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Overview of vegetable seed production research in India

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ABSTRACT Although seed saving of traditional vegetable crops has been a domestic practice through the ages, planned cultivation of seeds came into vogue later. In the beginning, we used to rely fully on imports for quality seeds, but now we are exporting open pollinated as well as hybrid seeds of several vegetables. Efforts in public sector started soon after the independence, which still holds a major share of R&D in India. Indo-American Hybrid Seeds was the first indigenous private sector to introduce and popularise F_1 hybrid vegetables in India. As the cultivation of vegetable crops spread and exchange of seeds from one area to another started, the workers witnessed stresses of all kinds: biotic and abiotic. Therefore, emphasis was laid on production of resistant varieties and F_1 hybrids by combining different resistance genes from various available sources. The package of practices for most of the vegetable crops has been standardized. At the same time, information generated on floral biology and evolution of male sterility, self-incompatibility and other cross-pollination mechanisms encouraged the scientists as well as progressive farmers produce hybrid seed on commercial scale. India is about to enter into a new IPR regime to shortly. Hence, to meet the challenges of international market and to stand the provisions made in the new legislation, it is imperative to take a look of our achievements in the past and strengths as of now in order to mitigate the shortcomings before we barge into future.

Keywords: Vegetables, seed production research, historical perspective,

Before second world war, the seeds of all temperate vegetable crops (European types) were being imported from abroad but during war period, there were difficulties in import and Government of India established a research station at Quetta-Baluchistan (now in Pakistan) in 1942-43 for producing temperate vegetable seeds. After partition, the Government of India set up a Central Vegetable Breeding Station at Kullu Valley in 1949. In 1955, the Station was transferred to the Indian Agricultural Research Institute, New Delhi with a view to intensify the improvement work and seed production on temperate vegetables and was renamed as IARI Vegetable Research Station and finally as IARI Regional Station. Late Pt. Jawaharlal Nehru, in summer 1958, on his way to Manali stopped over at Sarsai experiment farm of IARI R.S., Katrain and after an interaction with scientists and local peasants instructed to include into the mandate of the research station to provide quality planting in form of seedlings to the local farmers. This has remained an important duty of the station until vegetable crops became sufficiently popular among the hillmen of Kullu. Late Dr. B.P. Pal, the then Director of IARI, addressing a meeting of Horticulture Society of India, had remarked "lack of production and multiplication of quality seed in vegetable crops has been major road block in the path of vegetable production and recently planned programmes for stepping up seed production are underway". It was estimated that against a massive annual seed requirement of 9.7 lakh tonnes, the current levels of production were not more than 40,000 tonnes i.e., a meager 4.1 percent of the potential [1]. "Thus", they observed, "the industry has a long way to go." This explains the vast unconquered horizon thrown open to India's budding seed industry to explore and grow.

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Saving seeds of vegetables for kitchen garden has been a traditional practice in India. The concern about seed quality has been quite ancient as reflected from the hymn in Rig Veda "*Subeejam sukshetre jayate sampadyate*" and innumerable others. Commercial vegetable growers were always conscious about the quality of seed. Local growers had to depend on local grocers, who produced seed with little attention to quality and purity of seeds. Consequently, until very recent times in the recorded past, we were completely dependent upon the imports for quality seed. However, the concerted efforts by the Government of India (GOI), agricultural scientists and private entrepreneurs were made and the flow of river has been turned. Now, we are not only self reliant in terms of vegetable seeds, but we are exporting the seeds of a number of varieties and hybrids belonging to various species.

India has ushered into a new regime of intellectual property rights (IPR) very shortly, which will present before us many new challenges. Therefore, it is imperative to take a retrospect of what we have accomplished so far, which will generate a lot of confidence among us. At the same time, introspection into our own system of seed production and distribution will serve to make us aware of our strengths and shortcomings. In view of above, it was considered worthwhile to look back into the historical past of vegetable seed production in India.

Ancient perspective on vegetable seed production

Kautilya (4th Century BC) in *Seetaadhyaksha prakaran* of *Arthashashtram* has indicated the suitable soils and moisture regimes for different vegetable crops. He has also thrown some light on materials used for priming different seeds. Surapala in his *Vrikshayurveda* (around 1000 AD) has produced a detailed account of mode of propagation of different plants. He has indicated the correct stage of fruit for seed harvesting. "Seed is extracted from dried fruits which become ripe in natural course and season. It is then sprinkled with milk and dried for 5 days and fumigated with mustard seed mixed with bidanga (*Embelia ribes*)". Various natural products and botanicals have been mentioned for use in seed treatment and priming, including milk, mustard, ash of sesame, brihati (*Solanum indicum*), honey, cow dung, bidanga, kamalnal and fumigation with marrow. The procedure for priming of Urvaru (*Cucumis sativus*) has been described as "seeds of Urvaru become fit for sowing when sprinkled with water mixed with plenty of jaggery, tied in a leaf vessel, heated with fire for three days." Surapala has also enlisted some horticultural wonders of the time which include producing flowers on non-flowering creepers, mixing, increasing the size of fruits and flowers, transformation into another species etc. Few records were found during medieval India making any mention of practice of vegetable seed production. *Ain-e-Akbari*, however, indicates that cabbage had been a part of mughal cuisine and surprisingly chilies do not find mention among the items used in mughlai dishes. It is also not clear whether the cabbage seeds were regularly imported, were cultivated in the royal garden or by seedsmen in Kashmir or were occasionally brought as gift by European visitors.

Vegetable seed production during British rule

First systematic efforts of seed distribution started when mughals were still ruling India with advent of M/s Sutton and Sons in 1850s. They set up an office in Calcutta in 1916 and their business in India was to import seeds mainly of vegetables and flowers and distribute them. From this, it is clear that a good market of quality seed existed in India even at that time. However, the need for organized seed production even on limited

scale came to be identified only in the late 1920s, when the Royal Commission on Agriculture (Lord Linlithgow commission) constituted in 1925 examined *inter alia* the introduction and spread of improved varieties and seed distribution. The observations of commission on the status of seed production and distribution efforts were:

1. In cotton, groundnut, jute, sugarcane and wheat, progress in introducing improved varieties and their coverage is satisfactory but much further work remains to be done.
2. Millets, oilseeds and pulses remained neglected for a long time; for some time, seed distribution may rest with the agricultural departments.

The commission review was followed by several similar analysis of seed status in the following decades. Notable among them are those by Sir John Russell (1937), the Imperial Council of Agricultural Research (1940), Dr. Burns (1944), Famine Enquiry Commission (1944) and Foodgrains Policy Committee (1944). These reviews reveal that the administrative and technical process of organization in the pre-independence era consisted of;

i. Initial seed multiplication on seed farms of agricultural departments,
ii. Subsequent seed increase, if necessary, by registered seed growers under close supervision by agricultural departments and
iii. Purchase of seed by departments from growers at a premium and its subsequent distribution to farmers, sometimes at concessional rates.

Vegetable seeds other than those peculiarly Indian such as brinjal, gourds, pumpkins etc. were obtained from Australia, Germany, U.K. and the U.S.A. The ceasing of supplies due to outbreak of second world war in 1939 resulted in hardships to seedsmen and vegetable growers. These difficulties were partially overcome by the development of vegetable seed production facilities in Quetta (Baluchistan) and Saharanpur (U.P.). While the progress of field crop seed production was slow, vegetable seed industry made a rapid progress. By 1945, a few private seed companies developed temperate vegetable seed production facilities in Quetta and Kashmir valley and even had their seed samples from their production tested abroad. They established contacts with foreign seed firms and developed markets for Indian vegetable seeds to a significant degree in the international markets. Over the years, several private entrepreneurs designed vegetable seed production programmes, notable among them were M/s Sutton, Pocha, Palekar etc. As early as 1946, the Indian seedsmen, handling vegetable seeds organized themselves into an association- "The All India Seed Growers, Merchants and Nurserymen Association" to ensure the rapid development of indigenous vegetable seed industry and to develop codes of practices and business principles for vegetable seed growers, merchants and nurserymen.

Pioneer adventures in vegetable seed production

A pioneering attempt of producing seeds in hills was in 1948 [2-3]. The mature plants of 13 varieties of 6 vegetables crops were transported from Patiala to Mahog and Shellon orchards at heights of 6500 ft and 8000 ft, respectively and seeds were harvested from all of them, except cauliflower variety Patna Late. Encouraged with the results of first year experiments, 24 new varieties of European type of biennial vegetable crops were grown. Again, seeds of all crops could be harvested, except 2 late cauliflower varieties wherein only 14 percent of seed setting took place with only 40 percent germination. The poor performance of cauliflower was ascribed to its fall sowing, instead of July.

A preliminary study in inducing seed set in cabbage in the plains of U.P. was undertaken in 1950 at the Saharanpur nursery [4]. Out of 23 varieties tried, 6 produced flowers and only 4 of them could set seed. Around same time at the same nursery, Vishnu Singh tried to produce seed of cauliflower in plains. He obtained maximum seed in untransplanted curds. They, in their respective studies, concluded that seed raising *in-situ* does not have any serious drawback. On the other hand, the cost of seed production by this method will be low. Almost contemporaneously studies conducted on vegetables at Kalimpong (W.B.) showed that head incision method of cabbage seed production was not found quite useful whereas Stump method gave encouraging results. August-September transplanting of seedlings had given better results than later plantings. A variety prize winner drum head formed seed *in-situ*, but did not flower when transplanted. Another study was carried out by the same workers to find out the nature of compatibility and effect of continuous inbreeding for the maintenance of purity of cauliflower on nature of compatibility. Percentage of pod setting and seeds under selfing and open pollination were taken as the criteria. Higher seed set was obtained under open pollinated conditions. Inbreeding depression was observed, but the yield stabilized after four generations of selfing.

Systematic seed production: the foundation stone

In 1949, Central Vegetable Breeding Station at Katrain (Kullu Valley) was launched by GOI to carry out research on vegetable seed production and to evolve improved varieties of temperate vegetables. It was later brought under administration of I.A.R.I., New Delhi. A sustained effort was made by Padmashree late Sardar Harbhajan Singh, Drs. M. R. Thakur and P.M. Bhagchandani. A series of experiments were initiated in 1948 which continued till 1963 with the aim of standardizing the quality of seed production in India and to carryout experiments on methods of seed production [5-8]. They found that Kashmir climate is more close to European climate in comparison to Kullu valley. According to them another important feature of Indian temperate climate of Kashmir and Kullu valleys was that winter and summer seasons are so balanced that it is possible to grow for seed not only the biennial vegetables but also important summer vegetables so that seed growers can practice an intensive type of seed farming. Bu' the situation is aggravated by continued wet weather, which does not permit timely weeding. They suggested that at least one mile of isolation is necessary for cole crops, Chinese cabbage, root crops, onion, celery, parsley, parsnip and various cucurbits. They standardized the package of practice for cabbage, knol-kohl, cauliflower, Chinese cabbage, turnip, radish, carrot, peas, lettuce, celery, parsley, onion, leek and spinach. They also threw light on advantages and disadvantages of *in-situ* and *ex-situ* methods of seed production and compared the pros and cons of stump method and head intact method of seed production. They produced the first systematic schedule for control of diseases and pest of temperate vegetables.

