detected from new ecological zones throughout the world.

Hence in future, the various aspects of bio-security will be driving a lot of plant protection agenda in most of the countries, since we are not only dealing with agriculture but food, ecosystem and economic security are also implied. Since the farm trade and barriers will have an increasing role and decisive effect in the international politics, the situation will inherently require coordination between quarantine regulations for imports and effectiveness of the domestic controls. The plant quarantine must be activated at the international and domestic levels simultaneously so that we do not end up in a post mortem approach for the management of inadvertently introduced or aggravated pests and pathogens, as is being done for pomegranate in Maharastra, where in 2006 bacterial blight had damaged pomegranate cultivation over more then 30,000 ha, causing a loss of Rs. 1,000 crore by affecting 20,000 farmers.

Similarly a delayed domestic quarantine against flag smut of wheat had cost USA to loose wheat trade with China from early nineteenth century till 1950s.

The role of the agro-ecological regions in sustaining the basic food security in countries like India must have a fresh look on the "implementation aspect of the domestic quarantine legislations". Freedom to push seeds of new varieties of exotic or indigenous origin to unscheduled areas needs to be strictly dealt with. Regulated seed and other vegetative planting materials within the country is of paramount importance for progressive agriculture to sustain the benefits of plant introduction. Preparedness with respect to pest risks involved and pathway appraisals should complement these efforts so that inadvertent introductions can be traced.

The domestic quarantine measures should thus assume equal significance like the international quarantine. In the past 40 years indiscriminate seed movement within the country has created more problems than ever and contributed in increasing the cost of crop production. Therefore, alongwith implementation of quarantine on import, even when disease free material is introduced for cultivation, there is a need for data base and capacity building as indicated below:

a) Preparedness for pest risk and management protocols, taking into account the probabilities and economic impact of pest and pathogens with respect to threatening (likely to enter the region), new (previously unrecognised). Emerging (initially minor), re-emerging diseases (which become low due to management practices) and possibilities of genetic changes (introductions of new mating types or mutations) in the pest populations in new or indigenous environment.

b) Drafting of emergency action plans, providing legislative support and revoking domestic quarantine to check the indiscriminate sale and spread of the unscheduled seed and other planting materials in the domestic market to arrest spread of the introduced pathogens and also expanding domains of the endemic pathogen.

c) In case of germplasm exchange for breeding purposes, the various nurseries must be tested against major diseases as well as screening efforts should be made to test the new materials against minor pathogens, considering the extent of economic damage as Karnal bunt caused to the surplus wheat from north western plain zone of India.

Since increased movement of agricultural produce in future may entail increased spread of pathogens, therefore "preventive"- international and domestic measures are equally important to reduce the cost of plant introduction and contain ever expanding horizons of plant pathogens. A more vigilant and effective implementation of the stipulated quarantine measures at post-entry stage can prevent recurring cost to sustainability as this risk would aggravate with global trade in agricultural commodities.

References

Ambrose E (1996) Emergency action plans for exotic pests and diseases. A model for Caribbean Countries. *Miscellaneous publication series ISSN -5391*. A2/LC-96-IICA, Castries, St Lucia.

Deahl KL, DA Inglis and SP Demuth (1993) Testing for resistance to metalaxyl in *Phytophthora infestans* isolates from North-Western Washington. *Am Potato J.* **70(11):** 779-795.

Duran R (1972) Further aspects of teliospore germination in North American smut fungi. *Can J Bot.* **50**: 2569-2573.

Gupta K, BM Pandey and RK Khetarpal (2002) Pest risk analysis and its significance to India under WTO regime. *Seed Tech News.* **52**: 266-269.

Khetarpal RK and K Gupta (2004a) Challenges in plant protection in the wake of international agreements. Abs. S.16. *Indian Phytopath.* **57**: 327.

Khetarpal RK (2004b) A critical appraisal of seed health certification and transboundary movement of seeds under WTO. *Indian Phytopath.* **57**: 408-421.

Khetarpal RK, K Gupta and BM Pandey (2002) Sanitary and Phytosanitary agreement of WTO and its implications Abs, S.06, *Indian Phytopath.* **55:** 56.

Kiss L (2005) Powdery mildew an invasive plant pathogen: new epidemics caused by two north American species in Europe. *Mycological Res.* **109**: 259-260.

Ykema RE, JP Floyd, ME Palm and GL Peterson (1996) First report on Karnal bunt in the USA. *Plant Dis.* **80**: 1207.

Introduction of *Parthenium hysterophorus* L: Status and Management

M Mahadevappa[1] and RD Gautam[2*]

[1] *Advisor, Sri Shivarathrishvara Rural Development Foundation, Mysore-570004, Ex-Chairman, Agricultural Scientist Recruitment Board, New Delhi-110012, India*

[2] *Division of Entomology, Indian Agricultural Research Institute, New Delhi-110012, India*

Parthenium hysterophorus is now a serious weed of pastures, wastelands and also of agricultural fields growing under varied environmental conditions, from sea level to altitudes up to 2000 masl, in most parts of India. Concerted efforts including physical, mechanical, chemical and biological methods of its control together have to be made at least for initial 2 to 3 years for its effective suppression in the marked area. Individuals should render responsibility to eliminate the *Parthenium* plants establishing in their surrounding. Establishment of the effective botanical agents like exotic shrub *Cassia sericea* and other indigenous plants *viz., C. tora, C. auriculata, C. occidentalis, Tephrosia purpurea* and *Kochea indica* (suitable for arid region) is a viable strategy along with the release of leaf feeding Mexican beetle, *Zygogramma bicolorata.* Further, foreign exploration of safe and effective weed killer may be given a serious thought to compliment the potential of *Z. bicolorata,* in the light of recently introduced International Standards for Phytosanitary Measures (ISPM#3). Community based approaches consisting of activity classes for school children, NGO's and others will help in weed containment. Bringing short-term legislation/notification similar to that of mosquito especially in the metropolitan cities may be an added weapon in integrated parthenium management. Appropriate integration of these approaches could contain the spread of *P. hysterophorus* and provide sustainable suppression especially in non-cropped ecosystem. This may lead to direct protection of environment.

Key words: *Parthenium hysterophorus, Zygogramma bicolorata, Cassia sericea, Kochea indica,* Legislation, Management

The pernicious weed, *Parthenium hysterophorus* L, commonly known as congress grass, carrot weed, white top, star weed or fever few etc, growing naturally since centuries in Latin America and many other countries has emerged as one of the seven most dreaded weeds of the world. In India, it was noticed for the first time from Pune (Rao, 1956). It is presumed that it could have introduced as contaminant along with wheat consignments. According to Krishnamurthy *et al.* (1977) about 2 m ha of land is covered by this weed in the country, with a potential of dramatic increase. The distribution of this abnoxious weed is mostly on no-man's land like abandoned and wastelands, vacant sites, roadsides, railway tracks, graveyards, backyards, cultivated lands etc. (Mamatha and Mahadevappa, 1992).

Due to the rapid and gregarious growth of parthenium, the ill effects on human, livestock (Narsimhan *et al.,* 1980; Towers and Rao, 1992) and plants, have been well published and demonstrated to create public awareness. Besides, the weed has posed wide interference in agriculture (Vartak, 1968; Kanchan and Jayachandra, 1975). Its distribution, chemistry, hazards, competitive plants and management have been extensively reviewed (Krishnamurthy *et al.,* 1977; Towers *et al.,* 1977; Parihar and Kanodia, 1986; Joshi, 1991; Agarkar, 1999; Mahadevappa, 1999; Sharma and Gautam, 2004). Sometimes, in chronic parthenium linked photo-dermatitis patients, situation may be incurable and fatal.

Special Features of the Weed

All the plant parts, particularly pollens have allergic effects on other organisms. The life cycle of the weed is of short duration. It can germinate, flower and set seeds within four weeks. A single plant alone can produce 14-15 thousand seeds. Once established, it can survive severe droughts and frosts (Mahadevappa, 1999). Further, factors such as (1) the absence of potential natural agents that restrict the spread of this plant as in its original home, (2) high fecundity, (3) efficient seed dispersal mechanisms, (4) monopolistic allelopathic impact on most other plant species, (5) unsuitability for grazing because of the presence of antifeedant in the plant system and (6) wide adaptability to varying soil and agroclimatic conditions have enabled this plant to invade a variety of growing environments particularly in situations associated with human activities (Mahadevappa,1999; Sharma and Gautam, 2004).

