ADVANCES IN QUALITY SEED PRODUCTION OF VEGETABLE CROPS

(6th to 26th September 2017)

Organized by:

CENTRE OF ADVANCED FACULTY TRAINING IN HORTICULTURE (VEGETABLES)
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Vegetables are a rich source of carbohydrates, proteins, fats, vitamins and minerals, along with roughages which are essential constituents of balanced diet. Vegetables also contain significant amounts of biologically active components that provide health benefits through their antioxidant properties. The dieticians advocate an intake of 300 g of vegetables everyday to make our diet balanced. However, daily per capita consumption of vegetables in our country is 200 g which is lower than the recommended quantity. Our demand for vegetables will be 225 m tonnes by 2025, and 350 m tonnes by 2050. In order to ensure food and nutritional security, there is an urgent need to augment the production of vegetables in India.

Seed is one of the most critical inputs for enhancing crop productivity. Quality seed acts as a catalyst for realizing the potential of all the inputs such as fertilizers, irrigation and pesticides. Use of quality seeds alone could increase vegetable production by 15-20 per cent. The farmers also save large quantities of seed for vegetable production.

Therefore, the topic entitled, “Advances in Quality Seed Production of Vegetable Crops”, chosen for the present training course under the Centre of Advanced Faculty Training in Horticulture (Vegetables), is highly relevant for deliberating on modern techniques in vegetable seed production.

I am sure that the lectures delivered by the faculty of this university and the invited guest speakers of various organisations besides practical demonstrations in the experimental farms and laboratories made during the training course will enrich the technical knowhow of the participants in developing high yielding varieties of vegetables, and crop management for quality production, use of DNA markers for testing genetic purity of seeds, DUS and IPR issues and marketing of seed. The compilation of the lectures in the form of compendium will also be of great value in strengthening the teaching programmes in different institutions. The faculty of the Department of Vegetable Science has done a commendable job in conducting this training programme professionally and systematically, and I am sure that this information will be highly useful to the stakeholders in future.

(Hari C Sharma)
Vice Chancellor
ACKNOWLEDGEMENTS

Vegetables are the mainstay of farmers in the hilly regions. Growing vegetables has become major occupation of farmers because of off-season produce and high prices in the market. There are also ample opportunities to produce temperate vegetables and their quality seed, which is not only improving the economy of the growers but also adding to the state exchequer annually. To remain competitive in the national and international market in vegetables, quality produce is going to be the watchword. The possibilities and exploitation of heterosis in temperate vegetables have special significance because the growing population needs nutritional security which can be complemented by more vegetable production viz-a-viz consumption. Hybrid varieties are the only option in increasing production and productivity alongwith their quality seed production. In this context, the present training programme organised by the Centre of Advanced Faculty Training in Horticulture (Vegetables) [CAFT] on “Advances in Quality Seed Production of Vegetable Crops” is important as it will sharpen the focus on quality seed production of vegetable crops besides multiplication of productivity. The CAFT gratefully acknowledges the patronage provided by Dr Hari C Sharma, Hon’ble Vice Chancellor of this University. The financial assistance received from the Indian Council of Agricultural Research in conducting the training and generating useful instructional material alongwith assistance for need based post-graduate research is highly acknowledged. The Centre also appreciates sincere efforts of all the speakers for enriching the knowledge of participants especially in the field of quality seed production. All the faculty members and staff of the Department of Vegetable Science, Deans, Directors and other statutory officers deserve special thanks for their cooperation and support provided for the successful conduct of this training programme.