Genetic studies in vegetable crops

Early genetic studies

The investigations carried out on hybrid vigour in brinjal and recorded heterosis for height, yield and earliness [9]. Prolonged fruiting period was also observed in hybrids. A project on utilization of hybrid vigour in tomato earlier initiated in the division of botany of IARI was reoriented after the MS lines became available for the project. The prime aim was to determine the relative suitability of different types of MS Lines for production and usefulness in hybrid seed production than pollen sterile (ps) and stamen

less condition because of their easy manipulation and maintenance, high percentage of fruit set and better GCA. Carrot is one of the few species in which male sterility was documented as early as in the year 1885. Several other genetically male sterile mutants have been described in carrot. However, none of them have been utilized for commercial seed production due to the availability of more efficient CMS system in carrot. Two duplicate genes (one recessive and other dominant) and 2 complementary dominant fertility restorer genes have been reported [10].

Genetic studies during green revolution era

Manifestation of hybrid vigour in F_1 and its retention in F_2 generation of tomato was demonstrated [11]. Hybrid vigour was observed in cucumber with respect to early and total yield and number of fruits/plant [12]. The decade of 1970s started with an important achievement by E. Pochard in France. He was successful in inducing the male sterility by mutation in *Capsicum annuum* through application of mutagens on monoploid material. (MC-509), which was renamed MS-10 by Daskalov and Poulos, introduced in India at PAU and recessive MS allele was introgressed in three chili genotypes *viz.*, MS-12, MS-13 and MS-41 [13]. All the reported MS alleles were highly stable; hence promising for hybrid seed production [14]. While transferring powdery mildew resistance from *Capsicum baccatum* into bell pepper and chilies, a variant was encountered in which anthers failed to open and style was almost non-existent and fruit setting was parthenocarpic [15]. Further study revealed that the character is recessive and such a functional male sterility would cut emasculation cost. Hybrid research in chilies was carried out by during 1980s and tight linkage of MS genes with phenotypic marker traits was reported by several workers [16-18]. However, till date none of them have been exploited for early identification of male sterile plants.

During 1970s, a lot of research was conducted on heterosis, combining ability, gene action and other related aspects in cauliflower. The first studies were carried out on combining ability, gene effects and heterosis in cauliflower [19]. An appreciable heterosis in all characters studied viz., plant weight, curd weight, curd to plant ratio, curd size index, maturity days, number of leaves etc. was observed, including 33 percent heterosis for yield and 2.5 percent heterosis for earliness [20]. GCA and SCA variances were highly significant and the mean sum of squares for GCA was larger than those for SCA. Similar studies were conducted on other crops also. Another study reported 30-35 percent heterosis for early yield and total yield in spinach and also that lateness in bolting is a dominant character [21]. It was suggested that curd size index and weight were influenced by additive and non-additive effects; therefore, development of F_1 hybrids as well as synthetic varieties would be equally feasible [22]. The heterosis for yield and yield attributes was reported in bittergourd [23]. A detailed study on combining ability in sweet pepper suggested that GCA estimates and *per se* performance of a cultivar should be taken together for assessing its breeding value [24]. In the best performing crosses, either one or both the parents have high GCA effects for yield and component characters. The crosses with high SCA effects usually had one of the parents with high GCA. The combining ability, heterosis and gene action in tomato [25] and combining ability in cabbage were also studied [26]. They reported that vegetable yield is controlled by non-additive gene action and good GCA is present in varieties and variance for GCA is greater than that for SCA for most of the characters. The curd size index and weight in cauliflower were influenced by additive and non-additive effects [22]. Therefore, development of F_1 and synthetic varieties would be equally feasible.

Heterosis in watermelon was studied and heterosis upto 3-25 percent for fruits/plant, 46 percent for yield and around 6-7 percent for TSS was observed [27]. They also observed good retention of heterosis in F_2 generation for some of the characters. In an earlier study of similar kind, heterosis for yield and early yield as well as partial dominance and intermediate inheritance for TSS was observed [28]. They had also observed retention of heterosis for yield and other characters in F_2.

In the beginning of 1980s, the allelic relations between the SI alleles in cauliflower were studied and dominance was found more common in pollen than stigma; partial dominance was observed more frequently than complete dominance. It was concluded that three way hybrids can be produced utilizing only 2 S-allele lines and double cross hybrids utilizing only 3 S-allele lines [29]. Combining abilities studies were conducted in Brussels' Sprouts and heterosis for yield, sprout weight, size of sprouts and number of sprouts per plant was recorded [30].

In 1987, it was reported from IARI R.S., Katrain that 4 SI lines of cabbage homozygous for S2, S5, S8 and S15 being maintained, multiplied and doing well. Significant heterosis for yield and fruit number was recorded in bittergourd, whereas heterosis for fruit length was of low magnitude [31-32]. In cauliflower, 6-139 per cent heterosis for curd weight was observed and variance for GCA and SCA were significant for most characters [33]. A synthetic variety of cabbage "Pusa Sambandh" was developed at IARI Regional Station, Katrain and identified for release at annual workshop in 1991. However, it could never be released owing to some lapses in breeding procedure which could be identified at the fag end of entire process of release [34].

Recent genetic studies

It was observed that SI becomes unstable with advancement of flowering in cauliflower [35]. A high level of SI existed in maturity group I and intermediate to weak SI in maturity group II [36]. The information on heritability is derived from data on 16 characters and yield components in 8 *Cucumis sativus* genotypes. Studies on correlation and path co-efficient analysis carried out in 8 genotypes of cucumber (*Cucumis sativus*) showed that yield per plant had strong a positive association with main vine length, number of secondary branches, leaf area, fruiting percentage, number of fruits per plant, fruit weight and fruit length both at genotypic and phenotypic levels. Path co-efficient analysis revealed that number of fruits per plant had maximum direct genotypic effect on yield, followed by fruit weight. These traits were considered important parameters in any selection programme for the yield improvement in cucumber [37].

CMS was successfully transferred into prominent varieties of several cole crops (TablE 1) for utilization in hybrid seed production [38].

A high degree of additive and dominance variance as well as heterosis for yield in cauliflower was reported [39]. It was observed that considerable heterosis is present in cauliflower, but isolation of stable SI lines and their maintenance in pure form is problem [40]. Moreover, additive as well as dominant gene and high GCA and SCA have been reported. Therefore, heterosis can be exploited through development of synthetic varieties as well.

The results on extent of variability, heritability and genetic advance in 30 chilli genotypes for seven polygenic traits studied showed considerable genetic variability for pod yield and other traits. Heritability estimates were high for all traits, except days to 50 percent flowering. Higher heritability linked with moderate genetic advance was observed for pods per plant, pod yield, fresh and dry weight of pods [41].

Table 1. Transfer of SI in different varieties of cole crops.

Crop	Varieties
Cabbage	Pusa Mukta, Golden Acre, MR1, 83-6, Pride of Asia, EC172999 and Red Rock Mammoth
Cauliflower	PS1, PSK1 and Pusa Himjyoti
Broccoli	KTS1
Curly kale	Westo
Calabrese	Romanesco
Brussels' sprouts	Hild's ideal
Knol-kohl	White Vienna and Giant Kohl Rabi
Kale	Georgia

Selection against the thermo-sensitive breakdown of CMS in carrot at higher temperature (> 300C) continued at Katrain [42]. Efforts were also on to find suitable R-line for desirable hybrid combinations. Earlier workers had reported a lot of GCA variance and additive gene action for several traits.

Four perfect populations of MS-15 (a male sterile of tomato) were developed at Varanasi, which may be utilized for identification of good male combiner for VC-82B genotype and also for research purpose [43]. It was discovered that distribution of restorer (Rf) allele is more frequent in hot pepper lines, while the distribution of maintainer allele (rf) is more frequent in sweet pepper lines [44].

Variability studies in brinjal revealed highly significant differences among the varieties for all characters. Correlation and path analysis revealed that fruit length, diameter, weight influenced the fruit yield in plant with high direct effect and significant positive correlation. Therefore, fruit length, diameter, weight are an important characters which may be included in selection criteria for improvement in fruit yield per plant [45].

Floral biology studies in vegetable seed crops

For understanding any hybridization programme, it becomes imperative for the breeders to equip themselves with information regarding the floral biology of the crops. In 1958, a plant with cleistogamous flower in tomato variety was obtained [46]. This was a functional male sterile mutant with potential to drastically reduce the expenditure borne on emasculation and pollination. Further, a study classified flowers of brinjal into four types on the basis of

Table 2. Effect of 2, 4-D spray on fruit setting in different types of flowers in brinjal

Type of flowers	Relative proportion (percent)	Fruit setting (percent)	Fruit setting (percent) as a result of 2,4-D spray
True short styled	39.4	Nil	Nil
Pseudo short styled	7.8	Nil	66.6
Medium styled	5.7	40	100
Long styled	47.6	58	100

position of stigma in relation to anthers. Their relative proportions, fruit setting percentage and effect of 2,4-D spray on fruit setting in each are given below (Table 2) [47].

A series of experiments were initiated to thoroughly investigate the floral biology, sex ratio and sex expression in cucumber and ways to modify them. It was found that all treatments (NAA, MH and Gibberellins) induced appearance of first flower on comparatively lower nodes of main axis as compared to control. NAA 100 ppm recorded highest female/male ratio, whereas MH 800 ppm induced temporary pollen sterility and even under long days and high temperature conditions, it was possible to modify the sex expression and ratio in cucumber by spraying certain PGRs. In further studies, most suitable concentrations of PGRs for discrete results were established. MH (100 and 200 ppm), NAA 50 ppm and IAA 200 ppm were most effective in causing appearance of first female flower on lower node and increased number of female flowers. MH 800 and 1000 ppm suppressed the number of male flowers and MH 200 ppm produced highest female/male ratio. Moreover, studies were conducted on the effect of gibberellin on sex expression and fruit development and spray of 10 ppm solution at 1-2 true leaf stage and 3-4 true leaf stage was suggested, as it produced more vigorous plants and affected appearance of first female flower earlier and on lower node. This also resulted in marked suppression of male flowers with a substantial increase in size female/male ratio and induced giant and parthenocarpic ovaries. However, the pollen fertility in the sprayed plants was not affected. Further, they conducted a comprehensive study of floral biology of cucumber. Anthesis starts at about 8 PM in the evening and opening of petals is complete by 7 AM in the morning and the flower closes by upward curling of petals by 7 PM. The pollen grains remain viable till noon after which the fertility of pollen decreases sharply and the stigma remains receptive from 2 h before anthesis to 2-3 h after anthesis [48-49].

The first study on sex expression and sex ratio in *Luffa* species was conducted in 1950. Four types of sex forms *viz.*, monoecious, androecious, hermaphrodite and gynoecious were reported in *Luffa acutangula*, while *Luffa cylindrica* and interspecific hybrids exhibited only monoecious sex expression [50]. *Luffa* spp. and their hybrids showed predominance of male flowers once during blossom period and maximum male flowers appeared during rains. The studies on floral biology and breeding of *Momordica charantia* revealed that the flowers open and anthers start dehiscing at 7:30 AM and 10:00 – 10:30 AM, respectively in December [51]. The pollen grains start losing viability after 12 noon and stigma was receptive from one day before till one day after flowering. The bitterness decreases by crossing with wild types.