Weed Utility Aspects

Parthenium has been regarded as a beneficial plant too. It is used as a folk remedy against various afflictions such as ulcerated sores, skin diseases, facial neuralgia,

* *E-mail: gautamjul@yahoo.com*

for cleaning the blood and also as an insecticide. It is reported that "parthenin", the principal ingredient of this plant possesses anticancer properties. *Parthenium* plants have been commonly used as centering material in the construction of buildings and bridges. Also, converting it into a resource by its multifarious uses like fuel for cooking, organic manure, biopesticides for plant protection (known to have insecticidal, bactericidal and herbicidal properties), making paper pulp for writing and corrugated sheets and as additive with cattle manure for higher methane production in biogas plant. However, there is a strong need to remember that parthenium linked problems to human, animal and plant health are yet to be investigated. Chemical constituents may remain viable source of health hazards even in parthenium-based product (s), in question, hence such products may be thoroughly examined before commercialization.

Possibility that *Parthenium* plants can be ensilaged after mixing it in certain proportion with conventionally used feed is also reported. The ensilaged *Parthenium* is reported to be devoid of the contact allergen/toxin and becomes palatable to live stock. The fibrous nature of the *Parthenium* stem is a point that needs the attention of industrial researchers to see if it has potential in manufacturing paper and such other materials as helmets, molded furniture, doors etc. In the years of drought when most plant species fail to grow, *Parthenium*, by virtue of its tolerance to drought, grows and brings down CO_2 level in the atmosphere. It is reported that 20 per cent *Parthenium* leaf water extract when sprinkled on mulberry leaves improved the quality as well as quantity of cocoon due to presence of steroids. As felt at present, its harmful effects both from medical as well animal health and agricultural production point of view are serious matters for consideration.

Global Spread of *Parthenium*

Overseas spread of parthenium is reported from different countries (Table 1) and is spreading fast. Many countries have identified it as a pest of quarantine importance. A few observations based on literature search in India (Table 2) and authors own surveys carried out abroad are highlighted in Table 3.

Reasons for its Wide Spread Dominance Across the Country

Several physiological and morphological features of the weed help in its large-scale dispersal and dominance in wide range of habitats.

- Prolific seeding potentiality (8000 – 15000 seeds per plant).
- Absence of seed dormancy (seen throughout the year).
- Absence of potential natural enemies.

Table 1. Overseas spread of *Parthenium hysterophorus*

Country	Provinces	References
Argentina	Large areas, Province of Cardoba	Castex *et al.* (1940)
Australia	Queensland, Central Highlands and Clermonth, New South Wales	Dale (1980)
Bangladesh	Not in alarming proportion	Mahadevappa (1996)
Bourbon	Large areas	Vaid & Naithani (1970)
Guyana	Large areas-major problem	Krishnamurthy *et al.* (1976)
Jamaica	Large areas-major problem	Krishnamurthy *et al.* (1976)
Mauritius	Large areas	Vaid and Naithani (1970), Maheshwari and Pandey (1973)
Mexico	Throughout the country	Arny (1897)
Nepal	Very sparse	Personal observation
North Vietnam	Large areas	Vaid & Naithani (1970)
Rodrigues	Large areas	Vaid & Naithani (1970)
Seychelles	Large areas	Vaid & Naithani (1970)
South Africa	Large areas	Vaid and Naithani (1970), Maheshwari and Pandey (1973)
Trinidad	Large areas-major problem	Krishnamurthy *et al.* (1976)
USA	Florida, Texas, North of Massachussetts, Pennsylvania, Ohio, Michigan, Illinois, Missouri and Kansas; Minnesota; Louisiana Cantan, Baltimore, Maryland, New Port and Virginia	Castex *et al.* (1940), Arny (1897) Mackoff and Dahl (1951) Ogden (1957), Arny (1897)

Table 2. Spread of *Parthenium hysterophorus* in India

State	Areas	References
Andhra Pradesh	Most parts of the state	Krishna Murthy *et al.* (1977) Mahadevappa (1996)
Bihar	Motihari, Narkatiarganj, Balmikinagar,Gangetic plains	Maheshwari and Pandey, (1973) Chandra (1973)
Delhi	Through out	Personal observations
Gujarat	Ahmedabad, Anand and Baroda	Mahadevappa (1996)
Haryana	Rohtak, Hisar and Faridabad, Eastern parts of Haryana	Mahadevappa and Ramaiah (1990)
Himachal Pradesh	Kulu and Manali	Vaid & Naithani (1970)
Jammu & Kashmir	Throughout the State	Prabhakar (1988) (Personal communication)
Karnataka	Most parts of the state except coastal belt and thick forests	Mahadevappa *et al.* (1990) Jayachandra (1971) Mahadevappa (1996)
Kerala	Palghat, Quilon, Kottayam and Kasargod	Mahadevappa (1996)
Madhya Pradesh	All over the state except in hills	Tiwari & Bisen (1984)
Maharashtra	Mumbai city (Juhu area), Forest nurseries, Joshi Estate	Tiwari & Bisen (1984) Chandras and Vartak (1970)
Pondichery	Scattered distribution throughout the state	Mahadevappa (1996)
Punjab	Many parts of Punjab	Mahadevappa (1996)
Rajasthan	Udaipur	Mahadevappa (1996)
Tamil Nadu	Kotagiri of Nilgiri hills, Aliyar submergenic area, Coimbatore, Katpadi, Jolarpet, Madurai, Salem, Tanjore	Mahadevappa (1996)
Uttar Pradesh	Pantnagar, Rae Bareli, Jhansi, Haridwar	Mahadevappa (1996)
West Bengal	Calcutta, Bank and river basins	Krishna Murthy *et al.* (1977) Mahadevappa (1996)
Orissa	Not much, only in the peripheral parts	Mahadevappa (1996)

Source: Mahadevappa, 1999

Table 3. Studies conducted on nature of invasion in a few countries

Country	Year of observation	Nature of invasion	Type of land where observed
Australia	1986	Low	Roadsides and abandoned land
Canada	1987	Very low	Abandoned land and road side
China	1966, 2000	Low	Roadsides and on land of rice
Cuba	1987	Low	Vegetable gardens, banana and maize fields
Ethiopia	2005, 2006	Major problem	Orchards and savannah's
Grenada	1996, 1997, 1998, 2005*	Low to medium, Problematic	Wastelands
Guyana	1998	Major problem	Wastelands
Jamaica	1996	Moderate	Wastelands
Kenya	1987	Moderate	Wasteland
Mexico	1989	Low	Waste and cultivated land
Montserrat	1998	Low	Road sides, wastelands
Nepal	2002, 2006	Very low	Roadsides
Saint Kitts and Nevis	1996	Low	Wasteland, vegetable fields and road sides
South Africa	2005, 2006	Medium	Wastelands
Suriname	1998	Moderate	Wastelands and roadsides
Trinidad and Tobago	1996, 1998, 2005**	Low to moderate, Problematic	Waste land and roadsides
USA	1987, 1992	Very low	Abandoned land

* – respondent Andall, A; **-respondent Maraj, C (Surveyed through E. Mail)

- Presence of allelopathic properties to suppress native vegetation.
- Photo and thermo-insensitivity.
- Rapid colonizing and dominating nature.
- High drought and water stress tolerance.
- Greater ability to grow in diverse ecological conditions (seen to grow from higher altitude of Kullu Valley to sea level in Chennai).
- Extremely light- weight, capacity to float and armed with pappas, are some of characteristics of the seed, which help its extensive spread.
- Hazardous to crops, human and animal health, which restricts its manual removal.

Besides above, the plant normally completes its life cycle within 4 months. However, its periodicity depends upon frequency and distribution of rain during the year. The young leaves pressed closely to ground offer severe competition and does not allow other plant species to come up. Flowering commences within a month of sprouting of seeds and continues throughout the year.

Need to Eliminate *Parthenium*

(a) *Parthenium* is well known to cause contact dermatitis, skin allergy, eczematous dermatitis, rhinits, nasal and bronchial asthma hay fever in human beings due to the presence of water soluble lactones and flavenoids. These diseases may be caused by repeated contact with weed or with its parts particularly pollens. A slight physical contact with this weed in very sensitive person is said to cause/develop swelling and blisters on exposed/contacted part of the body. Its air borne dried material may also perpetuate dermatitis in very sensitive human beings. Generally, adult males are mainly affected by this weed as compared to females. However, children below twelve years of age are, often spared.

(b) The studies conducted on the toxicity of the weed to cattle at various institutions *viz.*, Indian Institute of Science, Bangalore and at Delhi University showed that *Parthenium* causes intestinal ulcers in grazing animals and reduces milk yield. Milk also contains a poisonous substance "Parthenin" and develops "Bitter Milk". Its accidental or willful intake for want of green fodder may cause severe disease syndrome and prove fatal to grazing animal.

