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Review Paper

Status of Crop Biodiversity and Registration of Farmers' Varieties in India

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INTRODUCTION

India is recognized as a mega-diversity centre, possessing unique crop diversity, including a number of crops that have long been naturalized and cultivated here. The human civilization owes its origin and survival to agro-biodiversity. Plants are the major source of food for most of the living organisms on the earth and to date, approximately 300,000 plant species have been identified. In olden days 70,000 to 100,000 crop species were being cultivated for food and out of these 30,000 plant species were used for edible purpose. At local level about 7000 species were used for food. At present, more than 300 plant species are cultivated around the world for food and feed. India has notified 156 crop species of economic importance for registration of plant varieties, including farmers' varieties for registration to get Intellectual Property Rights (IPR). Owing to the prevalence of diverse climatic conditions, varied ecosystems of the Indian Subcontinent have supported enormous agrobiodiversity that provided opportunity for cultivation and selection of many edible and non-edible plant species. The Indian Subcontinent is known as one of the important centres of origin of crop plants that have been cultivated for more than 10,000 years. Based on floristic diversity and species endemism, India has been recognised as one among the 12 mega-biodiversity centres of the world. Whereas the floristic diversity is represented by 17,926 species of angiosperms, the Indian agriculture cultivates only 811 plant species. The cultivated crop species can be either of primary or secondary origin that have been differentiated on the basis of whether the cultivated species was derived from local or exotic populations of wild progenitors or introduced as cultigens and perpetuated. The former represents primary origin whereas the latter indicates secondary origin. The biodiversity present in India can be divided into the following two broad categories:

Indigenous Domesticates – The concept of 'Centre of Origin' for crop plants was proposed by Vavilov way back in 1926 according to which the centre of origin is a geographical area where a plant species was either domesticated or is considered to have first appeared under cultivation from their wild progenitors. The Indian subcontinent has been recognised as one of the centre of origin/domestication by most of the evolutionary biologists (de Candolle, 1883; Vavilov, 1926; 1935; Zeven and Zhukovsky, 1975 and Harlan, 1975). A recent publication by Singh (2016) presents a list of plant species originated/domesticated or first brought into cultivation in India.

(i) Introduced Exotics – Apart from the indigenously domesticated plant species, the agrobiodiversity in Indian subcontinent has been further enriched by the introduction of exotic plant species domesticated elsewhere, as for example, presence of American cereals such as maize, grain amaranth, vegetables like pumpkin; African cereals like, pearl millet, sorghum and West Asian legumes such as chickpea, field pea, grass pea etc. (Saraswat, 1992). The introduction of exotic crops got further boost after the discovery of sea route to India at the fag end of the 15th century by Vasco da Gama followed by British, Dutch, French and Spanish travellers bringing more crops to the Indian shores during the 16th century. With passage of time these crops acclimatised and adapted to the diverse agro-climatic conditions (provided by the Indian subcontinent) to such an extent that they appear natural making India either secondary centre of diversity for some crops or regional centre of diversity for others.

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Genetic diversities in cultivated plant species

There have been several attempts to estimate the total number of cultivated plant species in India. While Pareek et al. (2000) from the National Bureau of Plant Genetic Resources reported 583 species which was later rationalised to 480 (Nayar et al. 2003). However, the 4th Country status report submitted to the Convention of Biological Diversity reported 800 species (Goyal and Arora (2013). A recent attempt to document an inventory of cultivated plant species reported existence of 811 cultivated species along with their wild relatives belonging to 495 genera and 139 families (Singh et al. 2013).

Of the total geographical area of 329 million ha of India, around 143 million ha is used as crop land. The indigenously domesticated as well as introduced crop species interacted with the diverse agro-climatic conditions and thus have helped in selection of a large range of crops by the farmers and other stakeholders. In addition, the local communities based on crops, crop combinations and crop rotations have worked with these crop plants and generated huge diversity which have differentiated into land races due to selection, natural outcrossing and adaptation for thousands of years as evidenced by 'Raipur collection' of 18,541 cultivars by Dr Richharia from Chhattisgarh region only (*www.frontline.in/static/html/fl2002/stories/*). These land races have been cultivated by the farmers for a long time. However, with the advent of Green Revolution (in late 1960s and early '70s), dwarf varieties of wheat and rice were introduced and popularised at large scale. The dwarf varieties of the two staple crops *viz.* rice and wheat are irrigation and fertilizer responsive and yield higher than the land races; therefore, were adopted by the farmers in a big way. However, the land races, on account of being cultivated for thousands of years, have adapted to the local agro-climatic conditions and thus developed resistance/tolerance against some of the biotic and abiotic stresses due to selection of favourable gene(s) and gene complexes. The ICAR's National Bureau of Plant Genetic Resources based in New Delhi in collaboration with All India Coordinated projects of various crops has made collection of this diversity, and maintains in its gene bank that has been supported by the Indian Council of Agricultural Research (ICAR)(Table 1).