Floral biology of sweet pepper was studied comprehensively and flowering was observed to commence in 50-55 days after transplanting and period of effective flowering lasted 65-69 days; fruits mature in 17-20 days, thereafter [52]. Anthesis started at 7.15 AM and continued up to 11.15 AM with peak at 7.15 AM. Anthers dehisce after 30 minutes of anthesis and stigma was receptive from the day of anthesis and remained receptive up to 2 days after anthesis, with the maximum on the day of anthesis. Pollen grains were light yellow, round with 1-3 pores, double walled and 26.6 – 40 microns. The pollen grains become fertile from one day before anthesis and remain receptive up to 2 days after anthesis with the maximum on the day of anthesis temperature- 26.50C and R.H.- 75 percent.

Pioneering pollen experiments

A study related to the development of seed and its parts in tomato revealed that the time between pollination and fertilization

appeared to be rather long; in no case, it was less than 48 h [53]. Cotyledons were not found to differentiate until about 16th day after pollination and the dermatogen, periblem, plerome and root cap was visible after 24 days of pollination. An experiment was conducted to study the compatibility and overcoming non-receptivity between stigma and pollen [54]. Pollen germination was found to start immediately and 90 percent of pollen grains germinated within 2 hours; as much as 90 percent of the pollen grains were observed to be polysiphonous. Formation of callose plugs was observed and pollen grains germinated fairly well in a 29 percent culture solution of sucrose mixed with 10 percent agar. The application of this solution on the stigma of Kenaf *Hibiscus cannabinus* may prove helpful to make a successful cross. The continuation of this study revealed 2 types of callose plugs; at some places, deposition of callose was so heavy that pollen tube was almost blocked. However, in other cases, the blockage was incomplete with a narrow passage left in the middle and only 23 percent of the pollen tubes showed plugs, average length being 13 microns [55]. The development of callose plugs was supposed to be an expression of incompatibility reaction [56].

Self incompatibility and bud pollination in crucifers

In dry stigma, the pellicle is involved in pollen germination. Removal of the pellicle components by enzymes or detergent inhibits pollen germination or pollen tube entry into the stigma in many systems, including *Cruciferae*. In some systems digestion of pellicle proteins by pronase does not affect pollen germination, but totally inhibits the entry of pollen tubes into the papillae. Unilateral incompatibility was reported in large number of crosses [57]. The crosses in general show incompatibility, when a SI species is used as female parent [i.e. SI X SC], irrespective of the presence or absence of SI in one of the species The pistil of the cultivated species generally inhibits pollen of the wild species, whereas the pistil of the latter permits good pollen germination and satisfactory tube growth of the cultivated species [58]. Ovary culture has been applied in many species: it was successful in Brassica hybrid [59]. A large number of interspecific and intergeneric hybrids have been produced in Brassicas through sequential culture of ovary, ovules and often embryos [58, 60].

Mentor effects in pistil mediated pollen-pollen interaction

In *Brassica campestris* x *B. oleracea* cross, pollen mixed with irradiated pollens was used which overcome the stigmatic barrier and at least one hybrid was produced. The interspecific cross of *B. campestris* X *B. oleracea* produces at least one true hybrid using irradiated mentor pollen [61]. Irradiated mentor pollen was used to overcome both intra and interspecific incompatibility, they were partially but overcome [62]. Self compatibility ranged from 2.87 percent (Palam Samriddhi) to 6.96 percent (DPGB13). Seed set under bud pollination was comparable to that under open pollination [63].

Storage of pollen

Comparative studies on pollen morphology and physiology showed that binucleate and trinucleate pollen grains show differences in their physiological and structural characters at the time of pollen dispersal. Under natural conditions, the two-celled pollen grains have a much larger life span because of their protective structure, low plasma content, and reduced metabolic activity. However, the trinucleate pollens are thin-walled, more sensitive to desiccation and storage and are short-lived. This type of pollen has a high rate of metabolism [64-65]. The pollen embryos in Brassica were isolated and cryo-preserved for successful recovery of plants [66].

Insect pollination

A review on insect pollinators and orchard planning on the basis of foraging behaviour of different insect species was published. Bathua, chilies, Indian spinach, purslane, spinach and sweet potato were counted as pollen sources; whereas asparagus, carrot family, cucurbits, fenugreek, garlic, onion, cruciferous vegetables and mustard were classified as minor nectar and pollen sources. It was observed that most species of beans are only occasionally visited by bees for pollen in India, but Lima beans yield surplus honey in California [67]. Another study of far reaching consequences during 1960s was that on extent of natural cross-pollination in vegetable crops. Tomato in spring summer did not show any amount of cross-pollination, whereas 3.84 and 7.4 percent natural cross-pollination at 60 cm and 2.4 m, respectively was observed in autumn winter. Brinjal showed natural cross-pollination of 1.1 percent and 0.14 percent at 60 cm and 2.4 m, respectively. Okra showed considerable out-crossing (5-9 percent), whereas radish showed high out-crossing (27-57 percent) [68].

The bumblebees were identified as pollinators for cauliflower seed production [69]. The bumblebees are available in large number at Kalimpong in cardamom plantations during its flowering in March-April, which coincides with the flowering of cabbage. Within a few hours of introduction, the bumblebees were found to visit the open flowers within cages; therefore, fresh introductions were necessary which had to be done twice more during the flowering period.

The average yield of seeds per plant was almost doubled when bumblebees were used, although 1000 seed weight was higher when honeybees were employed as pollinators. However, the ultimate performance with regard to viability and yield of vegetable was not affected.

Honey bee was used for pollination at vegetable breeding station, Katrain, Kullu [70]. Bees were found to improve fruit set in watermelon [71]. Watermelon is monoecious; pollen grains are heavy, large and sticky which cannot be transported by wind. The experiments conducted by CBRI in Maharashtra and A.P. indicated that when there was no insect visit, there was no fruit set and visit of natural insect pollinators resulted in good fruit setting. They enlisted a number of insects visiting watermelon flowers. Houseflies proved more efficient pollinators than honeybees in carrot, whereas honeybees increased the seed yield of the crop over wind pollinated control in sugarbeet [72]. The results were in contrary with earlier belief that sugarbeet is wind pollinated and carrot is honeybee-pollinated crop. Bee pollination and its impact on cauliflower seed production was studied; *Apis* species constituted around 80 per cent of pollinators is Pusa Deepali and line 328-5-10-5-1[73]. Bee visit was found to be highest during 12 noon to 2 PM; though there was no difference between seed obtained from open and caged plants, significant increase in setting percentage pods/plants and seed yield/plant in open plot was observed.

In preliminary studies to find the affinity of pollinators towards cms lines of cabbage Golden Acre planted adjacent to open pollinated plot, no significant difference was observed in seed yield obtained from male sterile and fertile plants [74]. It was concluded that pollination with camel hairbrush or glass rod with end tapered to stigma width, accompanied by covering with cotton capsule was found a superior treatment combination [75]. More congenial microenvironment around the flower created by cotton capsule or butter paper bag might be responsible for effective fertilization. An experiment on natural cross pollination in chilies revealed that average seed developed in fruits set through open pollination were 64.1

and 44.5 percent, during 2000-01 and 2001-02, respectively in male sterile plants of MS-12 line, while 47.78 and 26.4 percent, respectively were obtained from fruit developed through manual pollination [76]. Similar results were obtained from the line CCA-4261. The difference between average fruits per plant on male sterile plants of MS-12 and its isogenic fertile line (B-line) were non-significant. However, mean natural cross-pollination 11.4 and 1.8 percent at 2.4 m and 24 m, respectively was observed in brinjal [77].

Chemical induction of male sterility

In Solanaceae, the effects of GA application vary by species. In tomato, normal plants treated with GA_3 produce fertile flower with separate stamens and split pistils [78]. However, GA_3 application produces feminization of flowers and inhibition of pollen development in pepper [79]. The gibberellin synthesis inhibitor, CCC at certain concentrations selectively inhibits the development of the stamens or otherwise suppresses pollen development in tomato [80]. Similarly, ABA caused effects on developing floral buds similar to those produced by CCC [78, 80]. In both GMS and CMS systems, the activity of esterases is decreased. In sl-2 mutant of tomato, the number and intensity of isozymes of esterases are reduced at stages when abnormalities are observed in tapetum and when pollen wall development is affected [81].

Studies on diseases of vegetable seed crops

The incidence of sclerotinia rot of peas in Kullu valley was first recorded in experimental plots at Naggar farm [82]. During 1968-71, the loss ranged from 21 to 70 percent. *Sclerotinia* rot caused by *Sclerotinia sclerotiorum* was observed in Solan in Kullu valley in 1971. An estimated loss of 40 percent in Kullu valley due to disease was observed. Farmers in saproon valley faced heavy losses year after year and desperate seed growers gave up seed production of snowball group of cauliflower in the valley. The seed transmission reported of brinjal mosaic disease was reported in some studies [83-84]. The intensity of mycoflora on vegetables seeds in Kullu valley was investigated and 17 vegetable crops were studied for percentage of infection of 16 fungi on their seed borne nature [85], 95.8 percent infection of *Alternaria brassicicola* on cabbage seed and 100 percent infection of *Verticillium* spp. in brinjal was observed. Capsicum seeds were found to be infected up to an extent of 80.5 percent with *Verticillium* spp., 68-80 percent with *Fusarium moniliforme* and 63 percent with *Colletotrichum* spp.

A control schedule was worked out for *Sclerotinia* rot [86]. The authors had not expected this rot before flowering, but quite a good number of cauliflower plants were noted in 1974 and showed symptoms even at curd stage in 1975. In 1974, loss in Kullu and Kashmir valley was 60 percent in cauliflower and 33 percent in in cabbage, respectively. Four years of research experiments confirmed that fertilizers have no effects on the disease; it was confirmed by applying different levels of N, P and K. The fungus does not spare even okra, brinjal, turnip, carrot and peas and it was found to be seed borne up to 11 percent. Mixing Kelo (*Cedrus deodara*) saw-dust @ 10 q/ha at the time of ploughing (cheapest control) besides deep ploughing, flooding, soil treatment with calcium cyanamide, seed treatment with a mixed suspension of 50 ppm Aureofungin + 50 ppm Streptocyclin for 30 min., seedling treatment with 0.25 percent, Benlate suspension for 5-8 min. seedling dip and drenching the root region with PCNB (Brassicol) at 10 days intervals are different effective control methods for this disease. Resistant lines were being selected in cabbage for cabbage yellows in a sick plot [87].