(c) *Parthenium* removes a major portion of nutrients and depletes soil fertility and reduces crop yield considerably.

(d) It affects nodulation in legumes due to inhibition of activity of nitrogen fixing and nitrifying bacteria *viz.*, *Rhizobium* and *Azotobacter.*

(e) Its pollen inhibits pollen germination and fruit setting in many vegetables *viz.*, brinjal, chili and tomato.

Management

Various methods of weed control *viz.*, physical, mechanical, chemical and biological have been practiced normally in isolation for its control, however, with a limited success. An integrated approach involving physical, chemical and biological methods alone can offer an effective control strategy.

(a) Physico-mechanical Method

Repeated manual uprooting of this weed before flowering provides immediate but temporary control. Manual removal should be carried out before flower and fruit setting particularly when the soil is wet to prevent further re-enforcement of its seed to the soil and dispersal to newer areas. It is suggested to form a 'Task Force' from among school children who are spared from its ill effects for manual eradication programme in the residential premises/parks. Large-scale use of this technique is expensive, impracticable and highly risky, as it needs the use of gloves and protective clothing to avoid physical contact with sensitive people as precautionary measures. Moreover, partial pulling of stem encourages regeneration and repeated removal at least for a season-long control.

(b) Chemical Method

Remember, chemicals provide fast but short-term control. Besides, these are expensive, non-ecofriendly and require knowledge of spray technology. Moreover, these are less effective in cases where seeds are already deposited in soil. Also, special care has to be taken to avoid spray drift risk to adjoining sensitive crops. Chemicals/herbicides found effective against *Parthenium* control in cultivated and non-cultivated areas are metribuzin (1000 and 1500 g ai/ha) or glyphosate @ 2000g ai/ha (Sharma and Gautam, 2004). Widely used herbicide (paraquat) is no more effective now against white top due to resistance. These may be replaced with urea (20% water solution) common edible salt lumps (15% water solution) for control of weed in non-cropped areas.

(c) Biological Method

(1) *Use of Botanical Agents:*

In this method living things (allelopathic plants, insect, fungus etc.) are used to suppress the growth of this weed. Infestation of *Parthenium* can be suppressed by increasing the density of the existing natural vegetation like *Ipomoea* spp., *Acacia* spp. especially in the city forests, as it can not compete with dense natural vegetation. Use of plants possessing negative allelopathic effects is an important component of biological control of weeds wherein presence of one plant suppress the growth of other plants growing in the same habitat (Kohli and Kumar, 1997).

Botanical survey done across the country has revealed the negative allelopathic effect of following species in suppressing *Parthenium* in natural habitats. *Cassia sericea* SW., *C. tora* L., *C. auriculata* L., *Croton bonplandianum* Baill (*C. sparsiflorus* MaL), *Amaranthus spinosus* L., *Tephrosia purpurea* L. (best for arid region), *Hyptis suaveolens* Pois, *Sida spinosa* L., *Myrablis jalapa, Ipomoea* spp. and *Stylosanthes haemata.* Amongst the above species *C. sericea,* an exotic plant has been proved most effective botanical agent in controlling *Parthenium* substantially and perpetuates on its own in the forthcoming years. Its effects on *Parthenium* were confirmed through laboratory and field studies. In fact, plant leachates of C. *sericea* have "Kolines" which accumulate in the soil and inhibit the germination and growth of *Parthenium.* After establishment of *Cassia, Parthenium* growth subsides gradually to the point of elimination. Unlike *Parthenium, Cassia* is useful in many ways. It is important to identify botanical agents specific to each situation in all the regions where this weed is problematic. For instance, *Kochea indica* (earlier reported as *Chenopodium album*) is a viable option for Delhi and North Indian conditions (Gautam *et al.*, 2005c) as against *C. sericea.*

(2) *Use of insect Agents*

Use of insects is another important component of its biological control, which appeared from several surveys in the Caribbean (Mc Clay, 1981). A leaf eating beetle, *Zygogramma bicolorata* Pallister (Chrysomelidae: Coleoptera) introduced from Mexico (known as mexican beetle) is found highly specific to the *Parthenium.* Interestingly, its larvae and adults are helpful in reducing *Parthenium* growth through feeding. The beetles cause large-scale defoliation under tropical weather (Jayanth and Bali, 1994; Sushilkumar *et al.*, 1998).

The Mexican beetle was introduced in Delhi in September 2001 in order to suppress *Parthenium* at a prevailing temperature of 20°-38°C and 39-73% relative humidity. The operation was covered in the daily newspapers as big event (Bhatnagar, 2001; Kumar, 2001), wherein several persons having environmental concern participated. The beetles were also released at the research fields of the Indian Agricultural Research Institute, New Delhi, during September 2001 and were found multiplying at 3 out of 5 release sites till the end of October 2001 (14.4-36.4°C and 41-66% RH). The beetle remained unnoticed with decline in day temperature during the winter, though in the laboratory, at 26±2°C and 60±10% R.H, it continued breeding without over wintering. Adults approaching over wintering laid few eggs up to third week of the November (temperatures ranging from 9.4° to 35.4°C and relative humidity ranging from 61-93%), which failed to hatch afterwards. No egg laying was observed during foggy and chilling weather in December 2001 with a minimum and maximum temperature between 8 to 17.2°C and 22.2°C to 35°C, respectively. Non-over wintering females showed profuse egg laying continuously during chilling weather up to 3 days when released on *Parthenium* plants grown in pots. Survival of scanty adults during chilling weather as well as scorch summer at Delhi thus suggests that even though *Parthenium* beetle is unlikely to reproduce, its establishment can not be ruled out (Gautam, 2002).

Interestingly, surveys carried out during December 2004 and January 2005 revealed that beetles are active even in cooler months (Gautam, 2005). These were seen in some places as mating, laying eggs and developing larvae indicating that the population has acclimatized. By end of 2006, beetle has well established in Delhi and its neighboring states, remain active through out the year and noticed naturally spreading without entering into diapause/hibernation/aestivation (Gautam *et al.*, 2005 a, b; Gautam *et al.*, 2006; Bhoopathy and Gautam, 2006).

Judicious Use of Mechanical Method

Its large-scale menace can be solved to some extent by deploying mechanical control in small pockets, isolated places, uprooting isolated plants through public participation. However, it should be deployed carefully and judiciously as a component.

Integrated *Parthenium* Weed Management

All the above techniques should be adopted simultaneously in an integrated manner so that the spread of *Parthenium* and its harmful effects could effectively be reduced. Besides, some of the major operational tips for controlling *Parthenium* at a glance are listed here.

- Mark the boundary of the area in which *Parthenium* is to be controlled/treated.
- Maintain natural biodiversity and avoid undue disturbances of natural habitat except *Parthenium.*
- Uproot the *Parthenium* plants before flowering on the day after a rainy day for easy removal.
- Open the shallow furrows about 2.5 cm deep and 22.5 cm apart and sow the scarified seeds of *C.*

sericea @ 15 kg/ha and cover the furrows just before the onset of rains.

- Continue the uprooting of *Parthenium* plants/ seedlings at 3-4 weeks interval so as to enable *C. sericea* and other vegetations to put up full growth and cover.
- Once *C. sericea* is established, it will spread and grow on its own and perpetuate.
- Release 10,000-15,000 Mexican beetle, a bio-agent for 1 ha of *Parthenium* infested land.

Suggested Strategies

1. *Parthenium* continues to spread undisturbed in public, waste, abandoned fallow lands in residential and industrial premises and in lawns. Therefore, individuals may not have any interest and capable in controlling it. Hence, ensure to pay special attention to launch Community / Public Awareness Campaign jointly by Government and Voluntary organizations (NGO's) with active public participation. Flourists may be educated about its ill effects and advised not to use *Parthenium* florets in bouquets as it causes certain allergies as and when placed in the rooms.
2. Bringing out legislation similar to that of mosquito control in order to fix responsibility to the public, Municipal Corporations and other responsible public/ private sector bodies in order to assist in the management of Parthenium Plague.
3. Basic studies on mode of action of parthenin and other constituents of the weed.
4. In cultivated land, grow highly competitive species or varieties in cropped areas coupled with regular cultural practices along with use of specific recommended herbicides for its suppression.

References

Agarkar SV (1999) A survey of *Parthenium* competitive plants for environmental protection. *Environment and Ecology* **17(1)**: 228-229.

Arny (1897) *Parthenium hysterophorus* L. *J. Pharm.* **69**:168.

Bhatnagar G (2001) Extra-ordinary war and extra ordinary warriors. *The Hindu*, a daily newspaper, September 20, 2001, pp.1.