Managing agrobiodiversity for the posterity presents a formidable challenge which requires paradigm shift in our understanding the legal intricacies involved in protection and sharing of genetic resources for betterment of

Table 1. Number of indigenous/total accessions conserved in major crops of various crop groups, reflecting richness of genetic diversity

Crop group/cultivated species	Indigenous collections	Total collections
Cereals		
Rice, *Oryza sativa*	85793	89258
Wheat, *Triticum aestivum*	13564	15651
Maize, *Zea mays*	7418	8188
Kodo millet, *Paspalum scrobiculatum*	2229	2230
Pearl millet, *Pennisetum glaucum*	2728	2755
Sorghum, *Sorghum bicolor*	10927	19402
Grain Legumes		
Pigeonpea, *Cananus cajan*	9504	9650
Chickpea, *Cicer arietinum*	11211	13401
Black gram, *Vigna mungo*	5820	5820
Green gram, *Vigna radiata*	3628	3654
Oilseeds		
Indian mustard, Brassica juncea	3677[2]	10660
Groundnut, *Arachis hypogaea*	7931	11962
Safflower, *Carthamus tinctorius*	4624	7152
Sugar-yielding Plants		
Sugarcane, *Saccharum officinarum*	794	1645
Fibre Crops		
White jute, *Corchorus capsularis*	2507	2663
Sun hemp, *Crotalaria juncea*	122	122
Asiatic cotton, *Gossypium arboreum; G. herbaceum*	1867 + 573[2]	8815
Forage/Fodder crops		
Indian sweet clover, *Melilotus indicus* (L.) All.	77[2]	77
Prickly sesbania, *Sesbania cannabina*	622	629
Indian sandbur, *Cenchrus biflorus* (Vast diversity[4])		
Vegetables		
Okra, *Abelmoschus esculentus*	2454	2691
Eggplant, *Solanum melongena*	4821	
Tomato, *Lycopersicon esculentum*	406	1666
Cucurbit vegetables	2650	2709
Leguminous vegetables	12	12
Cole group (*Brassica's*)	55	308
Fruits and Nuts		
Citrus spp.	51[2]	
Mango, *Mangifera indica*	1200	
Musa spp. (field collections)	1407[2]	
Prunus spp. (collections)	260[2]	
Pyrus spp. (collections)	117[2]	
Spices and condiments		
Black pepper, *Piper nigrum* (9 exotic)	3172[3]	3181
Cardamom, *Elettaria cardamomum*	618[3]	
Cinnamon, *Cinnamomum* spp., including *Cassia*	408[3]	
Cumin, *Cuminum cyminum* (five institute)	526[2]	
Turmeric, *Curcuma longa*	1404[3]	
Ginger, *Zingiber officinale*	668[3]	
Plantation crops		
Tea, *Camellia sinensis* (TES & UPASI)	2532 + 440[2]	2972
Coconut, *Cocos nucifera* (CPCRI)	150	421

Crop group/cultivated species	Indigenous collections	Total collections
Medicinal and Aromatic Plants[1]		
Kalmegh, *Andrographis paniculata*	94	94
Safed Musli, *Chlorophytum borivilianum*	34	34
Datura, *Datura metel*	33	40
Tulsi, *Ocimum sanctum*	152	152
Sarpagandha, *Rauvolfia serpentina*	22	22
Giloe, *Tinospora cordifolia*	4	4
Ashwagandha, *Withania somnifera*	137	137
Ornamental plants		
Bougainvella, *Bougainvillea* spp. (Growing in gardens)	400	
Champa, *Magnolia* spp.	1	1
Malabar jasmine, *Jasminum malabaricum*	56	
Kaner, *Nerlum oleander*	Vast diversity[4]	
Rose, *Rosa* spp. (11 indigenous spp.; 600 cultivars)	600	
Agro-forestry Species		
Acacia, *Acacia catechu*	227	227
Babul, *Acacia nilotica* (immense diversity)	Vast diversity[4]	
Neem, *Azadirachta indica* (immense diversity)	Vast diversity[4]	
Khejri, *Prosopis cineraria*	48	48
Other crops		
Bamboo, *Bambusa* spp.	4	4
Indian arrowroot, *Curcuma angustifolia*	Vast diversity[4]	
Karanji, *Pongamia pinnata*	826	826
Henna, *Lawsonia inermis*	110	110
Jatropha, *Jatropha curcas*	2053	2053