Seed mycoflora in capsicum was studied at IARI R.S., Katrain and seed from

affected fruit having incidence of 3 rots viz., Anthracnose, basal rot (*Cercospora capsici*) and black rot (*Alternaria* sp.) and healthy fruits were extracted and inspected under stereobinocular microscope. Seed borne pathogens were observed in seeds from all diseased lots. It was suggested that capsicum seeds should invariably be treated either with captan or thiram prior to sowing. A new disease was reported to affect cauliflower crop during May 1988. The disease appeared to be mysterious, showing typical symptoms on flowering stalks or bolters. The fungus involved was identified as *Fusarium moniliforme* pv. *intermedium* Neisch. It was reported that rhizoctonia disease (*Rhizoctonia solani*) of tomato, capsicum and bean was threatening vegetable production in areas of Kullu valley. Hence, a new technique of artificial inoculation of seedlings for screening cauliflower lines for resistance against *S. sclerotiorum* was developed [88]. A reduction in seed yields from 400 kg to less than 125 kg/ha was reported in cauliflower [89]. The symptoms appear in generative phase and curds fail to bolt. When bolters are attacked, wilting occurs and branches die eventually. A biological observatory was also developed for the effective management of the disease. It works on the principle that sclerotia buried within 5 cm of soil depth are of epidemiological significance. The sprays should be initiated with the appearance of apothecia in the indicator pots buried in the corner of the field.

S. sclerotiorum was first observed in Nagaland on Knol-Kohl in November 1984 and the disease was becoming a deciding factor in agricultural production [90]. A two-fold package was recommended to stop the spreading disease; prevention of humidity build up by increasing the inter row distance, by removing the basal foliage and sowing graminaceous crops (wheat, rice and maize) in rotation. It caused a heavy loss of up to 50 percent in knol-kohl and 100 percent in cabbage, but early Vienna and white Vienna varieties of knol-kohl were found resistant. It was reported from IARI R.S., Katrain that exposure of *S. sclerotiorum* for more than one-month maturation period before burial is necessary for successful survival of apothecia and the functional life span of mature apothecia is approx. 15-18 days. It was reported to cause drop in more than 30 percent plants; this finding is of vital importance in forecasting and disease management [91]. Further, it was reported that sclerotia of *S. sclerotiorum* have been observed as mixture in seed lots of radish, turnip, cabbage and peas up to 2 percent. The outbreaks and new records of following fungus were made from Kullu Valley [92];

1. *Phoma nebulosa* on spinach,
2. *Fusarium pallidoroseum* on lettuce,
3. *F. equisetti* on Lettuce, beans and dahlia,
4. *F. oxysporum* on beans,
5. *F. accuminatum* on pea,
6. *Colletotrichum coccoides* on brinjal,
7. *Pythium ultimum* on peas.

Severe outbreak of bacterial blight caused by *Pseudomonas pisi* in Kullu valley caused seed crop of peas to suffer greatly and some growers failed to harvest anything. The bacterium which is known to be seed borne in nature appears to have been introduced into the valley through seed, as it has not been noticed previously. *Sclerotinia* attack on eggplant was observed in which more than 40 percent of eggplant var. Pusa purple cluster in fall bearing and dried up within a month's period during September 1987. Standard Blotter method failed to establish the internal or external seed borne nature of *S. sclerotiorum* in affected eggplant seed. In peas KTP-4, a powdery mildew resistant line developed at IARI R.S., Katrain was included in AICVIP (which has subsequently been identified for release).

It was reported from IARI R.S., Katrain that *Sclerotinia sclerotiorum* was becoming

increasingly important in seed crop of carrot since at least 1982 [93]. Disc inoculation technique for screening of carrot germplasm against *S. sclerotiorum* was developed. To control soft rot in seed crop of cabbage, recommendations were made on the basis of 3 years experimentations. Four sprays of antibiotic plantomycin 500 ppm + CuOCl (3000ppm) at 15 days interval starting with the appearance of initial water soaked spots on the head or with the onset of rains. The control schedule for buck eye rot of tomato by *Phytophthora infestans* and *P. parasitica* and of curd rot complex of cauliflower caused by frost, *Sclerotinia, Peronospora parasitica* and *Erwinia carotovora* was worked out. Chemical control of powdery mildew of peas caused by *Pseudomonas syringae* pv. *pisi* and of *Phoma nebulosa* on spinach was worked out [94].

Studies on insect pests of vegetable seed crops

The population dynamics of chilli mites *Polyphagotarsonemus* spp. with respect to seasonal fluctuations were studied and attempts were made to find out suitable chemicals for their control [95]. Two peaks of populations were observed, first between February and May and second during October-November. 0.2 percent micronised sulphur dust and 0.05 percent Dicofol was found effective for 7 days and 0.05 percent and 0.03 percent Dimethoate was effective for 15 days.

A few pests of Taro (*Colocasia esculenta*) in the NE region were recorded; three major and 4 minor pests of Taro were reported for the first time from temperate climate in India [96]. Out of these, *Palpifer murinus* (Corm caterpillar) is of major significance as a pest of stored or over wintering corm.

Studies on weed conrol in vegetable seed crops

Manual weed control in carrot has been found quite expensive in some studies; instead butachlor and fluchloralin for were recommended weed control in carrot [97]. A study on use of pre-emergence herbicides in okra (Pusa Sawani) for control of nutgrass indicated that Lasso and Tok E-25 @ 2 kg/ha were most effective in controlling the weed population and both herbicides improved the yield of okra in comparison to control [98]. Later, alachlor was found to be an effective weedicide in okra in similar experiments [99-100].

Agronomic practices

It was concluded that a very strong correlation of seed yield exists with steckling size over all dates of transplanting and whole root gave highest seed yield [101]. Loss of seed yield as a consequence of delayed sowing could be made up by increasing the size of stecklings. A study on the effect of planting time, bulb cut pinching of bolt treatment on yield and quality of seed of onion exhibited that bulb cut and pinching both reduced the seed yield significantly [102]. No effect of varying levels of nitrogen and phosphorus on germination was observed; nitrogen did not affect 1000 seed weight, whereas phosphorus had significant effect on 1000 seed weight [103]. Maximum seed yield was obtained with 70 kg N and 70 kg P /ha. It was found that 1000 seed weight was greatly influenced by different levels of nitrogen and number of cuttings, besides green yield and seed yield [104]. Test weight, germination and seed yield/ha showed maximum values with the application of N 100 kg/ha, P 50kg/ha and K 25 kg/ha whereas test weight at wider spacings was significantly higher as compared to closer spacings [105]. Numerous studies have been conducted on this aspect of various crops. A compilation of such works would be out of scope of this article. Nevertheless, the findings of these experiments are of definite utility in seed production.

Institutional development for vegetable seed research and supply

National seed project was started with the assistance of World Bank in 1974. In 1976, fifteen quintals of snowball cauliflower seed was exported to the Netherlands. Post vegetative phase characteristics of biennial vegetable crops were compiled, documented and published in 1999 by IARI R.S., Katrain. Henceforth, the practice of roguing and inspection became easier than earlier and it can be used as a ready reckoner in vegetable seed production. Post graduate education and training in Seed Science was initiated at Indian Institute of Agricultural Institute, New Delhi in 1974 as a diploma course. A full-fledged M. Sc. programme was started in 1984 and the first batch for Ph.D. degree in Seed Technology commenced in 1994.

Underutilized vegetable seed crops

An observation was made on Jackfruit seeds, which can easily be applied to other minor crops; the reasons for its limited cultivation include non-availability of nursery plants locally and high mortality following transplanting [106]. While studying certain aspects of jackfruit seeds, it was observed that three fourths of seeds weigh 4-6 g and seeds with 4-6g weight gave 85 percent germination. Ungraded cracked seeds had shown poor sprouting, but cannot be considered wholly useless if selected for size prior to sowing. Jackfruit seeds did not lose their viability for full one month, even if stored under ordinary conditions.

In late 1960s, farmers were made available the seeds of an exotic collection EC-36910 (from Germany) of Meetha Karela (*Cyclanthera pedata*) by IARI. R. S. Phagli (Shimla), in an attempt to popularize this underutilized vegetable among farmers who used to cultivate several low yielding local strains throughout Himalayas. This crop is an introduction from South America, which has no recorded history of entry into India [107]. Some observations were taken on the process of seed development in annual moringa; the seeds became germinable after 40th day of fertilization and maximum germination was recorded on 100th day after anthesis and gave rise to seedlings with maximum dry weight [108].

An effort was made to produce true seeds in sweet potato. For this purpose, polycross was compared with controlled cross for its usefulness [109]. There was no apparent relationship between RH, temperature and photoperiod with seed setting and the compatibility factors among the genotypes influenced the seed setting, rather than the environmental factors. Jerusalem artichoke owing to its potential to give bumper yields, even on poor soils and to thrive well under rainfed conditions has been termed as poor man's potato. A high yielding selection, JAK-1 was developed at Solan [110].

New crop opportunities

The decade of 1960s began with revolution in seed industry. Pusa Sawani, a new leaf vein mosaic resistant variety of bhindi bred at IARI was released in 1960. It became extremely popular, resulting in introduction of bhindi crop to new regions. Some cultivators remarked that it is not only a new variety but also a new crop for them because they had not earlier thought of growing bhindi as a commercial crop. In spite of fact that 30,000 kg of true seed was produced in Maharashtra, U.P. Gujarat, Delhi and Punjab in 1962, the demand cound not be not fully met in 1963. Badrinath Barwale cultivated seed in 14 acre plot yielding 800 kg/acre, whereas in U.P. tarai, two brothers Lal Singh and Munshi Singh had had a 25 acre good seed crop in 1962 [111].

With the view to introduce and popularize sugarbeet as an alternative sugar crop, ICAR initiated a scheme at Kalpa, Kinnaur in 1960. The idea was to keep the sugar mills running during the period before and after cane crushing period, when the sugar

mills were idle. But, seed production posed a problem, since the initial efforts to raise seeds in plains were not successful. Two varieties were included in the scheme viz., Romanskaya and Eros Type E, selected based on root yields and sugar content. The introduction of crops to new regions continued in 1960s. An attempt was made to grow 84 varieties in Kullu valley in order to introduce watermelon in temperate climate; only Asahi Yamato was found worthy [112]. It is a mid season variety with average fruit weight of 6 kg and package of practices were standardized for crop as well as seed production. In the same year, carrot variety Pusa Kesar - an oriental type variety was released. It was a high carotene containing selection from a cross between Local Red x Nantes Half Long with a month longer root stay ability in the field. The incidence of forked roots is lesser in this variety; the core is narrow and the core colour is sufficiently orange. The seed crop matured in about 15 days, but seed development was normal. Turnip variety Pusa Kanchan was released along with carrot Pusa Kesar. It was a selection from a cross between Local Red Round and Golden Ball with longer root bulb staying ability in the field, without getting split and an increased carotene containing variety. It has the ability to produce seeds in plains and the seed crop matures a fortnight later [113].