Bhoopathi Rand RD Gautam (2006) Effect of temperature on biological attributes of *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelidae). *J. Ent. Res.*, **30(3)**: 255-258.

Castex MF, MF Moltino and Moreno Ruiz (1940) Primera contributional estudio de la flora alergogena de la Repubilca Argentina. *Parthenium hysterophorus*: note previa First contribution to the study of the allergic flora of the Argentinian Republic, *Parthenium hysterophorus*. *Bol. Acad. Nac. de med. de buenos Aires* pp.91-96.

Chandras GS and VD Vartak (1970) Symposium on problems caused by *Parthenium hysterophorus* in Maharashtra region, India. *PANS*, **16**: 212-213.

Chandra S (1973) Parthenium-a new dermatitic weed in Bihar. *Proc. Sixteenth Indian Sci. Congress* III P. 375.

Dale IJ (1980) The habitats of *Parthenium hysterophorus* L. in South America, Mexico and the United States of America compared with the Queensland environment. Alan Fletcher Research Station, Sherwood, Queensland pp.14.

Gautam RD (2002) Investigations on the release of exotic beetle for control of *Parthenium hysterophorus* in Delhi. *Indian J. Weed Sci.*, **34(3&4)**: 259-263.

Gautam RD (2005) Advances in Parthenium Beetle, *Zygogramma bicolorata* Research and Field Utilization. In Second International Conference on Parthenium Management, held at University of Agricultural Sciences, Bangalore, 5-7 December, 2005, pp 170-176.

Gautam RD, Arun Samyal and Md Aslam Khan (2005a) Changing status of diapause in *Zygogramma bicolorata* Pallister in North India *Ann. Pl. Protec. Sci.*, **13(2)**: 343-346.

Gautam RD, Arun Samyal and Md Aslam Khan (2005b) Release, recovery and establishment of mexican beetle, *Zygogramma bicolorata* Pallister (Chrysomelidae: Coleoptera) in and around Delhi on *Parthenium hysterophorus* Linnaeus. *J. Ent. Res.* **29(2)**: 167-172.

Gautam RD, Md Aslam Khan, Arun Samyal, AK Garg, M Mahadevappa and Rajvir Sharma (2005c) Survey of the plants suppressing *Parthenium hysterophorus* Linnaeus in Delhi. In Second International Conference on Parthenium Management, held at University of Agricultural Sciences, Bangalore, 5-7 December, 2005, pp 94-97.

Gautam RD, Md Aslam Khan and AK Garg (2006) Ecological adaptability and variations among population of Mexican beetle, *Zygogramma bicolorata* Pallister (Chrysomelidae: Coleoptera). *J. Ent. Res.*, **30(1)**: 21-23.

Jayachandra (1971) Parthenium weed in Mysore State and its control. *Curr. Sci.* **40**: 568-569.

Jayanth KP and G Bali (1994) Biological control of *Parthenium hysterophorus* by the beetle *Zygogramma bicolorata* in India. *FAO. Pl. Protec. Bull.* **42(4)**: 207-213.

Joshi S (1991) Intereference effects of *Cassia uniflora* Mil. on *Parthenium hysterophorous* L. *Pl. Soil*, **132**: 213-218.

Kanchan SD and Jayachandra (1975) Allelopathic effects of *Parthenium hysterophorous* L. I exudation of inhibitors through roots. *Pl . Soil* **53**: 27-35.

Kohli RK and S Kumar (1997) Control of *Parthenium hysterophorus* L. through allelochemicals from a few multipurpose exotic trees. *First international conference on Parthenium management*, Dharwad, India 6-8 October 1997, pp. 37-39.

Krishnamurthy K, TV Ramchandra Prasad, TV Muniyappa and BV Venkata Rao (1977) *Parthenium*, a new pernicious weed in India. *UAS, Tech. Ser.*, No **17**: pp 66.

Krishnamurthy K, TV Ramchandra Prasad, TV Muniyappa (1976) Ecology and control of *Parthenium. Proc. of Seminar on Parthenium a Positive Danger,* Bangalore (India). September 4, pp. 8-10.

Kumar M (2001) Beetles join grim battle against deadly weed, *Hindustan Times* South Delhi Live, September **22**: pp 1.

Mackoff S and AOA Dahl (1951) Botanical consideration of the weed oleoresin problem. *Minn Med.* **34(12):** 1169.

Mahadevappa M (1999) *Parthenium* and its Management. Publication Centre, *Univ. Agric. Sci.,* Dharwad, India, 132p.

Mahadevappa M (1996) *Parthenium Prasaranga*, University of Mysore, Mysore, p. 66.

Mahadevappa M and H Ramaiah (1990) Pattern of replacement of *Parthenium hysterophorus* plants by *Cassia sericea* in waste lands. *Indian J. Weed Sci.,* **20**: 83-85.

Maheshwari JK and RS Pandey (1973) *Parthenium* weed in Bihar State. *Curr. Sci.*, **42**: 733.

Mamatha M and M Mahadevappa (1992) Biological survey in relation to *Parthenium* control. *Advances in Pl. Sc.,* **5:** 426-429.

Mc Clay AS (1981) Studies of the natural enemies of *Parthenium hysterophorus.* Trinidad-and-Tobago, Common Wealth-Institute-of-Biological-Control: Report-of-work-carried-out-April-1980-March-1981, 62-63. *Commonwealth Agricultural Bureaux.* Slough; UK.

Narsimhan TR, M Ananth, M Narayanaswamy, R Babu, A Mangla and PVS Rao (1980) Toxicity of *Parthenium hysterophorus*: Partheniosis in cattle and buffaloes. *Indian J. Anim. Sci.* **50**: 173-178.

Ogden HD (1957) Diagnosis and treatment of parthenium dermatitis. *J La State Med Soc.* **109(10)**: 378-379.

Parihar SS and KC Kanodia (1986) *Parthenium hysterophorus*-A review of Indian work. *My Forest,* **22**: 51-59.

Rao RS (1956) *Parthenium*-a new record for India. *J. Bombay Nat. Hist. Soc.* **54**: 218-220.

Sharma R and RD Gautam (2004) Problems and management strategies for the control of congress grass. *Indian Farming* **53(10):** 17-21.

Sushilkumar, VM Bhan and S Kumar (1998) Establishment and dispersal of introduced exotic beetle *Zygogramma bicolorata* in relation to ecological factors at Vindhyanagar. *Indian J. Ecol.* **25(1):** 8-13.

Tiwari JP and CR Bisen (1984) Ecology of *Parthenium hysterophorus* L. *Indian J. Weed Sci.* **16**: 203-206.

Towers GHN, JC Mitchell, E Rodriguez, FD Bennett and PV Subba Rao (1977) Biology and chemistry of *Parthenium hysterophorus* L., a problem weed in India. *J. Sci. Ind. Res.* **36**: 672-684.

Towers GHN and PVS Rao (1992) Impact of the pan-tropical weed, *Parthenium hysterophorus* L. on human affairs. *Proceedings of the 1st International Weed Control Congress,* **1:** 134-138, Weed Science Society of Victoria; Melbourne; Australia.

Vaid KM and HB Naithani (1970) *Parthenium hysterophorus* L.: A new record for the North Western Himalaya. *Indian Forester* **96**: 791-792.

Vartak KD (1968) Weed that threatens crop and grasslands in Maharashtra. *Indian Farming* **18(1):** 23-24.

Technological and Policy Developments in Relation to Conservation and Use of Genetic Resources

JMM Engels
Bioversity Intenational, Understanding and Managing Diversity Programme, Rome, Italy

The paper analyses the developments that have taken place in the political framework since the 1970s, in particular the history of conservation and use of plant genetic resources with regard to questions of ownership, access and legal protection. Special attention is paid to the Convention on Biological Diversity and the International Treaty for Plant Genetic Resources for Food and Agriculture. It also examines developments with regard to technologies that have impact on the conservation and use of plant genetic resources, in particular advances in the field of molecular genetics and genetic engineering. The marker technology and use of genomics have enabled the development of tools to allow a thorough assessment of the genetic diversity found in genepools and resulted in significantly improved possibilities for the evaluation of germplasm, and thus, to a better exploitation of existing genetic diversity in germplasm collections. Furthermore, an assessment of the global economic developments that have impact on the conservation and use activities is made, especially from a developing country perspective. The impact of globalization can be observed on one hand in a drastically reduced number of private plant breeding companies, and an increased importance of genetically modified varieties in food production for the major crops, on the other. The implications for conservation of the use of genetically modified varieties are yet to be studied and policies are still to be developed to promote reliable *in situ* and *ex situ* conservation efforts. Based on the aforementioned analyses suggestions are made how constraints that have been identified might be overcome.