(H S Kanwar)
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Current status of vegetable seed industry in India and future prospects

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Introduction

Seed is a key component among all inputs for sustainable crop production. It is estimated that quality of seed accounts for 20-25% of productivity. The importance of quality seed has been realized by mankind long ago. The need for a good viable seed for prosperity of human race is mentioned in *Rigveda* of ancient India. It is mentioned in the Primeval Manusmriti as “SubeejamSukshetreJayateSampadyate” which literally means “A good seed in a good filed will win and prosper”. Albeit there have been few private seed industries dealing with production of vegetable seeds, the growing of crops especially for seeds in an organized fashion to maintain quality in terms of genetic and physical purity is realized for first time during green revolution period with the establishment of National Seeds Corporation (NSC) in 1963. It is setup by aiming at promoting healthy development of seed industry in India. The principle responsibilities of NSC are establishing an adequate system of quality control inspection for scientific processing, storage and marketing of seeds. Currently there are about 850 seed companies (mostly seed producers) operating in India in 2014, of which about 50 have capacity in crop breeding research. It also undertakes the responsibility of multiplication of seed of pre released varieties and production of foundation seed of varieties. The SRR in vegetable crops has gone from 20 percent in eighties to >90 percent.

At present the total Indian traded seed market is Rs. 20,000 crore. Out of this total vegetable seed market including Open Pollinated varieties is Rs. 4000 crore. Out of 110 hybrids released by AICRP, 60 percent are from Pvt.
Indian seed Industry is currently occupying the 5th position. During the past 5 years the Indian Seed Industry has been growing at a CAGR of 12% compared to global growth of 6.7%. Few milestone events in seed policy by Govt. of India are below.

1. The Seeds Act, 1963 
2. National Seeds Project 
3. New Seeds Policy, 1988 
4. PPV & FRA, 2001 
5. The Seeds Bill, 2004 

The overall market value of the global vegetable seed market increased roughly 6% from 2009 to 2010 to an estimated $4 bn USD. With continued growth and new shifts occurring within regions and production practice, the industry required accurate and applicable data to market effective and critical decisions. The global seed sector outlook 2025 for major vegetable crop spices such as Brassica (Cabbage, cauliflower, broccoli), cucurbits (Muskmelon, watermelon, cucumber, squash), corn (Baby corn, sweet corn), Legumes (Pea, beans), leafy vegetable (Lettuce, spinach), Root – Bulb (Carrot, radish, onion), and Solanaceae (Pepper, eggplant, tomato) is a dynamic capture of semi-annual long range (10-15 year) forecasting data for global vegetable seed market. These crops provide a unique perspective of a complex global sector of agriculture with significant growth opportunities. The Indian seed industry is the fifth largest seed market in the world, accounting for 4.4% global seed market after the US (27%), China (20%), France (8%) and Brazil (6%). In terms of global trade, India is self-sufficient in seed of vegetable, flower, fruit and filed crops. It is expected that market size of Indian seed will grow at a rate of 11% per annum to $3.2 bn till 2016 financial year on account of governments continued focus on improving seed replacement rate.

Vegetable seeds are the fastest growing category within the overall seed market. Vegetable play a major role in proving an affordable balanced died.
Globally, vegetable seeds market has grown consistently over the past 5 years on account of rising worldwide population, expanding middle class and shifting eating habits with growing consumption of green vegetables in the diet.

**Potential of vegetable seed production in India**

India is endowed with several advantages making it competitive for production of open pollinated varieties and hybrid vegetable seeds for domestic and foreign companies and meeting domestic and international seed quality standards. With the liberalization of seed policy in 1988 in India, the private companies grew fast and currently, there is a 60:40 ratio between the private and public sector. There are more than 200 private seed companies of which over 30 percent have global partners. The role of 13 state-owned corporations has declined and they now deal with government notified products. Vegetable seeds account for about 18 percent of the total production of certified seeds. In the public sector, there are 15 state seed corporations, 22 state seed certification agencies and 104 state seed testing laboratories in addition to the National Seed Corporation of India.

With low cost labor availability and environment suitability for quality, vigorous and bold seed production, all kinds of vegetable seeds can be produced in India for domestic and export markets which will not only save foreign exchange but earn it besides empowering rural poor with skills, generate employment and income. Private sector instead prefers to import than to empower and develop entrepreneurship among our own small holder farmers.

**Global Perspective**

High quality seed production and export is the best choice, since it does not require additional investment by the government. Seed industry can expand on its own, both in domestic and export trade, once we have market-friendly regulations and encourage more investigation. In future, the vegetable seed sector is expected to be active and dynamic with hybrid varieties developed indigenously for domestic markets and commercial farmers and superior open
pollinated varieties produced for the benefit of marginal farmers and homestead gardens.