In 1971, first F_1 hybrids among vegetable crops from public sector were released from IARI in form of bottle gourd hybrids Pusa Meghdoot and Pusa Manjari. Close on the heels, a summer squash hybrid Pusa Alankar was released from IARI Regional Station, Katrain in 1972. It was an early HYV, a F_1 hybrid between EC27050 and Sel. IPL-8 (a selection from a cross between Local chappan kaddu and Early Yellow Prolific). In the same year, a cucumber hybrid Pusa Sanyog was released, which was also developed at IARI R.S., Katrain. In 1975, radish variety Pusa Chetaki was released, which was developed from sample packets of seeds from Denmark received in 1966. It yielded 2-8.5 kg in 40 days as compared to 1.6-3.5 kg in 50-55 days of sowing in Pusa Desi and Pusa Reshmi [114]. Subsequently, an early maturing tropical turnip variety, Pusa Sweti was released. Many good varieties of temperate group of turnip were available for growing in winter season, but little work had been done on improvement of tropical group of turnip. It was selected from a farmer's field in Punjab and seeds can be produced in north Indians plains [115]. During the same year, carrot variety Pusa Yamdagni was released by variety release committee of IARI. It is a selection made from a cross EC-7981 X Nantes Half Long, an improvement over Nantes Half Long in terms yield/ha, days taken to root formation [10 days early], carotene content (10 percent increase) and seed yield [30 percent increase] [116]. A tomato hybrid capable of setting fruit even if the night temperature touches a low of 8oC, named Pusa Sheetal was released in 1990. It was a selection from Balkan (Bulgaria) X Jemnorrosnij (USSR) [117]. A synthetic variety of cabbage 'Pusa Sambandh', developed at IARI. R.S., Katrain entered into AICVIP for multilocational trials in 1986. The variety was proposed for release in 1991, but denied for release at annual workshop. In order to breed F_1 hybrid of European carrot, material was selected for incorporation of ms into cultivar Nantes. In brinjal, Pusa Anupam has been released for cultivation in bacterial wilt prone areas of country. A pole type French bean Pusa Himlata was released for table consumption as well as dry canned beans [118].

Broccoli variety, KTS-1 was released by IARI release committee in 1996 and its seed production was taken up at IARI Regional Station, Katrain in 1997. CMS was incorporated into the European carrot var. Pusa Yamdagni from line 29 and into Nantes

from lines 39, 95, 103 and EC-240607. Isogenic lines were developed and it was reported that such male sterility was broken at high temperature at greater than 30°C. Tomato hybrid KT-4 (Pusa Divya) was released in 1997 and capsicum hybrid Pusa Deepti was released the same year by CVRC [119].

An improved variety of Swede *viz.*, FRL Swede Sel. 1 was recommended, as there was no improved variety of swede (*Brassica campestris* var. *rapifera*) [120]. It was selected from available local germplasm. Being biennial, clean roots are stored in pits in November and taken out in March, stored at normal room temperature until plantation in last week of April to first week of May. The blooming starts from mid July and silique are ready for harvest from mid September. The Swede silique shatters badly, when fully ripe; therefore whole crop is cut the when 70 percent of silique turn yellow or cut in 2-3 flushes; the average yield is of 8-9 q seed / ha. In chilies, the male sterile line MS-12 has been utilized to develop the first commercial MS based chilli hybrid by the Indian public sector [121].

For exploiting the heterosis in knol-kohl, a hybrid KKH-1 was developed at IARI R.S., Katrain and it was found to give superior performance. To economize its hybrid seed production, the development of CMS line for use as female parent is in progress. F_1 hybrid utilizing CMS in carrot continued and 11 hybrids developed at the station were found to yield significantly higher than control Pusa Yamdagni. The best among them also posed desirable attributes like orange colour, smooth roots and small self-coloured core [122]. The process of tropicalization confined the onion crop to the peninsular and western India and the Indo-Gangetic Plains. A long day onion variety was developed for the hills, which could be cultivated at an altitude of 1000 m and above [123]. Prior to that, it was not possible to grow onions in hills, neither for vegetables nor for seeds. Cauliflower variety Pusa Himjyoti was released for cultivation in hills during spring and summer. In spinach, F_1 hybrid SH-1 was developed and package of practices for hybrid seed production of spinach were also standardized. Three lines *viz.*, KN_1, KN_2 and KN_3 were planted for seed multiplication, as they have been recommended for cultivation as 'saag'. They were developed from Chinese cabbage x Turnip x Mustard [119]. In 1986, a promising variety of brussels sprouts was proposed for release by IARI variety release committee.

Experiments on vegetable seed quality

A study was conducted on different methods of extracting tomato seeds and acid method was the quickest that requires only 20 minutes of fermentation of pulp in acid [124]. Three methods of extraction of bhindi seed *viz.*, splitting, bullock treading and floatation method were in vogue and IARI recommended splitting method for commercial seed production. A comparison of different seed extraction methods was done in tomato; fermentation method gave maximum seed recovery/kg, pulp yield and acid method produced bright and shiny seeds [125]. Germination percent, speed of germination and seedling vigour were found important parameters for determining the physiological maturity of brinjal seeds [126].

Musk melon

Shull discovered heterosis as early as 1914, but its exploitation in different crops is still to be accomplished. In muskmelon, the efforts in India started as late as 1970s. The story of exploration of different mechanisms to exploit heterosis in musk melon commercially in India is an interesting one. Male sterility is monogenic recessive and has been utilized for ascertaining the magnitude of heterosis and combining ability [127-131]. MS line (ms-1), identified by Bohn and Whittaker in 1949 has been utilized effectively [127-128] and showed

good nicking ability, when tested in a series of hybrid combinations. Hybrid seed started with release of Punjab hybrid (F_1 of ms 1 x Hara Madhu) in 1980 in Punjab state [132] and subsequently at national level in 1985. The seed production technology was standardized and 6 seedlings per hill were recommended so that sufficient plant population was maintained after the rouging of male fertile plants [133]. The use of marker genes to simplify the procedure of identification, thus improving the quality of hybrid seed was attempted [134]. However, the results indicated that linkage of genetic marker with ms gene was poor.

Monoecy

Muskmelon in general is andromonoecious, but some genotypes show monoecious sex expression. Since the use of monoecy excludes emasculation, it can reduce the labour requirement for a given number of pollination by 50 percent and enhance fruit set by 40-70 percent as compared to 5-10 percent in parents, perhaps the first in the world [135]. Monoecious lines, M_1, M_2, M_3 & M_4 were developed for use in heterosis breeding [136]. A F_1 hybrid, M_3 x Durgapura Madhu was found promising and released for commercial cultivation in 1990. Monoecious character is controlled by a single pair of recessive genes (Pusa Rasraj). The problem in using monoecy in heterosis breeding is undesirable linkage between gene controlling monoecy and fruit shape [137]. Consequently, F_1 combination with round fruits cannot be easily obtained and the problem was evident in Pusa Rasraj. Although the method really yielded some success, but commercial hybrid seed production using monoecy under open pollinated field condition was handicapped on account of large mixture of selfed or sibbed seed in hybrid progenies [138-139].

Gynoecy

The first gynoecious muskmelon line developed was Wisconsin 998 [140]. WI-998 exhibited good combining ability for yield and earliness, when used in hybridization [141]. A cross between WI-998 x Punjab Sunehri was found promising and released for common cultivation in Punjab State in 1995. Several other gynoecious lines in muskmelon have been developed and a gynoecious line GM-6 E-7 was found quite promising, which can be exploited for commercial hybrid seed production [142]. Uses of Ethrel. Alar and Silver Thiosulphate [143] have also been suggested for inducing maleness for maintenance of the gynoecious lines.

Improved techniques of vegetable seed production

Cycocel [CCC] was a newly developed PGR found to increase the seed yield of radish, owing to increase in the number of branches [144]. Spacing, instead of close planting resulted in increased yield as well as 1000 seed weight; 60X60 cm spacing was found optimum for maximum yield of radish seed [145]. A study on effect of spacing and PGRs on seed yield of radish revealed that gibberellic acid spray resulted in an increase in plant height, whereas CCC 500 ppm recorded highest number of branches per plant. Maximum 1000 seed weight as well as yield was recorded with combination of wider spacing and higher concentration of cycocel [146]. It was found that seed dip treatment of radish seed for 24 hours in 5 ppm 2,4-D could result in increased early and total yield, weight and number of seeds per kg of fruits as well as percentage seed germination [147].

In an unprecedented experiment, ratooning of lettuce seed crop was done in which regeneration was found to take place in 67.5 per cent of plants, yielding 1.27 q/ha in second flush; 14.5 q/ha was harvested from

the main harvest. The curd pruning, scooping and half curd cutting were effective in increasing the seed yield of cauliflower [148]. However, scooping method was best for increasing the seed yield.

An attempt was made to start seed production of temperate vegetables in cold desert of Leh valley. The climate of Leh was found suitable for cabbage seed production [149]. An attempt was made to produce cabbage seed at Horticulture Research station, Kodaikanal, 2225 m above MSL on varieties Pride of India, Golden Acre and September flowering occurred in all three varieties after 195, 185 and 200 days respectively, but seed formation was observed in Golden Acre only. Head incision method gave the highest yield and spraying of 400 ppm gibberellic acid increased the seed yield significantly [150]. Seed plot technique was developed to grow virus free potato seed in sub-tropical plains [151]. Subsequently, a breeder seed scheme was initiated in 1967 and CPRI has been entrusted the major responsibility of producing breeder seed.

An increase in seed yield attributes as well as germination, 1000 seed weight and yield per ha was observed with increasing head compactness in cabbage [152]. The role of type of seed in culture of potato was investigated and a general increase in yield with increase in the size of seed piece was observed. Tuber yield thus, shows an increase of over 100 percent, when size is changed from 5 to 40g. The variation in number of eyes is found to produce practically no difference in either the top or tuber weight [153].

Synthetic seeds

The concept of synthetic seeds caught pace with a report on polyox as an artificial seed coat for a sexual embryos [154]. They also produced first report on synthetic seeds in carrot. Somatic embryogenesis was reported in sweet potato [155]. The studies on synthetic seed production were conducted in Sweet potato (*Ipomea batata*. L) [156] and Cassava (*Manihot esculenta* Crantz) [157]. Cryo-preservation of embryogenic tissue in sweet potato genotypes was attempted by using an encapsulating protocol [155] and synthetic seeds were produced in this crop [156].

True potato seed

A study of heterosis in potato and use of some introduced tetraploids for its exploitation was conducted [158] and heterotic effects for yield in true potato seeds were obtained when *andigena* clones are bred with *tuberosum* clones. Maximum heterosis for tuber yields were reported for *tuberosum* X *andigena* crosses, both in F_1 seedlings and F_1C_1 tuber generations. The desired seed size, embryo type and endosperm filling in TPS was attained through adequate nutrition/moisture supply to the mother plants in the field during berry development and seed formation together with in 8-10 weeks of plant maturation time for berries after pollination [159]. Comparisons made between hybrid and open pollinated TPS families for yield and other traits showed that hybrid TPS have an edge over OP families [160]. The extraction and processing of TPS was standardized [161].

CONCLUSION

After 4 conducting a series of research experimentation in seed production of European vegetables it was concluded "the seed production of these vegetables had to be abandoned on elevation below 5000 feet, owing to inadequacy of winter chills and to greater incidence of diseases and insect pests there" [2-3]. He made an observation that the importance of the seed production business of this type has not been properly impressed upon our government. He suggested "India, being almost a continent, should start a score of Naggar (Kullu) like experiment stations between Kashmir and Kumaon region."