Key words: Genetic resources conservation and use, Technologies, Policy framework, Genebanks

Over the past decade substantial progress has been made in the development of a political framework for the conservation and sustainable utilization of agrobiodiversity. The conclusion of the Convention on Biological Diversity (CBD) in 1992 and, more recently in 2001, the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) have been key developments, both addressing the urgent need for long-term conservation of threatened genetic resources world-wide and stressing their sustainable use. With regard to the latter the advances in molecular genetics and information technologies have been dramatic and are very relevant to the conservation and the sustainable utilization of genetic resources.

Coinciding with the aforementioned developments the world experienced the impact of globalization of economies and a drastic shift in the property rights regime, in particular the use of patents to protect biological inventions/discoveries. The impact of globalization can be observed on one hand in a drastically reduced number of private plant breeding companies, and an increased importance of genetically modified (GM) varieties in food production for the major crops, on the other. The implications for conservation of GM varieties are yet to be studied and policies are still to be developed to promote reliable *in situ* and *ex situ* conservation efforts.

E-mail: j.engels@cgiar.org

The above-mentioned developments coincided with the degree of governmental support to agricultural research, including activities such as pre-breeding and conservation, particularly in developing countries. However, these countries usually lack the financial resources to exploit the locally available genetic diversity in order to ensure their contribution to human well-being. Moreover, the technologies and the required human resources are similarly lacking and thus, the benefits of these technological developments do not reach the main guardians of agrobiodiversity, i.e. the farmers and foresters. This, in turn, does not provide them with any real incentive to continue to contribute towards badly needed conservation activities.

This paper analyzes how the existing policy framework as well as the technological and global economic developments impact conservation and utilization efforts, particularly in developing countries, and suggests how identified constraints might be overcome.

Policy Framework

In this section the history of conservation and use of plant genetic resources for food and agriculture (PGRFA, especially with regard to questions related to ownership, access and legal protection) are being assessed. During the past two decades this history has been strongly influenced by several international agreements on (agricultural) biodiversity and these are briefly described in their historical context.

International Undertaking on Plant Genetic Resources

In 1983, the International Undertaking (IU) was established by the member states of FAO as a legally non-binding agreement on the conservation, use and access to PGRFA. The principle of common heritage of humankind was possibly the most important aspect of that agreement and that reflected the "spirit" of the time. The IU endorsed the idea of "open access" to genetic resources and benefit sharing was very much understood to be "in kind" and for present and future generations (Bragdon, 2004). In fact, the agreement established a kind of global multilateral system for PGRFA. The concept of "Farmers' Rights", an innovative and new aspect included for the first time in an international agreement, recognized the substantial contributions that farmers and farming communities had made to the creation and maintenance of genetic diversity and called for adequate recognition of these contributions. After substantial debate in 1987, particularly instigated by the then already active NGOs that participated in the meeting of the FAO Commission on Plant Genetic Resources (PGR), the concept of Farmers' Rights was declared to be compatible with plant breeders' rights. It should be noted that during the seventies and eighties the main focus of the debate and of the agreed activities was on *ex situ* conservation and on the establishment of genebanks and germplasm collections as part of the Global System. There was a strong focus on technological aspects of conservation, e.g. the establishment of the technical infrastructure, on the development of new technologies, in particular for the conservation and use of crop genetic resources that could be stored as seed. Gradually, the emphasis moved to also include crop plants that could not be stored as seed since such crops either do not set seed or their seeds are recalcitrant. For these types of crops, conservation methods such as *in vitro* storage through slow-growth techniques or cryopreservation have been developed (Engelmann and Engels, 2002). The IU was superseded in 2004 by the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA).

Convention on Biological Diversity (CBD)

The negotiation of the Convention on Biological Diversity (CBD) in the eighties and early nineties, under the auspices of the United Nations Environment Programme, did result in drastic changes in the aforementioned focus. Besides creating a legally-binding framework for the conservation and sustainable use of biodiversity, after it came into force in 1993, it provides that access to valuable biological resources be carried out on "mutually agreed terms" and subject to "prior informed consent" of the country of origin. The national sovereignty of states over biodiversity within their borders was recognized as a key principle in the CBD and, as a consequence this became the "driving force" in the thinking and approaches of the negotiations and future developments. Besides the fact that states were encouraged to "look after their own biological resources and conserve them, whenever possible in their own country", this caused also a strong incentive to countries to favour bilateral rather than multilateral arrangements for the exchange of genetic resources. From an agricultural perspective it should be noted that the negotiations that eventually led to the CBD convention were strongly influenced by environmentalists and nature conservationists and, as a consequence, a bias towards wild (i.e. non-domesticated and non-agricultural) plant and animal species can be observed. In fact, agriculturalists were hardly present in the negotiations and it was only through a separate resolution (Resolution 3 of the Nairobi Final Act) that FAO was asked to address two important but unresolved agricultural genetic resources issues, i.e. the question of Farmers' Rights and the need to address the legal status of existing genetic resources collections established prior to 1993 (Bragdon, 2004).

The negotiation process of the CBD caused a dramatic shift with regard to the overall conservation approach, i.e. from a rather technologically driven *ex situ* conservation approach ("putting the germplasm safely away for the future"), towards a much more people-centered conservation, with a strong emphasis on *in situ* and on-farm conservation and sustainable utilization efforts. Alongside, due attention was being paid to participatory research activities in order to recognize the important role of local communities in the management of and their dependency on biodiversity. This also led to the recognition of traditional and indigenous knowledge to be an important component of biodiversity that needs to be collected and/or conserved. In addition, environmental issues were closely interwoven with conservation activities. Furthermore, there is also due recognition given to the importance of technology for the conservation and use of genetic resources and for the importance of providing access to such enabling technologies. These aforementioned aspects facilitated (and required) a much closer link between conservation and development and led to a greater participation of local communities and small subsistence farmers (frequently assisted by development-orientated NGOs) in conservation and use related activities. It is in this context that the access and benefit-sharing guidelines were developed and agreed upon in 2002 within the framework of the CBD by an *Ad Hoc* Open Ended Working Group on Access and Benefit-Sharing (Anonymous, 2002). Unfortunately, the so-called Bonn Guidelines also have a bias towards wild species, with a strong focus on nature conservation and seem to ignore, to a large extent, the specific requirements of agricultural crops.

The CBD recognized the application of intellectual property rights (IPRs) on biological materials as a means of protecting inventions and stimulating innovation. This led to a further expansion of the scope and/or application of IPRs, especially patents and plant breeders rights (PBRs), in agricultural research, including plant breeding. The latter was also stimulated by the fast development of molecular genetics, genetic engineering and information technologies that gave rise to the development and cultivation of GM plant varieties. Due to concerns that the latter could cause a threat to the environment it was felt that a legal framework on biosafety aspects was needed and, as a consequence, the so-called Cartagena Protocol on Biosafety was developed as a legal framework for biosafety legislation, also as part of the CBD implementation process. Biosafety legislation is currently being developed and implemented by many nations around the world (Cartagena Biosafety Protocol can be found on the CBD's website (http://bch.biodiv.org).

International Treaty on Plant Genetic Resources for Food and Agriculture

The ITPGRFA was adopted in 2001 by the FAO member states, entered into force in June 2004 and is the result of the revision of the International Undertaking. It addresses the conservation and sustainable use of PGRFA as well as the fair and equitable sharing of benefits that derive from their use, in harmony with the provisions of the CBD. It includes, among others, a multilateral system for 35 crop genepools and 29 forages, listed in Annex I of the Treaty. This multilateral system is based on the principles of the CBD, recognizes the specific requirements of agricultural crops and it undertakes to respect the free "flow" of genetic resources that are maintained in the public domain and included in Annex I as well as those made voluntarily available. Specific access and benefit-sharing (ABS) arrangements for the Annex I crops are being negotiated whereas Farmers' Rights, defined as a range of political and social rights, should be realized through national instruments. It can be stated that the IT has a strong focus on the sustainable use of PGRFA and reflects the interests of both developing and developed countries (Moore and Tymowski, 2006).

Other International Legal Instruments

Other important international instruments and agreements that have contributed to the shaping of the international policy framework for the conservation and use of genetic resources include the Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources (the GPA, agreed upon in 1996 in Leipzig, Germany by more then 150 countries), agreements of the World Trade Organization (WTO) such as the Trade-Related Aspects of Intellectual Property Rights (TRIPS) as well as of the World Intellectual Property Organization (WIPO).