**PVP pattern in public sector**

India’s Plant Varieties and Farmers’ Rights (PPV&FR) Act of 2001, the establishment of the PPV&FR Authority in 2005, and the commencement of varietal protection application processing in 2007 have helped to some extent in providing the IPR environment needed to incentivize private investment in the seed sectors. The objective of this legislation was to provide an effective system for the protection of farmer's rights which would also stimulate investment for research and development both in public and private sector for the development of new plant varieties by ensuring appropriate returns on such investments. In total, about 1700 varieties developed by the ICAR were eligible for registration under PPVFRA, but only about 50 per cent of these varieties were protected.

**Factors promoting vegetable seed industry in India**

1) Ever Increasing Demand  
2) Varied Agro Climatic Conditions  
3) Cheap labour availability  
4) Vast Domestic and International market

**Influence of vegetable seed industry on economy**

1) Income generation  
2) Employment generation  
3) Foreign Exchange Earning
Role of Public & Private Seed Sector

The private sector has started to play a significant role in the seed industry over the last few years. At present, the number of companies engaged in seed production or seed trade is of the order of 400 or 500. However, the main focus of private seed companies has been on the high value low volume seeds and market for low value high volume seeds of cereals, pulses and oilseeds is still dominated by the public sector seed corporations. Private sector companies have a significant place mainly in the case of maize and sunflower and cotton. However, in the case of vegetable seeds and planting materials of horticultural crops, the private sector is the dominant player. As the private sector has not been enthusiastic about entering into seed production of high volume low margin crops of wheat, paddy, other cereals, oilseeds and pulses, the public sector seed corporations will continue to remain dominant in cereals, pulses and oilseeds for many more years to come. At present 15 State Seeds Corporation and 2 National level seeds Corporations.

Constraints in vegetable seed industry

1) High Cost and Vague Market Demand
2) Perishable Nature of Seed
3) Problems linked with contract farming
4) Climate, Pest and Disease related problems
5) Stringent seed policies and laws

Conclusion

- Vegetable seed business will ever have huge scope to success and will play an important role in economy in countries like India
- Making available quality seeds to the farmers in time and in sufficient quantity at reasonable prices
- Policy making and implementations shall be free from political motivations
Strengthening of public sector in R&D is needed to compete with private seed companies so as to provide good quality seeds to the farmers at cheaper rates

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Advances in Quality Seed Production of Onion

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Onion (Allium cepa L.) belongs to family Alliaceae and thought to have ancestors in Central-Asia. Physiologically onion is a long day plant, but due to suitability for cultivation to specific photoperiod and temperature, it is classified into temperate long, intermediate and short day and, tropical short day bulb, shallot and multiplier groups.

It is mainly grown for bulb, which is used almost daily in every home. Its main use is due to its aromatic, volatile oil ally-propyl disulfide that impart cherish flavor to the food. Worldwide onion is grown on 43.64 lakh ha with 863.44 lakh tonnes production and 19.79 t/ha productivity. In last decade 53.49 % increase in area, 72.87 % in production and 12.63 % in productivity are the indicators of onion growth on the globe. India ranked first in area (12.03 lakh ha) and second in production (194.02 lakh tonnes) of onion in the world. Though, onion production in India has increased by 300 % in last two decades, but country requires 211 lakh tonnes onion by 2050 with present rate of consumption (6.7 kg per/capita), export (9 %), processing (6.75%) and losses (20 %). If export and processing is increased by 25 and 9 %, respectively, then 286 lakh tonnes onions would be required which can be achieved by increasing productivity to 28 t/ha or by expansion of area under onion. Among the reasons for lower productivity of onion in India; availability of quality seed is one of the major ones.