Source: http://www.nbpgr.ernet.in.8080/PGRPortal/.SimpleSearch.aspx. 1. 2000 accessions of 150 species of medicinal plant collected between 1980-2000; 2. Conserved at respective crop based institute; 3. Prasath *et al.* (2015): At Indian Institute of Spices Research; 4. Not accounted/conserved *ex situ*

Adopted from Singh (2016) with permission

humankind in general and India's interest in particular (Paroda, 2016). India has been benefitted immensely by liability-free introduction of dwarf varieties of wheat and rice during and after the Green Revolution. The high productivity potential of these introductions did not only made India self-sufficient but a net exporter of these commodities. Therefore, while India should join the global efforts to feed the world, it needs to protect and use its biodiversity - the sovereign right, for feeding the future generations.

Sui generis System for Protection of Rights of the Stakeholders in Varietal Development

India having ratified the agreement on Trade Related Intellectual Property Rights, made a provision for giving effect to the Article 27.3.b(II) by enacting the "Protection of Plant Varieties and Farmers' Right Act" in 2001 and establishing an effective *sui generis* system of protection of plant varieties and farmers' rights in harmony with UPOV system of Novelty, Distinctiveness, Uniformity and Stability. Accordingly, Government of India established an Authority (PPVFRA), in the year 2005, that grants IPR to plant breeders, researchers and farmers who develop(ed) new or extant plant varieties. The major objectives of this *sui generis* system of India are:

(i) To establish an effective system for the protection of plant varieties and the rights of the farmers and plant breeders

(ii) To recognise and protect the rights of the farmers in respect of their contribution made at any time in conserving, improving and making available plant genetic resources for the development of new plant varieties

(iii) To contribute to accelerate the agricultural development in India, protect plant breeders' rights; stimulate investment for R&D in public and private sector for development of plant varieties and

(iv) To facilitate the growth of the seed industry for ensuring availability of high quality seeds and planting materials to the farmers.

The PPVFR Authority started functioning with its HQ in New Delhi and has established branch offices at Ranchi in Jharkhand state and Guwahati in Assam. In addition, three new branch offices were established in 2017 at Palampur in Himachal Pradesh, Pune in Maharashtra and at Shivamoga in Karnataka to cater to the needs of Northern Hill zone, Central and Western zone and Southern zone respectively.

Registration is accorded to plant varieties in 156 species, which include 21 crop species in cereals, 8 in legumes, 6 in fibre crops, 12 in oilseed, one in sugarcane, 20 in vegetables,19 in flower and ornamentals, 8 in spices, 28 in fruit crop species, 9 in medicinal and aromatic crops and 24 in plantation crops. The details of crop species notified for registration is presented in Table 2.

Status of Registration of Varieties with PPVFRA

As presented in Table 2, the PPVFR Authority has, till Dec. 2019 notified 156 crop species for registration and one crop species is under the process of notification which is likely to come soon making the total of 157 crop species. The Authority had so far received 16,490 applications for registration of crop varieties till Dec. 31,