The agreements of the WTO that have relevance for the political framework is in particular the TRIPS agreement as it requires countries to provide for the protection of animal breeds and plant varieties either by patents, an effective *sui generis* protection, or by a combination thereof. The WIPO already provides for the protection of plant breeders rights under the Union for Protection of Plant Varieties (UPOV) agreement and recently established an Intergovernmental Committee on Genetic Resources, Traditional Knowledge and Folklore. In many of these international fora one can observe an increased presence and influence of developing countries and/or their interests. However, many of the aforementioned developments have led to a much more restrictive attitude in providing access to genetic resources and there have been systematic and dramatic changes (i.e. a drop from about 30,000 new germplasm samples accessed every year to the genebanks from the Consultative Group on International Agricultural Research –CGIAR- to less than 5,000 (Figure 1; SINGER communication, 2005).

It can be summarized that, in general terms, for the (long-term) conservation and utilization of PGRFA a conducive policy environment has been created and the international policy framework for the conservation, sustainable use and equitable sharing of benefits of

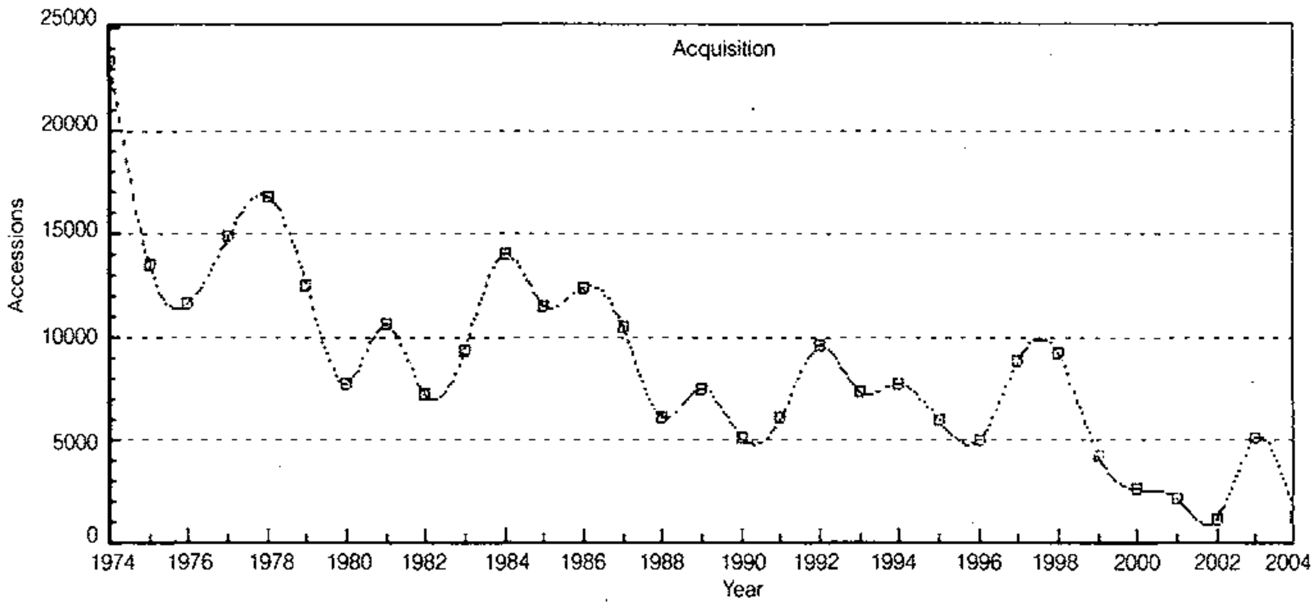


Fig. 1: Acquisition of new germplasm samples by the CGIAR Centres since 1974.

PGRFA has been established, through processes in which developing countries have been participating more and more. These developments have certainly contributed to a clearer recognition that conservation activities are important and need to be addressed within the national as well as international context.

Technological Developments

Over the past two decades or so we have seen rapid advances in the field of molecular genetics and genetic engineering. The marker technology and use of genomics have enabled the development of tools to allow a thorough assessment of the genetic diversity found in genepools and resulted in significantly improved possibilities for the evaluation of germplasm, and thus, to a better exploitation of existing genetic diversity in germplasm collections. With the possibility of identifying specific genes in collections, and the availability of the technology to transfer such genes into a desirable genetic background, a significant improvement in the utilization of germplasm has been observed over the past 10 years or so. At the same time the fast spread of genetically modified varieties worldwide and their significant increased cultivation over the past 8 years or so brings new challenges to conservation. The replacement of traditional landraces by GM varieties and, as a consequence, the potential spread of non-desirable genes through uncontrolled geneflow, causes threats to the genetic diversity of those crops and their wild relatives, both, to those conserved in genebanks as well as *in situ* / on-farm (Engels *et al.*, 2006).

Almost in parallel to developments in genetic engineering and in the area of genomics the world observed a revolution in information technology. The wide-spread use of computers, in developed and developing countries, has facilitated greatly the area of genetic resources conservation and use and has meant that conservation approaches can be implemented in a much more targeted and efficient manner. These developments helped in particular existing networks to become more effective and efficient. It has also allowed users to be better informed about the content of germplasm collections and to target the material to be included in their breeding efforts much better. One good example is the SINGER database that provides details of the germplasm collections maintained by the centres of the CGIAR. With the more recent developments in the area of bioinformatics, not only the understanding of the actual content of the collections has significantly increased but also enormous progress has been made with regard to the taxonomy, relationships and evolution of our crop plants and their wild relatives. This, in turn, results in a better understanding of the conserved genetic resources and, thus, to a better use.

However, it should be noted that these technological developments have not occurred evenly across countries. Developing countries, in particular, frequently lack the necessary trained personnel, technical resources and infrastructure, as well as the financial resources to be able to take full advantage of these developments. Despite this, it can be concluded that in general terms the technological developments have significantly contributed to improved and more rational conservation and utilization of PGRFA, also in developing countries.

Global Economic Developments

Agricultural Research

For several years there has been a tangible and steady decrease in the availability of funds for public agricultural research. This decline is most likely correlated with and possibly caused by a steady decline of general and political interest in agriculture. An indicator of this development is the fact that in a number of countries ministries of agriculture have been closed and/ or merged with other related ministries. In parallel, research institutes have been merged with others, changed their mandates and/ or were closed down all together. Unfortunately, this trend can also be observed in developing countries, despite the fact that they still depend to a large extent on agriculture both as an important source of revenue and food production. According to FAO the proportion of the total agricultural gross domestic product spent on research is about 0.5 % in developing countries compared to 2-4% in developed countries. In terms of intensity of investment the gap between rich and poor countries has grown. In 1995 rich countries spent $2.64 on public research for every $100 of agricultural output, 4.3 times more than the 62 cents on research per $100 of output invested by poor countries. In addition to these developments, technical assistance and development aid to developing countries is at its lowest level ever. It has fallen from 0.5% GDP in the early sixties to about 0.22% today, i.e. $52 billion a year compared to $350 billion for agricultural subsidies in the United States and Europe, and $900-1,000 billion for defence.