Status of requirements and supply of quality seed of onion in India

Seed is the basic input and contributes one-third in total productivity of the crop. The genetic purity is of more concern in this highly cross-pollinated and entomophilous crop for maintaining the uniformity of colour, size, shape
and maturity; tolerance to bolting, splitting, non-bulbing and insect-pests; longer storability. The annual onion seed requirement of the country is about 9600 tonnes @ 8.0 kg ha\(^{-1}\), besides 20 % additional stock required to cover poor germination, storage losses and as buffer stock. In this, 8% is supplied by the public sector organizations, 9% by the private seed companies, 13% by private traders and rest 70% by the farmers from their own saved seed. Thus, a big gap is there between the availability of improved varieties seed and the requirement. To cope this gap holistic planning is needed for production of breeder, foundation, certified and truthfully labeled seed by identifying areas for bulb and seed production of recommended varieties for different regions and for export. The objective should be to replace at least 50% area under improved varieties in the next ten years.

**Varieties:**

In India, the short day types of onion is cultivated on large scale in the northern plains, central and southern part of the country except higher hills where the long day types onion varieties like Brown Spanish and Yellow Spanish etc. are grown over a limited area.

**Climatic requirement and potential areas for seed production**

Onion seed production requires dry and moderate sunny days (18-25 °C) with cool nights (4-14 °C) at flowering and seed setting stage. During flowering, seed development and maturity excessive rainfall and very cool conditions are undesirable as they lead to disease development and poor seed setting. Good sunshine at the time of full blooming stage will facilitate the activity of beneficial insects for higher rate of cross pollination and seed set. The relative humidity should be lower at the time of seed development.

Accordingly, some of the areas considered suitable for onion seed production are Saurashtra in Gujarat; Nashik, Ahmednagar, Satara and Marathwada in Maharashtra; Khargaon, Indore and Dharin Madhya Pradesh; Jaipur, Chittorgarh, Udaipur and Sriganganagar in Rajasthan; Kurnool in
Andhra Pradesh and northern Karnataka. However, northern state like Punjab, Haryana and Rajasthan are not preferred by the seed industry due to untimely rains causing high humidity coupled with high temperature during flowering, seed development and maturity which leads to perpetuation of fungal diseases like stemphylium and purple blotch and lower seed yield.

**Land requirement**

Land to be used for seed production of onion should be free from volunteer plants. Although onion can be grown nearly in all types of soil from sandy loam to heavy clay soil, but clays are not satisfactory unless well supplied with humus to lighten them. The soils pH should preferably be 6.0-6.8.

**Isolation;**

Onion seed field shall be isolated from contaminants viz; fields of other varieties and the fields of the same variety not confirming to varietal purity requirement for certification at least 5 m for foundation seed and certified seed during mother bulb production and 1000 m and 500 m, respectively during seed production.

However, the maximum permissible limit for bulb not confirming to the varietal characteristics is 0.10 percent and 0.20 percent (by numbers) for foundation and certified seed during mother bulb production. The maximum permissible limit of off- types is 0.1% and 0.2% for FS and CS at and after flowering during seed production. Onion seed crop must also be isolated from any flowering multipliers types of onion and shallots.

**Method of seed production**

There are two methods of seed production. The seed to seed and bulbs to seed methods and both the methods are in use in onion seed production. But bulb to seed method is most commonly used method of seed production.
Seed to seed method
In this method seedlings are transplanted in first week of October and allow over-wintering at the same place and allowing bolting (flowering).

Merits
- Low-cost method of seed production
- Early maturity
- No need to store the bulbs.

De-merits
- It doesn’t allow the examination of true to typeness of the onion bulb and rouging of off types and diseased and multicentre bulbs.
- 2ndly, all the variety are not suitable for annual seed production due to poor bolting habit.
- Seed yield is low.
- Since, the genetic purity of the seeds produced from this method is usually poor, the seed produced is not suitable for further multiplication, only bulb crop for fresh consumption can be produced.

Bulb to seed method
The seed of onion is sown in October-November and seedlings are transplanted in December-January. The bulbs are ready by April end to mid May. The selected bulbs are stored up to mid-October and planted in well-prepared fields.

Merits
- Offers options of selection of true-to-type bulbs of good size, uniform, typical color, free from diseases and physical damages.
- Higher yield is obtained.
- Since, this method allows selection of true-to-type bulbs, gives genetically pure seed suitable for further multiplication.