Table 2. Number of Crop Species Notified till 2019 by GoI for Registration

Group	No.	Crop Species Notified till 2019 for Registration:156
Cereals	21	Bread wheat, Rice, Pearl millet, Sorghum, Maize, Durum wheat, Dicoccum wheat, Other Triticum species, Barley, finger millet, foxtail millet, Common/ Sweet Buckwheat, Tartary/ Bitter Buckwheat, Proso millet, Barnyard millet, Kodo Millet, Little millet, Ramdana (four species), Oat
Legumes	8	Chickpea, Mungbean, Urdbean, Field pea, Rajmash, Lentil, Pigeon pea, Faba bean
Fibre Crops	6	Diploid cotton (two species), Tetraploid cotton (two species), Jute (two species)
Oilseeds	12	Indian mustard, Karan rai, Rapeseed, Gobhi sarson, Groundnut, Soybean, Sunflower, Safflower, Castor, Sesame and Linseed, Jatropha
Sugar Crops	1	Sugarcane
Vegetables	20	Tomato, Brinjal, Okra, Cauliflower, Cabbage, Potato, Onion, Bottle gourd, Bitter gourd, Pumpkin, Cucumber, Paprika, Chili, Bell Pepper, Vegetable Amaranth, Ridge gourd, Spinach beet, Elephant foot yam, Taro, Giant Swamp Taro,Sweet Potato, Cassava
Flowers & Ornamentals	19	Rose, Chrysanthemum, Bamboo Leaf Orchid, Spray Orchid, Vanda or Blue Orchid, Orchids (Cattleya, Phalaenopsis), Bougainvillea, Orchid (Oncidium), Canna, Gladiolus, Jasmine, Tuberose, China Aster, Carnation, Orchid (Paphiopedilum), Mogra, Marigold, Jasmine,
Spices	8	Black pepper, Small cardamom, Coriander, Fenugreek, Turmeric, Garlic,Ginger, Nutmeg
Fruits	28	Mango, Almond, Walnut, Cherry, Apricot, Apple, Pear, Pomegranate, Grape, Ber, Acid lime, Mandarin, Sweet orange, Banana, Muskmelon, Watermelon, Papaya, Peach, Japanese Plum, Strawberry, Beal, Jamun, Sitaphal, Gvava, Litchi, Mulberry, Datepalm,Custerd Apple
Medicinal and Aromatic plants	9	Isabgol, Menthol mint, Damask Rose, Periwinkle, Brahmi, Noni, Kalmegh, Indian gooseberry, Betelvine,
Plantation crop	24	Coconut, Eucalyptus (two species), Casuarinas (two species),Cashewnut, Chironji, Arecanut,Tea (3 spp.), Deodar, Chir Pine,Tamarind,Poplar, Karni ,Neem,Villow (7spp)

2019. Fig. 1 shows the number of applications received during the last ten years starting from 2007. Initially the response was poor but gained momentum from 2013 onwards. This resulted in sharp increases in filing of applications during the year 2014, 2015, 2016 and 2017. Again, a downward trend was observed in the years 2018 and 2019, due to lack of efforts to encourage farmers and facilitate filing of applications through awareness programs and capacity building. The primary reason for achieving such high registration of Farmers' varieties between 2013-2017 can be attributed to a large extent, to the organisation of the awareness programmes and capacity building activities by the PPVFR Authority in collaboration with State Agricultural Universities, ICAR institutes and KVKs (Hanchinal et.al, 2016). However, the efforts made were not sufficient considering that India

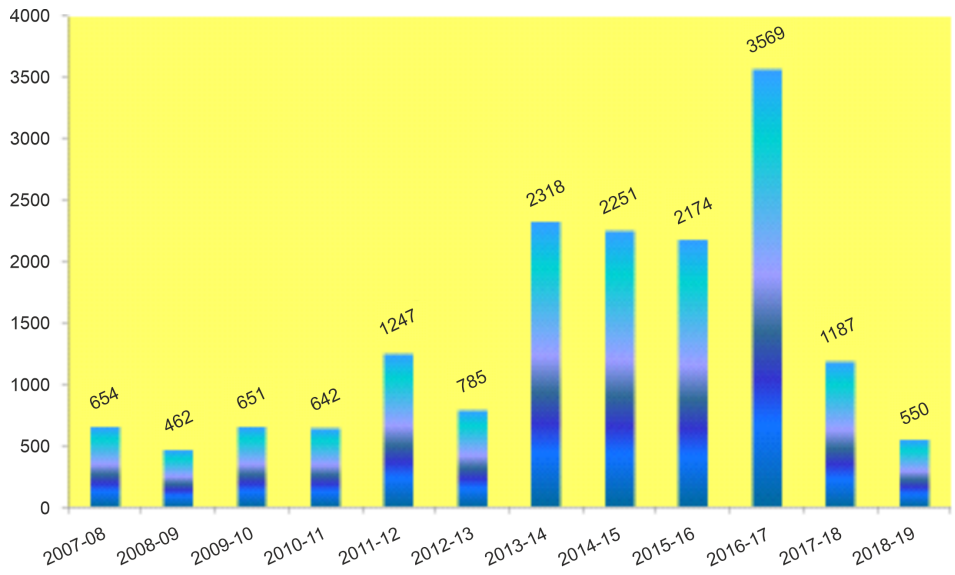


Figure 1. Applications received year-wise for registration (*Source:* PPVFRA)