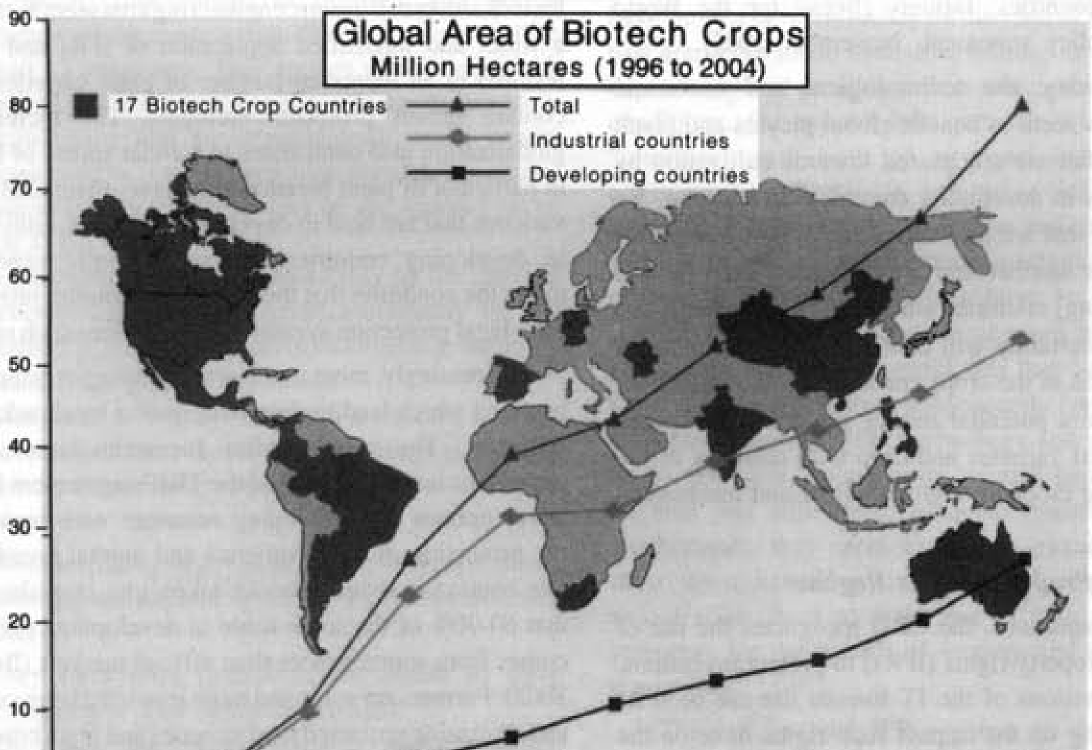
Most likely as a consequence of the above a brain-drain of young and dynamic researchers from the public to the private sector, both in developing and developed countries, as well as a migration of promising scientists from developing countries to developed countries has been observed. This, in turn, has resulted in an increased role of the private sector in agriculture. According to the World Bank (Ian Johnson, personal communication) public sector spending on agricultural research has taken a nosedive, leaving it to the mercy of the private sector. This had a direct effect and impact on the types and areas in which research and investments are being conducted, i.e. a stronger focus of potentially profitable areas (e.g. export orientation, focus on major food crops; use of imported varieties; etc.) and resulted in a concentration of the agricultural business and a more narrow focus on relatively few commercial producers and crops, including a withdrawal of public research organizations from plant breeding and seed production activities in many developing and developed countries (Morris and Ekasingh; 2002). This had a direct negative impact on the utilization of genetic resources and thus hit the sustainability of the conservation efforts twice.

As a consequence of the above developments, the public sector national agricultural research systems (NARS) in developing countries have been further weakened; they frequently lack the flexibility and responsiveness to client demand and are susceptible to political interference. Unfortunately, these developments have also led to a decrease in support for the conservation and utilization of PGRFA and, certainly, they will not help genebanks and conservation programmes that were already chronically under-funded. Long-term conservation efforts in particular suffer as the amount of operational funds being made available are insufficient and, thus lead to inappropriate management of conserved material, including losses of viability of stored germplasm and subsequently genetic erosion. Furthermore, hardly any characterization and evaluation activities are being conducted by genebanks and this, in turn, has a negative influence on the utilization of the conserved material as well as on the "utility" of the conservation efforts at large.

Globalization

We have seen a rapidly evolving global seed industry over the past twenty years or so, characterized by many mergers and thus, resulting in a concentration of plant breeding companies and an increased domination by a handful of multinationals. This trend is also characterized by an increased commercial attitude as a basis for decision-making, more and more privatization as well as an increased interest in legal arrangements. These developments were further fueled by stronger links between the chemical and the seed sector and by an increasing application of biotechnological inventions, in particular genetic engineering. This resulted in an increased importance of GM plant varieties worldwide (Figures 2 and 3) as well as in an increased number of crops for which GM varieties are being commercialized. At the same time, an increased application of intellectual property protected inventions in plant breeding could be observed, predominantly by the aforementioned multinationals. About half a dozen major firms hold substantial number of key patents on germplasm and on related enabling technologies such as gene guns. These factors make it difficult for developing countries to take advantage of these technologies and thus, it makes them more dependent on the GM varieties produced elsewhere. In addition, it becomes increasingly more difficult to get access to these varieties, also as they require specific and expensive chemicals (Falcon, 2000).

In 1995, the first commercial GM varieties of maize and cotton were released on a larger scale, either based on the *Bt* (*Bacillus thuringiensis*) insect resistance genes, or possessing tolerance to (specific) herbicides. Since then there has been a dramatic increase both in the acreage and the number of crop GM varieties. According to James (2004) the estimated global area of commercialized GM crops in 2004 was 81.0 million hectares. This was due to as much as 60% of soybean, followed by maize (23% of global area), cotton (11%) and canola (6%). Of this acreage, approximately 34% was in developing countries, especially Argentina, Brazil, Mexico, China, India, the Philippines and South Africa. Details of the increases in the cultivation of GM crops are shown in Figures 2 and 3. In 2004 only about 1% of GMO crops were grown in (South) Africa (James, 2004). Furthermore, it should be noted that of the more than 50 GM crop products released in developed countries none was specifically designed to address "African" problems and this might well apply to most of the other developing regions of the world as well. Most/ all of the GM varieties are being produced outside the developing countries and address those problems that exist with farmers that want to buy such varieties, i.e. commercial farmers in the developed countries and not those of



Increase of 20%, 13.3 million hectares or 32.9 million acres between 2003 and 2004.
Source: Clive James, 2004

Fig. 2: Area under cultivation of genetically modified crops in developing and industrialized countries (James, 2004)

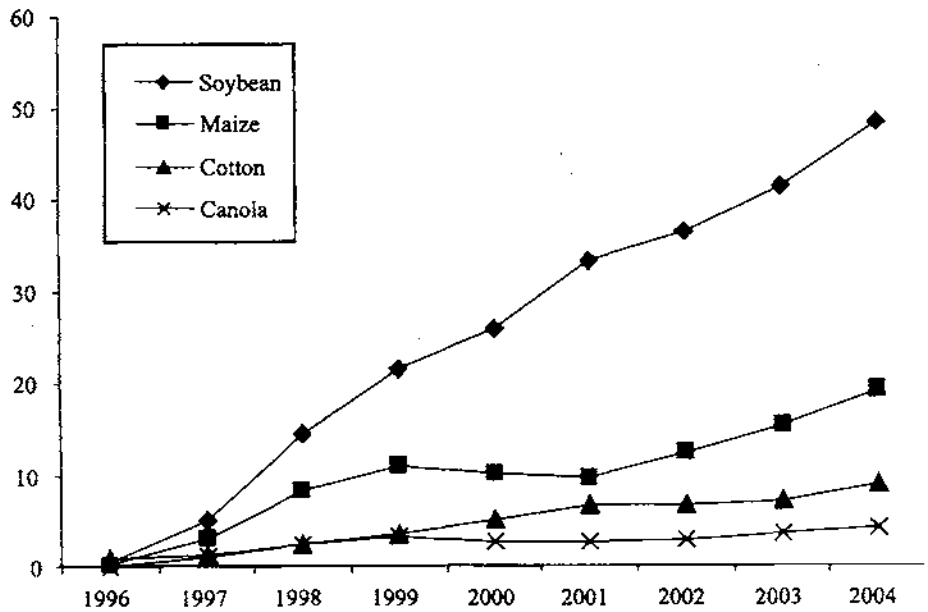


Fig. 3: Global area of genetically modified crops (James, 2004)

developing countries' farmers (Bread for the World Institute's policy statement, November 2002).

In summary, the technological and economic developments seem to benefit global players and result in products that are not geared towards cultivation by small farmers in developing countries. In addition, the GM varieties that are marketed in developing countries are limited in number and are in general bred outside the (developing) countries where they subsequently are grown. This certainly will contribute to an increase of genetic erosion in the crops concerned and, in addition, will introduce a potential risk of spreading transgenes into traditional varieties and crop wild relatives of the corresponding crops through geneflow and mechanical mixtures.

Intellectual Property Rights Regime

As already mentioned, the CBD recognizes the use of intellectual property rights (IPRs) to protect inventions. Also the provisions of the IT foresee the use of IPRs and, depending on the impact such rights have on the continued availability of the genetic diversity contained in the variety itself or in related material, still to-be-agreed benefit sharing arrangements will be required in such cases. The WTO-TRIPs agreement requires the acceptance of patents, a *sui generis* system or a combination thereof, for the protection of plant varieties. Furthermore, the fast developments in the biotechnological/ genetic engineering area seem to favour a wider and intensified application of IPRs and have resulted in an increased number of plant varieties that contain patent protected elements. The increasing globalization also contributes to a wider spread of IPRs, in particular of plant breeders rights on ornamental crop varieties that are bred in developed countries, cultivated in developing countries and subsequently exported, under the condition that the cultivating country provides for a legal protection system that recognizes such rights.