The development of seed industry in India has been gradual and brisk over a long period of time and was constantly backed by sound scientific research. The experiments were not only carefully planned and perfectly conducted, but also aimed to solve the problems faced by the industry from time to time. They came out with concrete results that had, most of the time, direct application in the field of seed production. However, there has been little hybridization between science and commerce. The export potential has not been tapped adequately, as the information generated through research programmes have not been put to commercial application to a satisfactory level. Biotechnological research in the field of vegetable seed production, in general and transgenic research, in particular is conspicuously absent. All said and done, it can be said that Indian seed industry is ready with skill but wanting in will, it is in a take-off stage.

FUTURE THRUST

As early as 1948, Dr. H.B. Singh visualized the need of a strong seed supply system in India and standardised the seed production technology in numerous vegetable crops. They compared climate of temperate regions of India with that of Europe and observed that Kashmir climate is more close to European climate in comparison of Kullu valley.

According to them, "another important feature of temperate climate of Kashmir and Kullu valleys is that winter and summer seasons are so balanced that it is possible to grow for seed not only the biennial vegetables but also important summer vegetables so that seed growers can practice an intensive type of seed farming." However, so far the potential of such locations have not been fully exploited. The government can allure private sector to these regions by providing tax holidays and identifying these areas as export promotion zones.

The impact of global climate has recently become a subject of increasing importance. Hence, a study was conducted on the changes in long-term climate parameters of Kullu valley during 1962-2004 and impact analysis of the climatic changes during 1981-2004 was on the seed yield of cabbage var. Golden Acre in the upper Kullu valley in Hindukush Himalayas. It was suggested that the planting of cabbage should also be delayed at least by a fortnight to avoid incidence of soft rot and increased seed yield [162].

A study was conducted on the changes in long-term climate parameters of Kullu valley during 1962-2004 and impact analysis of climate change during 1981-2004 on the seed yield of cabbage var. Golden Acre in the upper Kullu valley in Hindukush Himalayas. It was suggest that the planting of cabbage should be delayed by atleast a formight to avoid incidence of soft rot and increased seed yield.

They had also observed, "Lahul valley situated on the other side of the Rohtang pass has an ideal climate, resembling the climate of Quetta in being cool, but dry." They had expressed hope "when satisfactory transport arrangements are made in near future, this area would also possibly become important for this seed industry." The construction of tunnel to Lahul and Leh from beneath Rohtang is under way. Biotechnology research like gene mapping, recombinant DNA technology and tissue culture should be applied for vegetable improvement. Losses due to diseases have been devastating at different stages of time, which even forced farmers to give up seed production of certain crops. This necessitates identification and earmarking of disease free zones. This will strengthen the concept of organic vegetable seeds.

In order to facilitate isolation of varieties, the idea of seed production zones, seed village concept or isolated valley

approach should be given a tangible form through suitable institutional mechanisms like legislations etc. The steps can be taken to encourage the seedsmen and entrepreneurs to make more investments in vegetable seed production as well as related research and development activities. The identification of custom seed production zones would serve to revolutionize the export oriented seed production and research.

REFERENCES

1. MEHTA YR, DOUGLAS JE AND SINGH AMIR (1973). Historical Development of Seed Improvement in India. *Seed Res* **1** (1): 1-12.
2. VARMA SR (1951a). Trials on the production of European type of Biennial Vegetable seeds. *Ind J Hort* **8** (1): 18-9.
3. VARMA SR (1951b). Further trials on the production of European type of Biennial Vegetable seeds. *Ind J Hort* **8**(3): 9-11.
4. SINGH UP (1954). Preliminary studies in inducing seed set in cabbage in the plains of U.P. *Ind J Hort* **8**(3): 100-3.
5. SINGH HB, THAKUR MR AND BHAGCHANDANI PM (1959). Vegetable seed production in Kulu Valley–I. *Ind J Hort* **16** (2): 92-101.
6. SINGH HB, THAKUR MR AND BHAGCHANDANI PM (1959). Vegetable seed production in Kulu Valley-II. *Ind J Hort* **16**(3): 153-61.
7. SINGH HB, THAKUR MR AND BHAGCHANDANI PM (1960). Vegetable seed production in Kulu Valley-III. *Ind J Hort* **17**(1): 38-47.
8. SINGH HB, THAKUR MR AND BHAGCHANDANI PM (1962). Vegetable seed production in Kulu Valley-IV-Seed Production of Peas, Lettuce, Celery, Parsley Onion, Leek and Spinach. *Ind J Hort* **20** (3 & 4): 147-54.
9. MISHRA GM (1958). Investigations on hybrid vigour in brinjal (*Solanum melongena* L.) *Ind J Hort* **15** (4): 305-17.
10. BANGA O, PATEL J AND VAN BENNEKON JL (1964). Genetic analysis of Male sterility in Carrot (*Daucus carota* L.) *Euphytica* **13**: 75-93.
11. CHOUDHURY B, PUNIA RS AND SANGHA HS (1965). Manifestation of hybrid vigour in F_1 and its retention in F_2 generation of tomato. *Ind J Hort* **22** (1): 52-9.
12. SINGH JP, GILL HS AND AHLUWALIA KS (1970). Studies in hybrid vigour in cucumber (*Cucumis sativus* L). *Ind J Hort* **27** (1&2): 36-8.
13. POCHARD E [1970]. Obtaining three new male sterile mutants of pepper [*Capsicum annuum* L] through application of mutagens on monoploid materials. *Eucarpia* Versailles, France. pp. 93-5.
14. SINGH J AND KAUR S (1986). Present status of hot pepper breeding for multiple resistance in Punjab. In: *Proceedings of IV Meeting of Genetics and Plant Breeding of Capsicum and Eggplant*; Zaragoza, Spain. pp. 111-4.
15. ANAND N AND DESHPANDE AA (1988). Functional Male sterility in *Capsicum annuum* L. *Capsicum and Eggplant Newsletter* **7**: 32.
16. MURTY NSR AND LAKSHMI N (1979). Male Sterile mutants in *Capsicum annuum* L. *Curr Sci* **48**: 312.

17. MESHRAM LD AND NARKHEDE MN (1982). Natural male sterile mutant in hot chili (*Capsicum annuum* L) *Euphytica* **31**: 1003-5.

18. PATHAK CS, SINGH DN AND DESHPANDE AA (1983). Male and female sterility in chili pepper (*Capsicum annuum* L). *Capsicum Newsl* **2**: 102-3.

19. KUMARAN MN (1971). Studies on combining ability, gene effects and heterosis in cauliflower. *Ph.D. Thesis*, P.G.School, IARI, New Delhi.

20. KALE PN, CHATTERJEE SS AND SWARUP V (1979). Heterosis and combining ability in Indian cauliflower (*Brassica oleracea* var. *botrytis* L.) *Veg Sci* **6**: 11-20.

21. GILL HS, SINGH JP AND DOHARE SR (1975). Combining ability in spinach (*Spinacea oleracea* L). *Veg Sci* **2**: 56-60.

22. SINGH DP, SWARUP V AND CHATTERJEE SS (1976). Genetic studies in Indian cauliflower (*Brassica oleracea* var. *botrytis*): Heterosis and combining ability in maturity group II. *Veg Sci* **3** (1): 41-6.

23. SIROHI P. AND CHOUDHURY B. (1978). Heterosis in bittergourd, *Veg Sci* **5**: 102-7.

24. GILL HS, P.C. THAKUR AND T.C. THAKUR (1973). Combining ability in sweet pepper (*Capsicum annuum* var. *grossum.*) *Ind J Agric Sci* **43**: 918-21.

25. KALLOO G, SINGH RK AND BHUTANI RD (1973). Combining ability studies in tomato. *Theor Appl Genet* **8**: 358-63.

26. GILL HS, SINGH JP AND SWARUP V (1975). Combining ability in cabbage (*Brassica oleracea* var. *capitata* L). *Veg Sci* **2**: 50-5.

27. KALE PB AND SESHADRI VS (1988). Studies on Combining Ability in watermelon [Citrullus lanatus (Matsumara) Nakai]. *Punjabrao Krishi Vidyapeeth Res J* **12**: 45-8.

28. NATH P AND DUTTA OP (1971). New high yielding varieties in cucumber. *Ind Hort* **15**:11-4.

29. MURUGAIAH S. (1982). Studies on Sallele lines and their maintenance in Indian cauliflower (*Brassica oleracea* var. *botrytis* L.). *Ph.D. Thesis* P.G. School, IARI, New Delhi.

30. ANONYMOUS (1980). *Annual Scientific Report*, IARI-Regional Station, Katrian, Kullu Valley, HP.

31. LAWAND KE AND PATIL AV (1990a). Heterosis in bitter gourd. *Haryana J Hort Sci* **19** (3-4): 342-8.

32. LAWANDE KE AND PATIL AV (1990b). Studies on combining ability and gene action in bitter gourd. *J Maharashtra Agril Uni* **19** (1): 24-8.

33. SHARMA, PP DHIMAN SC AND ARYA PS (1983). Heterosis and combining ability in cauliflower (*Brassica oleracea* var. *botrytis* L.) *Himachal J Agri Res* **9**: 22-7.

34. ANONYMOUS (1991-92). *Annual Scientific Report*, IARI, Regional Station, Katrain [Kulu Valley], H.P. pp. 4.

35. SWARUP V AND CHATTERJEE SS (1972). Origin and Genetic improvement in Indian cauliflower. *Eco Bot* **26**: 381-94.

36. GANGOPADHYAY KK, GILL HS AND MORE TA (1995). Assay of self-incompatibility in Indian cauliflower [*Brassica oleracea* var. *botrytis* L.] with special reference to maturity group I & II. *Veg Sci* **22** (1): 42-7.

37. SAIKIA J, SHADEQUE A AND BORA GC (1995). Genetic studies in cucumber, correlation and path coefficient analysis. *Haryana J Hort Sc* **24**: 126-30.

38. ANONYMOUS (1996). *Annual Scientific Report*, IARI, Regional Station, Katrain (Kullu Valley), H.P. pp. 1- 4.

39. GANGOPADHYAY KK, GILL HS AND SHARMA SR (1997). Heterosis and combining ability studies in early group of Indian cauliflower involving self-incompatible lines. *Veg Sci* **24** (1): 26-8.

40. SINGH B, JADHAV KL AND PALJOR ELI (1997). Potentials of cabbage seed production in Leh Valley. *Ind Hort* **41** (4): 36-7.

41. SINGH AK AND SINGH A (1998). Genetic studies of polygenic traits in chilli (*Capsicum annuum* L.). *Crop Res* **15** (1): 61-2.

42. ANONYMOUS (1999). *Annual Scientific Report*, IARI, Regional Station, Katrain (Kullu Valley), H.P. pp. 2.

43. KUMAR R, SINGH AK, KUMAR S, BANNERJEE MK AND KALLOO G (2001). Introduction and characterization of male sterile and parthenocarpic lines of tomato (*Lycopersicon esculentum* L.). *Veg Sci* **28** (1): 30-3.

44. KUMAR S, RAI SK AND KALLOO G (2003). Genetics of fertility restoration and identification of restorers and maintainers in pepper (*Capsicum annuum* L). *Capsicum and Eggplant Newsletter* **22**: 79-82.