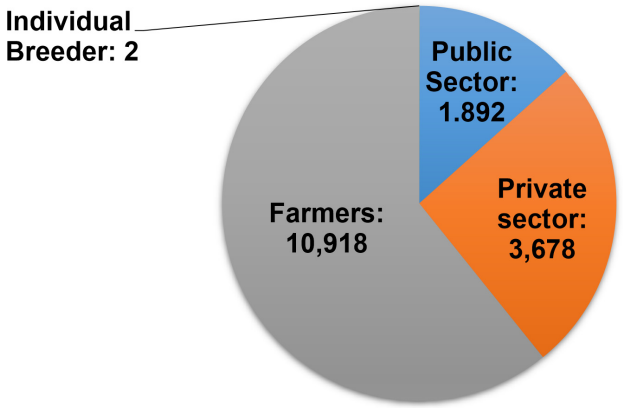


Figure 2. Applications received applicant-wise (*Source:* PPVFRA)

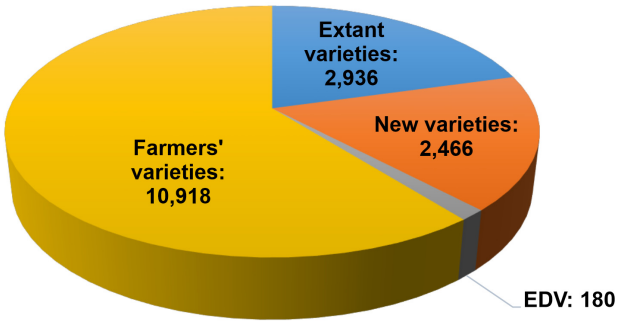


Figure 3. Applications Received Category-wise (*Source:* PPVFRA)

is the primary as well as secondary centres of origin for many species. Thus, an intensive effort is required to fulfil this important objective.

The Authority has received 16,490 applications for registration of crop varieties till December, 2019. Fig. 1 shows the number of applications received during the last 13 years starting from 2007. Initially the response was poor, but it gained momentum from 2013 onwards.

A close examination of the number of applicants (Fig. 2) shows overwhelmingly high response (10,918) for the farmers' varieties. The public sector, which has huge infrastructure for agricultural R&D, has been slow and till the end of March 31, 2019, they had together filed 1,892 applications only.

Further analysis of the applications filed for registration shows that only 2,936 applications were filed for the extant varieties whereas 1,0918 applications were filed for farmers' varieties (including two individual breeder varieties). Even though, largest number of applications have been filed for the farmers' varieties, yet the number is small if we take into account the degree of diversity conserved in the form of land races of various crops by the farmers. The details of applications received category wise is presented in Fig. 3. In the initial years larger number of applications in the category of Essential Derived Varieties (EDV) were applied. But due to strict query by the Authority, some seed companies withdrew their applications.

Figure 4 shows the year-wise issuance of registrations totalling 3,521 till 2018-19. While the largest number of