Increasingly, more and more technologies/genes are patented which lead to decreased access for developing countries. The same applies for technologies. The provisions in Art. 27.3 (b) of the TRIPs agreement leave fewer options for developing countries with regard to the protection of plant varieties and animal breeds. In this context it should also be taken into consideration that 60-90% of the seeds sown in developing countries comes from sources other than official markets (Butler, 2002). Farmers are more and more restricted from saving and replanting protected seed varieties and plant breeders face more restrictions to use (patent) protected varieties in breeding work. Furthermore, the IPR regimes are only to some extent compatible with traditional or indigenous knowledge and thus, do not leave sufficient room for protecting traditional resource rights and indigenous knowledge. Lack of financial resources and the absence of any type of bargaining limit the access by developing countries to protected technologies and to products generated by these technologies.

In summary, when analyzing the global economic and IPR developments it can be concluded that these are less favourable to or even harmful for the conservation and sustainable utilization of PGRFA, from a developing country perspective. In fact, several of the developments run directly counter to their interest, especially for small farmers, the custodians of a significant part of the still existing plant genetic resources world-wide.

Impact of Aforementioned Developments on Conservation and Use of PGRFA

The impact of the aforementioned developments on the conservation and sustainable use of PGRFA will be briefly analyzed from a developing country perspective. In general terms, it can be concluded that these developments have resulted in some overall conditions that are conducive to the conservation and sustainable use of genetic resources, including:

- A much more conducive political and policy framework for conservation and utilization activities than 15 years ago. This applies also to questions related to access and benefit sharing, to biosafety regulations and to international/ multi-lateral conservation (i.e. in particular through the multi-lateral system for the species on the Annex I list of the IT);
- An accepted political responsibility by the member states of the CBD to conserve, sustainably use and equitably share the benefits of biodiversity, including that of the genetic resources;
- Compared to twenty and even ten years ago, we have a much more favourable technological situation for the conservation and especially the utilization of genetic resources.

However, developing countries face severe problems in conserving and exploiting their own genetic resources, because:

- They have only limited or no access to these technologies and research products
- They lack trained human resources and institutional capacity to use such technologies as well as to improve their local crops and breeds
- They have none or only limited national agricultural research capacity to take advantage of these more favourable conditions.

The aforementioned conditions do have a direct bearing on the degree that developing countries are able to conserve the still existing but increasingly threatened genetic resources. The severe lack of infrastructure and human resource capacity, lack of funds as well as non-functional or ineffective institutional frameworks and the fact that breeding activities focus to large extent on crops that are being dealt with by centres of the CGIAR and not on minor local crops that are of importance to subsistence farmers, there is little or no effort being made to assist the local non-commercial farmers to improve their crops and to tackle their problems. This leads to little or no incentives for the local communities to contribute to conservation efforts since such efforts usually do not result in any form of income or even food.

As a consequence, conservation efforts do not result in sufficient benefits for either the country or for the small farmers/local communities to create incentives that could in the long run contribute to the maintenance of currently existing genetic diversity, both in farmers' fields and genebanks. Furthermore, developing countries have limited or no influence on the kind of GM varieties that are being made available, leading to an increased dependency and possibly to less sustainable production conditions. On top of this, the same GM varieties "interfere" with both *ex situ* and *in situ*/on-farm conservation efforts. In countries with biosafety regulations that regulate the import and export of GM varieties it might well be that genebanks as well as on-farm conservation schemes have to monitor the possible introgression of transgenic genes into conserved germplasm and thereby avoid that they would violate the law when distributing subsequently "contaminated" germplasm material. The technology and methodology to do this on a routine basis are still lacking. This is an area that still needs adequate research attention. Furthermore, they seem to lose or already have lost their own breeding and research capacity that would allow them to make use of their own genetic resources for the benefit of farmers and the countries themselves.

The international IPR regimes do not help local communities and farmers to protect their indigenous knowledge. These regimes are frequently not compatible with the existing traditional resource rights, including the landraces and other traditional varieties that have evolved over hundreds of years.

Finally, there is a decreasing "return" of the benefits that are being generated in developed countries (predominantly by the seed industry) by using genetic diversity that originated in developing countries, to developing countries through the provision of economic or technical assistance. In addition, through the agreement to accept the implementation of Farmers' Rights as a national obligation the developing countries have lost this "instrument" as a means of securing a contribution from developed countries for the continuing efforts to generate and maintain genetic resources.

What can be Done to Change and Improve this Situation?

The above described technological, economic and IPR related developments seem, from a global perspective, to be favourable for conservation and sustainable use activities. When analyzing the situation from a developing country perspective the picture looks much less positive. This situation can certainly be explained by the fact that most of the international instruments that have a direct or indirect impact on the conservation and use of PGRFA are being negotiated and agreed upon in international fora in which developing countries usually have less influence and/or are being traditionally dominated by the rich countries. It is against this background that potential solutions are being sought that can lead to an improvement of the situation and, thus, to a more sustainable and acceptable situation for the developing countries. The major suggestions include:

1. To provide equal opportunities to all at conference tables and in business. In general, the influence of developing countries on the negotiations of international agreements has been rather limited. In order to create PGRFA/biodiversity conservation and utilization schemes (and for any other negotiation process) it seems critically important to treat each other as equals and to make an effort to understand the needs and priorities of the developing countries well.
2. To ensure equitable benefit sharing arrangements between all parties involved. The agreed Access and Benefit Sharing (ABS) guidelines seem to provide a good basis for meaningful benefit-sharing arrangements. However, it has to be understood that such regulations are as strong as the will of the developed countries to level the playing field and to accept the very disadvantageous position of most developing countries to be able to actually reap benefits from using PGRFA/biodiversity.
3. The further strengthening of the agricultural research capacity and of the overall institutional framework in which conservation and utilization activities take place is a pre-condition to allow changes for the better.
4. In order to achieve the necessary changes in developing countries it will be important to establish strategic alliances and partnerships between public sector research institutes and the private sector, including national as well as regional/ international research institutions such as the CGIAR, ensuring that both genetic resources and technologies are available and that capacity building is at the heart of the business.

While keeping these general provisions in mind it will be important to also address approaches and principles at the local and national level that will strengthen the situation of the local communities and farmers to allow sustainable long-term conservation and utilization efforts of the precious but dwindling genetic resources found predominantly in developing countries. These include:

- The active participation of stakeholders in developing countries in any decision-making processes that include or affect the conservation and sustainable use of PGRFA at the national and local level is a pre-requisite to ensure necessary ownership of the activities as well as for a sustainable and long-lasting arrangement or initiative.
- The principle of self-determination should, wherever possible and relevant, also be applied to the conservation and use of PGRFA. In fact, this principle should be applied at any level where people traditionally manage genetic resources.

References

Anonymous (2002) Bonn Guidelines on Access to Genetic Resources and Fair and Equitable Sharing of the Benefits Arising out of their Utilization. Secretariat of the Convention on Biological Diversity. Montreal, Canada.

Bragdon S (ed.) (2004) International Law of Relevance to Plant Genetic Resources: A practical review for scientists and other professionals working with plant genetic resources. Issues in Genetic Resources No. 10, March 2004. International Plant Genetic Resources Institute, Rome, Italy.

Butler LJ (2002) Conflicts in intellectual property rights of genetic resources: implications for agricultural biotechnology. *In:* Evenson RE, V Santaniello, D Zilberman, (eds.). *Economic and social issues in agricultural biotechnology.* Wallingford, UK: CAB International.

Engelmann F and JMM Engels (2002) Technologies and strategies for *ex situ* conservation. *In*: Engels JMM, VR Rao, AHD Brown and MT Jackson (eds.). *Managing Plant genetic Diversity.* CABI, Wallingford, UK Pp. 89-103.

Engels JMM, AW Ebert, I Thormann and MC de Vicente (2006). Centres of crop diversity and/or origin, genetically modified crops and implications for plant genetic resources conservation. *Genetic Resources and Crop Evolution* **53**: 1675-1688.

Falcon WP (2000) Globalizing germplasm: barriers, benefits and boundaries. Paper presented at the 23rd International Conference of the International Agricultural Economics Association. Berlin, 14-18 August 2000.

James C (2004) Preview: global status of commercialized biotech/ GM crops: 2004. ISAAA briefs No. 32. ISAAA: Ithaca, NY.

Moore G and W Tymowski (2006) Explanatory guide to the International Treaty on Plant Genetic Resources for Food and Agriculture. IUCN Environmental Policy and Law Paper No. 57. IUCN-ELC, Bonn and IPGRI, Rome.

Morris M and B Ekasingh (2002) Plant breeding research in developing countries: what roles for the public and private sectors? *In:* Byerlee D and RG Echeverria (eds.), 2002. *Agricultural research policy in an era of privatization*. CABI, Wallinford UK. Pp 199-225.