45. NAYAK BR AND NAGRE PK (2013). Genetic variability and correlation studies in brinjal (*Solanum melongena* L.). *Int J App Biol Pharma Technol* **4** (4): 211-5.

46. MITTAL SP AND THOMAS TA (1961). A functional sterile mutant in tomato variety Meeruti. *Ind J Hort Sci* **18**: 150-1.

47. KRISHNAMURTHY S AND SUBRAMANIAN D (1954a). Some investigations on the types of flowers in brinjal (*Solanum melongena* L.) based on the style length and fruit set under natural conditions. *Ind J Hort* **11** (2): 63- 8.

48. CHOUDHURY B AND PATHAK SC (1959a). Sex expression and sex ratio in cucumber (*Cucumis sativus* L.) as affected by plant growth regulator sprays. *Ind J Hort* **16** (3): 162-9.

49. CHOUDHURY B AND PATHAK SC (1959b). Sex expression and sex ratio in cucumber (*Cucumis sativus* L.) as affected by gibberellin. *Ind J Hort* **16** (4): 233-5.

50. SINGH HB, RAMANUJAM S AND PAL BP (1948). Inheritance of sex forms in *Luffa acutangula* Roxb. Nature (London) **161**: 775-6.

51. AGARWAL JS, KHANNA AN AND SINGH SP (1957) Studies on floral biology and breeding of Momordica charantia Linn. *Ind J Hort* **14** (1): 42–8.

52. VIJAY OP, SINGH DP AND YADAV IS (1979). Studies on floral development, fruit maturity and floral biology in sweet pepper (*Capsicum annuum* L). *Veg Sci* **6**: 5-10.

53. CHOWDHURY B (1958). Development of seed and its parts of *Lycopersicum esculantum*. *Ind J Hort* **15** (2): 72-5.

54. DUBEY DK (1963). Longevity of *Linum grandiflorum* Desf. pollen and comparison of three tests for pollen viability. *Agra Univ J Res* **12**: 69.

55. DUBEY DK AND SINGH SP (1965). Mechanism of pollen abortion in three

male sterile lines of flax (*Linum usitatissimum* L.). *Crop Sci* **5**: 121.

56. BREWBAKER JL AND MAJUMDAR SK (1961). Cultural studies of the pollen population effect and the self-compatibility inhibition. *Am J Bot* **48**: 457-64.

57. DHALIWAL MS. AND LAL T (1996). Genetics of some important characters using line x tester analysis in muskmelon. *Ind J Genet* **56** (2): 207-16.

58. NANDAKUMAR PBA AND SHIVANNA KR (1993). Intergeneric hybridization between *Diplotaxis siettiana* and crop brassicas for the production of alloplasmic lines. *Theor Appl Genet* **85**: 770-6

59. NANDAKUMAR PBA, PRAKASH S AND SHIVANNA KR (1988). Wide hybridization in Brassica: crossability barriers and studies on the hybrids and synthetic amphidiploids of *B. fruticulosa x B. compestris*. *Sexual Pl Reprod* **1**: 234-9.

60. VYAS P, PRAKASH S AND AND SHIVANNA KR (1995). Production of wide hybrids and backcross progenies between *Diplotaxis Erucoides* and crop brassicas. *Theor Appl Genet* **90**: 549 -53.

61. SARLA N AND RAUT RN (1988). Synthesis of *Brassica carinata* from *Brassica x Brassica oleracea* hybrids obtained by ovary culture. *Theor Appl Genet* **76**: 846-9.

62. SREE RAMULU K (1982). Genetic stability at the S-locus of *Lycopersicon peruvianum* plants regenerated from in vitro culture of anthers: generation of new S-specificities and S-allele reversions. *Heredity* **49**: 319-30.

63. KALIA P (2009). Genetic improvement in vegetable crucifers. In: Gupta S.K. (Ed.), Biology and breeding of crucifers. CRC Press, Boca Ratón, pp. 310-30.

64. SINGH S AND SAWHNEY VK (1992a). Cytokinins in a normal and the ogura (ogu) cytoplasmic male-sterile line of rapeseed (*Brassica napus*). *Pl Sci* **86** (2): 147–54.

65. SINGH S AND SAWHNEY VK (1992b). Plant hormones in *Brassica napus* and *Lycopersicon esculentum* pollen. *Phytochem* **31**: 4051–3.

66. BAJAJ YPS (1983c). Regeneration of plants from pollen-embryos of *Arachis, Brassica* and *Triticum* sps. cryopreserved for one year. *Curr Sci* **52**: 484–6.

67. SINGH S (1950). Behaviour studies of honeybees in gathering nectar and pollen. *Mem Cornell Univ Agric Exp Stn* **288**: 1-57.

68. SINGH S (1954). Insect Pollinators and the Breeding of Fruit Varieties. *Ind J Hort Sci* **11**: 123-5.

69. CHATTERJEE SS AND SWARUP V (1984). Self-incompatibility in Indian Cauliflower. *Cruciferae Newsl* **9**: 25-7.

70. ANONYMOUS [1952]. *Annual Scientific Report*, IARI, Regional Station, Katrain [Kulu Valley], H.P. pp: 1-4.

71. RAO MG AND SURYANARAYANA MC (1988). Studies on pollination of watermelon [*Citrullus lunatus* (Thumb.) Mansf]. *Ind Bee J* **50**: 5-8.

72. SHARMA PL AND SHARMA BR (1968). Role of insects in the pollination of *Daucus carota* (carrots) and *Beta vulgaris* (sugar beet). *Ind J Hort* **25** (3&4): 216.

73. SINHA SN AND CHAKRABARTI AK (1980). Bee pollination and its impact on cauliflower seed production.

Proceedings of Second International Conference on Apiculture in Tropical Climates, IARI, New Delhi.

74. ANONYMOUS (1997-98). *Annual Scientific Report*, IARI, Regional Station, Katrain (Kullu Valley), H.P. pp. 1&5.

75. PATHARE SB, LAWANDE KE AND SHINDE KG (1995). Effect of Pollination Devices and Covering Materials on Hybrid seed yield of Brinjal. *J Maha Agric Uni* **20** (3): 398-9.

76. KUMAR SANJEET, KUMAR SUDHIR, RAI SK, KUMAR VIRENDRA AND KUMAR RAJESH (2002). Considerable amount of natural cross-pollination on male sterile lines of chili (*Capsicum annuum* L). *Capsicum and Eggplant Newsletter* **21**: 48-51.

77. KANWAR JS AND GILL BS (2000). Natural cross pollination and pollen dispersal studies in brinjal. *Veg Sci* **27** (2): 145-7.

78. CHANDRA SEKHAR KN AND SAWHNEY VK (1990). Regulation of the fusion of floral organs by temperature and gibberellic acid in the normal and solanifolia mutant of tomato *(Lycòpersicon esculentum). Can J Bot* **68**: 713–8.

79. SAWHNEY VK (1983). The role of temperature and its relationship with gibberellic acid in the development of floral organs of tomato *(Lycopersicon esculentum). Can J Bot* ***61***:*1258–65.*

80. RASTOGI R AND SAWHNEY VK (1988). Suppression of stamen development by CCC and ABA in tomato floral buds cultured in vitro. *J Pl Physiol* **133**: 620–4.

81. BHADULA SK AND SAWHNEY VK (1987). Esterase activity and isozymes during the ontogeny of stamens of male fertile *Lycopersicon esculentum* Mill, a male sterile stamenless -2 mutant and low temperature – reverted mutant. *Pl Sci* **52**: 187-94.

82. GANGOPADHYAY S AND KAPOOR KS (1975). Sclerotinia rot of peas in Kullu valley. *Veg Sci* **3** (1): 74-8.

83. MAYEE CD (1974). Systemic local lesions of seed borne brinjal mosaic virus in some varieties of brinjal. *Curr Sci* **43**: 961-3.

84. MAYEE CD AND KHATRI HL (1975). Seed transmission of brinjal mosaic virus in some varieties of brinjal, *Ind Phytopath* **28:** 238-40.

85. GANGOPADHYAY S AND MATHUR SB (1978). Intensity of Mycoflora in Vegetable seeds in Kullu Valley. *Ind J Hort* **5**: 104-6.

86. GANGOPADHYAY S AND GILL HS (1977). Cauliflower and cabbage seed production. *Ind Hort* **22**: 7-8.

87. ANONYMOUS (1985). *Annual Scientific Report*, IARI, Regional Station, Katrain (Kullu Valley), H.P. pp. 1, 10, 24, 28, 30-2.

88. KAPOOR KS, GILL HS AND SHARMA SR (1985). A technique for artificial inoculation of cauliflower seedlings with *Sclerotinia sclerotiorum* (Lib.) de Bary. *Phytopath. Z* **112** (2): 191-2.

89. KAPOOR KS (1983). Foraging strategies and pollinating activities of *Apis cerana indica* F. and *Apis mellifera* L. on *Brassica campestris* L. var. *botrytis*. M.Sc. Thesis, HPKV, COA, Solan, India.

90. SINGH KP, MALIK YS AND LAL S (1985). Effect of date of steckling planting and spacing in radish seed crop. *Seed Res* **13** (1): 176-9.

91. ANONYMOUS (1990). *Annual Scientific Report*, IARI, Regional Station, Katrain (Kullu Valley), H.P. pp. 31-2.

92. ANONYMOUS (1986). *Annual Scientific Report*, IARI, Regional Station, Katrain (Kullu Valley), H.P. pp. 1&51.

93. ANONYMOUS (1991). *Annual Scientific Report*, IARI, Regional Station, Katrain (Kullu Valley), H.P. pp. 3-5.

94. ANONYMOUS (1993). *Annual Scientific Report*, IARI, Regional Station, Katrain (Kullu Valley), H.P. pp. 4&8-9.

95. MOTE UN (1975). Seasonal Fluctuation in Population and Chemical Control of Chilli Mites (*Polyphagotarsonemus latus* BANKS). *Veg Sci* **3** (1): 54-60.

96. BARWAL RN (1983). Natural enemies of greasy cut worm, *Agrotis ipsilon* Hafner (Noctuidae: Lepidoptera) in Manipur. *Sci Cul* **49**: 407-8.

97. LEELA D (1987). Weed control in herbicides in Knol-kohl and radish. *Tropical Pest Management* **33** (3): 274-9.

98. CHANDRA SINGH DJ AND GUPTA KM (1978). Studies on the use of Glyphosate in control of nut grass in Bhindi and cotton. *Abstract of paper ISWS/TNAU.* Weed Science Conference, Coimbatore.

99. VASHISTHA RN, PANDITA ML AND SINGH K (1974). Weed control studies in okra. *Ind J Weed Sci* **6** (2): 65-9.

100. SINGH RP (1978). Comparative efficiency and selectivity of herbicides in okra. *Ind J Weed Sci* **10** (1&2): 63-71.

101. GILL BS AND GILL SS (1995). Hybrid seed production through natural open pollination in chilli (*Capsicum annuum* L.) *J Appl Seed Prod* **13**: 37-8.