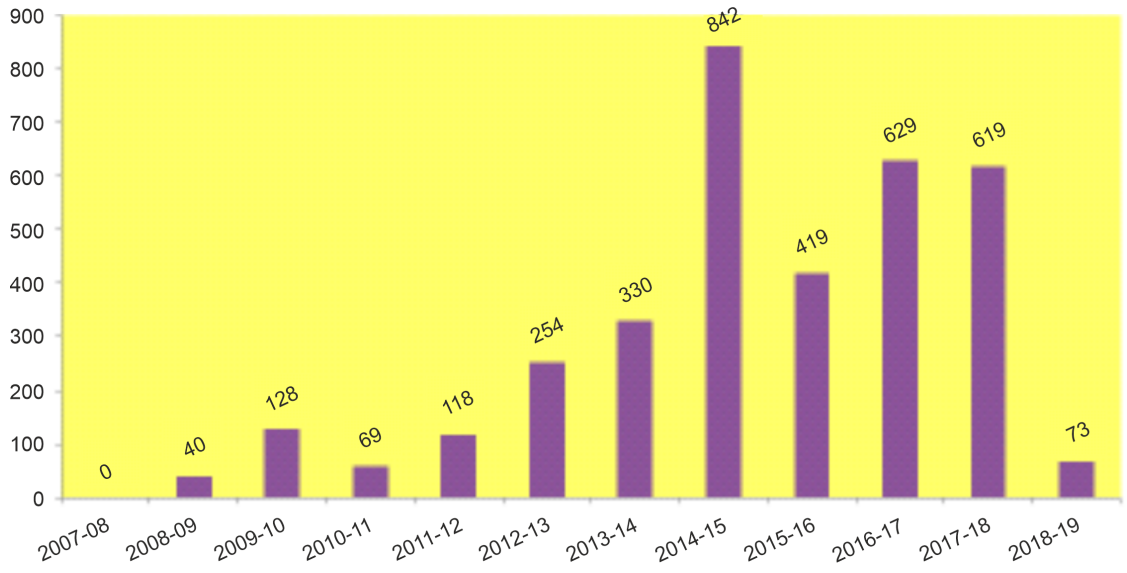
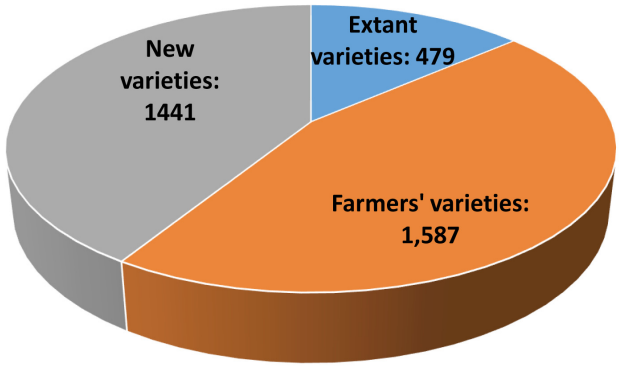


Figure 4. Registration Certificates Issued Year-wise (*Source:* PPVFRA)

registrations were issued in the year 2014, the speed somehow slowed down later, which needs to be accelerated. The Authority has geared up itself to meet this challenge and hopes to attain it in the years to come.

Harnessing the Resources for Registration of Farmers' Varieties

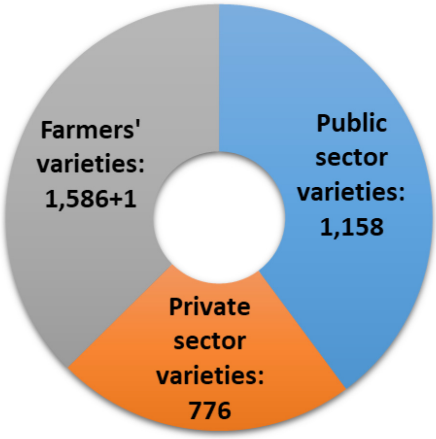
Registration of the varieties is a long process that involves widespread testing of the varieties for Distinctiveness, Uniformity and Stability (DUS), which is time consuming. The authority has made extensive efforts over the last decade to put them in place; consequently, the number of applications for farmers' varieties increased considerably during the year 2013-2015 (Hanchinal, 2016). The total number of registration certificates issued so far was 3,521 out of which 1,586 (Fig 5 & 6) are the farmers' varieties and one variety is of individual breeder which is too low in view of the fact that Indian subcontinent is the primary or secondary centre of origin of many crops and thus, a large number of land races have been cultivated by the farmers in the subcontinent for thousands of years. It is, therefore, necessary that a concerted effort is made to register the eligible varieties in general and farmers' varieties in particular in a time bound manner.



1 – Individual Farmer breeder; 14- EDVs

Figure 5. Registration Certificate Issued Category-wise (*Source:* PPVFRA)

The available resources at the national level can be leveraged to attain the goal of registering the vast genetic resources within a time bound manner. This will not only help in facing the future challenges of food security of India but will help the world agriculture through their rational deployment/use directly or indirectly for developing new varieties in the wake of climate change, the biggest threat for global agriculture.