102. MALIK YS, SINGH NARENDRA AND NEHRA BK (1999). Effect on planting time, bulb cut and pinching of bolt treatments on yield and quality of seed. *Veg Sci* **26** (2): 143-5.

103. BHAT KL AND DHAR RK (1999). Effect of N&P on seed yield ofokra. *Veg Sci* **26** (1): 89-90.

104. JANA JC, THAPA U AND MAITY TK (1999). Green and seed Yield of Palak (*Beta vulgaris* L. var. *bengalensis*) as affected by Nitrogen fertilization and cutting management. *Veg Sci* **26** (1): 61-3.

105. JADHAO BL, KULWAL V AND MAHAKAL KG (1999). Effect of N, P and K on growth and seed yield of radish (*Raphanus sativus* L.). *Veg Sci* **26** (1): 95-6.

106. SONWALKAR MS (1951). A study of jackfruit seeds. *Ind J Hort* **8** (2): 27-30.

107. SINGH BP, DADLANI SA AND MITTAL SK (1972). Try this Meetha Karela. *Ind Hort* **15** (3): 24.

108. PALANISAMY V, KUMARESAN K, JAYABHARATHI M AND KARIVARTHARAJU TV (1982). Studies on seed development and maturation in annual moringa. *Veg Sci* **12** (2) 74-8.

109. NASKAR SK AND GHOSH PK (1995). A comparison of matings for estimating seed setting in sweet potato. *Veg Sci* **22** (1): 52-4.

110. KOHLI UK AND SAINI SS (1985) Jerusalem artichoke (*Helianthus tuberosus*) a tuberous vegetable, cultivation and cultural practices. *Ind Hort* **29** (4): 5.

111. SINGH HB (1963). Plant introduction-past and present. *Ind Fmg* **12**: 33-40.

112. SINGH JP, GILL HS, AHLUWALIA KS AND KALDA TS (1963). Asahi Yamato can thrive in Hills too. *Ind Hort* **8** (1): 8.

113. SINGH HB (1963). Carrot and Turnip Varieties Pusa Kesar and Pusa Kanchan. *Ind Hort* **7** (4): 21.

114. CHOUDHURY B AND SIROHI PS (1975). Pusa Chetaki- an early maturing profitable radish. *Ind Hort* **19** (4): 15-6.

115. CHOUDHURY B, SIROHI PS AND SHARMA JC (1988) Pusa Sweti – an early maturing tropical turnip. *Ind Hort* **38**: 6.

116. ANONYMOUS (1997). *Annual Scientific Report*, IARI, Regional Station, Katrain (Kullu Valley), H.P. pp. 2-3.

117. TIWARI RN, CHOUDHURY B AND PACHAURI DC (1990). Pusa Sheetal can set fruit at low temperature. *Ind Hort* **40**: 4-5.

118. ANONYMOUS (2001-02). *Annual Scientific Report*, IARI, Regional Station, Katrain (Kullu Valley), H.P. pp. 2.

119. ANONYMOUS (1997). *Annual Scientific Report*, IARI, Regional Station, Katrain (Kullu Valley), H.P. pp. 1, 10, 24, 28, 30-2

120. SINGH, BRAHMA, K.L. JADHAV AND ELI PALJOR (1997). Potentials of cabbage seed production in Leh Valley. *Ind Hort* **41** (4): 36-7.

121. KALLOO G, BANNERJEE MK, KUMAR S AND PARKASH C (1998). Hybrid Vegetable technology in India- an overview. In: *Souvenir, Nat Symp On Emerging Scenario in Vegetable Research and Development*, PDVR, Varanasi, pp. 42-52.

122. ANONYMOUS (2003). *Annual Scientific Report*, IARI, Regional Station, Katrain (Kullu Valley), H.P. pp. 5.

123. SHARMA SR, GILL HS AND BHAGCHANDANI PM (1987). Brown Spanish- A Long Day onion for the Hills. *Ind Hort* **32** (3): 17.

124. ROY CHOWDHURY K (1957). Extracting the tomato seed. *Ind Hort* **2**(1): 5-6.

125. YADAV SK, KUMAR PR AND NEGI HCS (2004). Comparison of different methods of tomato seed extraction. *Seed Res* **32** (2): 160-2.

126. SINGH H AND SIDHU AS (1985). Effect of fruit maturity and water soaking of cut fruits on seed germination of brinjal (*Solanum melongena*). *J Res PAU* **22** (3): 449-52.

127. NANDPURI KS, SINGH S AND LAL T (1974a). Combining ability studies in muskmelon. *Pb Agri Univ Res* **11**: 225-9.

128. NANDPURI KS, SINGH S AND I AL T (1974 b). Study on the comparative performance of F_1 hybrids and their parents in muskmelon. *Pb Agri Univ Res* **11**: 230-8.

129. NANDPURI KS, LAL T AND SINGH S (1983). Line x tester analysis of combining ability in muskmelon. *Pb Agri Univ Res* **20**: 29-38.

130. MISHRA JP AND SHESHADRI VS (1980). Studies on heterosis in muskmelon. *Veg-Sci* **7**: 27-40.

131. MISHRA VP AND SHESHADRI VS (1988). Male sterility in muskmelon. I. Studies on combining ability. *Ind J Genet* **48** (3): 347-54.

132. NANDPURI KS, SINGH S AND LAL T (1982). Punjab Hybrid-A new variety of muskmelon. *Prog Farm* **18**: 3-4.

133. DHILLON NPS (1994). F_1 hybrid seed production in muskmelon management of male sterile population. *Seed Sci Technol* **22** (3): 601-5.

134. MISHRA JP (1981). Studies on male sterility in muskmelon. Ph.D. Thesis, CSAUAT, Kanpur, India.

135. MORE TA, SHARMA JC AND SHESHADRI VS (1982). A note on pollination studies in muskmelon. *Sci Cul* **48**: 177-9.

136. MORE TA, SHESHADRI VS AND SHARMA JC (1980). Monoecious sex expression in muskmelon. *Cucurbit Genet Coop Report* **3**: 32-3.

137. BAINS MS AND KANG US (1963). Inheritance of some flower and fruit characters in muskmelon. *Ind J Genet* **23**: 101-6.

138. SHESHADRI VS, MISHRA JP, SHARMA JC AND MORE TA (1983). Heterosis breeding in melons problems and prospects. *South Ind Hort* (Special Vol.) **30**: 74-82.

139. MORE TA, SHARMA SC AND MISHRA JP (1991). Per significant estimates performance of gynoecious muskmelon hybrids. In: Golden Jubilees Symposium on Genetic Res. And Education: Current Trends and Next Fifty Years (of ISGPB), New Delhi, Feb. 12-15, pp. 610-1.

140. PETERSON CE, OWENS KW AND ROW PR (1983). Wisconsin 998 muskmelon germplasm. *Hort Sci* **18**: 116.

141. LAL T AND DHALIWAL MS (1993). Performance of selected muskmelon hybrids over environments. In: Symp. on Heterosis Breeding in Crop Plants: Theory and Application, Ludhiana, India. pp. 34-5.

142. MORE TA, SHARMA SC AND MISHRA JP (1991). Per significant estimates performance of gynoecious muskmelon hybrids. In: Golden Jubilees Symposium on Genetic Res. And Education: Current Trends and Next Fifty Years [of ISGPB], New Delhi, Feb. 12-15, pp. 610-1.

143. MORE TA AND SHESHADRI VS (1987). Maintenance of gynoecious muskmelon with silver thiosulphate. *Veg Sci* **14**: 138-42.

144. LINGARAJ DS. AND SRINIVASAN KM (1967). A note on cycocel, a new released plant growth regulator. *Curr Sci* **36**: 215-6.

145. BRAR JS AND KAUL DL (1971). The influence of spacing and the date of steckling planting on seed production in radish. *J Res Punj Agri Univ* **8** (4): 416-9.

146. NAUTIYAL MC AND LAL H (1982). Effect of spacing and plant regulators on seed production of radish. *Veg Sci* **9** (2): 85-8.

147. MEHTA AK, SINGH RP AND LAL G (1989). Effect of concentrations and methods of applications of Dichlorophenoxy acetic acid on yield, fruit quality and seed quality of tomato (*Lycopersicon esculentum* Mill.). *Veg Sci* **16** (1): 1-8.

148. KUMAR PR, SINGHAL NC AND SINGH RAM (2000). Effect of Different Curd Cutting Methods on Seed Production of Cauliflower (*Brassica oleracea* L. var. *botrytis*), *Seed Res* **28**(2): 136-9.

149. SINGH B, JADHAV KL AND PALJOR ELI (1997). Potentials of cabbage seed production in Leh Valley. *Ind Hort* **41** (4): 36-7.

150. SAMBANDAMURTHI S AND SUNDARAM K S (1989.) A note on seed production in cabbages under Kodaikanal conditions. *South Ind Hort* **37** (3): 183-5.

151. PUSHKARNATH (1967). Seed potato production in the sub-tropical plains of India. *American Potato J* **44** (12): 429-41.

152. KANWAR HS, KOHLI UK AND SINGH RAVINDER (2000). Effect of compactness on bolting and seed yield of cabbage (*Brassica oleracea* var. *capitata* L). *Veg Sci* **27** (2): 203-4.

153. KAPOOE SL (1950). The role of type seed in the culture of potato I. Influence of size of seed piece on growth yield and grade of potato. *Ind J Hort* **7** (1): 25-9.

154. KITTO SK AND JANICK J (1982). Polyox as an artificial seed coat for a sexual embryos. *Hort Sci* **17**: 448.

155. BHATTI MS, PERCIVAL TC, DAVAEY M AND HEUSHAN GG (1997). Cryopreservation of embryogenic tissue of a range of genotypes of sweet potato (*Ipomea batata*) using an encapsulation protocol. *Pl Cell Rep* **16** (11): 802–6.

156. JAYANTHI S (1999). Studies on synthetic seed in sweet potato (*Ipomea batata* L). *M.Sc. Ag. Thesis* TNAU, Coimbatore.

157. LAKSHAMI S (2001). Studies on synthetic seed production in cassava (*Manihot esculenta* Crantz.) *Ph. D. thesis* TNAU, Coimbatore.

158. DAYAL TR (1981). Study of heterosis in potato (*Solanum tuberosum* L.) and the use of some induced tetraploids for its exploitation. *Ph.D. Thesis*, Agra University, Agra, India.

159. UPADHYAY MD, THAKUR KC, JUNEJA A AND KADIAN MS (1984). True potato seed production: Flowering Quality and Economics. In: Innovative Methods for Propagating Potatoes- *Report of the 28th planning Conference, International Potato Centre (CIP)*, Lima, Peru. pp. 117-47.

160. THAKUR KC (1987). Studies on the development of true potato seed technology. *Ph.D. Thesis*, H.P. University, Shimla, India. pp. 345.

161. THAKUR KC AND UPADHYAY MD (1990). Extraction and processing of true potato seed. *Seed Sci Technol* **18**: 589-96.

162. KUMAR PR, YADAV SHIV K, SHARMA SR, LAL SK AND JHA DN (2009). Impact of climate change on seed production of cabbage in north-western himalayas. *World J Agri Sci* **5** (1): 18-26.