1 – Individual Farmer breeder

Figure 6. Registration Certificate Issued Applicant-wise (*Source:* PPVFRA)

Conservation and Utilization of Land Races

Post 1960, India's agricultural development is a success story often cited around the world as the introduction of green revolution technology, which not only helped India attain self-sufficiency in food grain production, but also become a net exporter of rice and wheat. However, the genetic gain defined as annual increase in yield realised through breeding in most of the crops especially wheat and rice, has been <1% year^{-1}. And of late, yields of rice, wheat, maize and soybean have been stagnating in 37% to 70% of the area under cultivation of these crops (Ray et. al. 2012). Therefore, a strategy need to be developed to increase yield in these areas so that the country can meet the future demand of food grains.

Genetic variability is the basic raw material to power the current and future yield improvements through breeding. Consequently, conservation and efficient utilization of the genetic resources will be central to our efforts in feeding the future generations. However, in practice, the genetic diversity among the released varieties of various crops is narrowing. Besides, the present PGR laws discourage use of local germplasm by the International Research Institutions which have further hampered this process. The small and marginal farmers often find agriculture non-attractive due to the lower returns because of rising costs of inputs like chemical fertilizers, pesticides, irrigation and seeds of improved varieties. In contrast, some of the elite local varieties and land races which need much less input with a reasonably good yield, can make agriculture remunerative to these farmers.

Keeping in view the value of such traditional varieties and role of farmers/communities in conserving these, the

Govt. of India has ensured benefit sharing with farmers who have protected these land races for long time. The *sui generis* system developed by the country provides for 'Access and Benefit Sharing' in case of use of the germplasm developed, cultivated, and nurtured either by an individual or a community of farmers. This will bring substantial benefit to farmers and communities engaged in conserving precious genetic resources. However, conservation of enormous genetic resources, present in the form of land races/farmers' variety, requires a paradigm shift in our approach and needs to be accelerated with greater vigour with a time line.

Farmers' varieties are the outcome of centuries of efforts by the farmers / tribal communities, who selected the plants of economic importance from the wild species / relatives and landraces. Through continuous efforts, from the PGR available agro-biodiversity hot spot regions, these varieties were selected and conserved dynamically and possess climate resilience traits which could be extremely valuable in the present scenario (Hanchinal 2015). Some varieties in different crop species are tolerant to biotic and abiotic stresses besides their suitability to contingency planning in case of weather aberrations. Some of the varieties possess medicinal, nutraceutical, therapeutic and pesticidal values. Varieties such as "*Kasalat*" in rice possess a gene "*Pstol1*" which fixes phosphorus from phosphorous poor soils. Some important farmers' varieties with their unique traits are presented in Table 3. These varieties are unique genetic stocks for developing improved varieties / germplasm. Under post WTO era, where restrictions are imposed on free exchange of PGR worldwide, the dynamic conservation, promotion and protection of PGR in the form of local / farmers' varieties achieve greater importance (Hanchinal, 2015).

Community Seed Banks for Conservation of the Precious Land Races

Although there are huge genetic resources present in the form of land races in most of the crops, their conservation and utilization are limited. Establishment of community seed banks in the villages where these land races are being cultivated will pave the way for their conservation. Most of these land races have been selected for various biotic as well as abiotic stresses. Therefore, these are reservoir of useful gene selected over thousands of years, which can be utilized either as such or in the breeding programs for developing new varieties.

Table 3. Farmers' Varieties with Unique Traits

Crop	Special Traits
Navara-Rice	Medicinal: curing circulatory, respiratory digestive, nervous system ailments and pest resistance
Bao Rice	Absence of the need for cooking, instant cooking
Pokkali Rice	Salt tolerance and Drought tolerance
Kasalath Rice	*Pstol1* gene
Chennellu Rice	Curing stomach ulcer
Thondi Rice	Drought tolerant
Jugal, Sateen-Rice	Resistance to BLB & BPH, multiple grains
Rajmudi Rice	Quality rice
Sarvat Rice	Antidote to Poisonous snake bite
Bunny grass	Resistant to salinity (Rann of Kutch)
Karchia Local Wheat	Salt tolerance
Naga Chilli (Bhut jholakia)	Pesticidal value
Dagadi-Sorghum	Best quality Roti
Pundya-Sugarcane	Table purpose
Kali tur-Pigeon pea	Resistant to drought, SMV, Good quality
Jhakrana Bajra	Drought tolerant

Acknowledgements

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