De-merits
- It takes more time (one and half years)
- Losses of onion bulbs during storage
- Cost of seed production is more
**Selection and planting of bulbs**

Based on the colour, shape and size of the bulb and confirming to varietal characters, bulbs should be selected for planting. The bulb weight has markedly influenced the seed production. The increase in bulb weight will increase the seed yield. Bulbs weighing 50 to 80 gm and measuring 4-6 cm in diameter should be selected for planting. About 25-30 quintal bulbs are required to plant one hectare area or one hectare of bulbs from the first year will plant 3-5 hectares for seed production. Large sized bulbs may give seed yield upto 10.0 q/ha.

Bulbs can be planted in double row or single row per ridge. Onion producers mostly use single row per ridge with 50 cm between row and 20 cm between plants. The recommended spacing is 45 x 45 or 30 cm between bulbs for surface irrigation and 60 x 20 cm under drip.

**Planting time**

The best planting time under northern plains is October-end or November. If planting is done early, the crop gets damaged from rain which comes in March/April. If late planting is done, vegetative growth is less and due to this, there is lesser number of seed scape and flowers or seeds per umbel. The bulbs used in seed production should have been produced in recommended regions of the variety for maintaining the genetic stability.

**Flowering**

Flowering induction is sensitive to temperature, photoperiod and number of leaves. Optimum temperatures required for vernalization are 7-12 °C. In the tropics, cultivars generally are vernalized even at temperature as high as 15-21 °C. For the flower induction, onion plants must have 5-9 leaves and bulb diameter from 10-15 mm. Plants at a younger juvenile stage do not respond to temperature. The larger the bulb size, the more easily it is to induce flowering.
**Floral biology and pollination**

Anthesis occurs in early morning (6-7 hrs). Anther dehiscence is between 7.00 and 17.00 hr and on next day also with peak between 9.30 and 17.00 hr, however, pollen fertility and stigma receptivity are both highest on the days of anthesis (Jones, 1933). The duration of anthesis is approximately 4 weeks on individual umbel. The anthesis begins from outer flowers and goes centrally in succession. Being a protandrous flowering crop onion requires cross pollination and for that; 4-6 honey bees boxes/hectare are suggested for enhancing seed setting percentage. Insecticides should not be applied during noon time when the beneficial insect activity is high.

**Fertilizers:**

**Recommended dose of fertilization: FYM @ 25 tons/ha, NPK @ 125:75:60 kg/ha.** Apply all FYM, P and K as basal dressing & remaining N in two splits; one at 30 days and 2nd at 45-60 days after planting. Give 1% spray of liquid fertilizer (19:19:19, NPK) at 30 & 60 days after planting & one spray of multi K (0:0:50) after 60 days of planting. During, mother bulb production, the deficiency of copper or manganese should not be allowed. The deficiency of copper is indicated by bulbs of poor colour with thin, fragile scales that come off in handling. Therefore, the application of 80-120 kg powdered copper sulphate control the deficiency.

**Irrigation**

Water stress during bulb sprouting and beginnings of the anthesis reduce the number of umbels and flowers/plant. However, in practice, the soil surface should not be continuously wet because it will predispose the crop to infection to root rot.

The methods of irrigation also greatly influence the seed yield and seed quality of onion. Tomar *et al.* (2004) observed that drip irrigation gave higher seed yield (894.94 q/ha) than the surface irrigation (648.94 q/ha) in onion cv. Pusa Madhvi. The seed vigour index was also higher in drip (876.49) than surface
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(663.71) irrigation. However, sprinkler irrigation is not recommended as it affects pollination.

Field inspection

(a) **Mother bulb production stage:** A minimum of one inspection shall be made; the inspection shall be made during the bulbs lifting to verify the true to typeness.

(b) **True seed production stage:** A minimum of two inspections shall be made as follows; At planting for isolation, volunteer plants, off types including bolters; the second inspection is at flowering; plants with differential umbel height should be removed before opening of flowers; plants affected by aster yellow and stemphyllium blight should be removed before seed harvest.

Umbel harvesting & drying

All umbels per plant do not mature at one time due to difference in the stalks to flowering; hence harvesting may take 3-4 times. Also, one could start harvesting when greater than 10 % of black seeds are exposed on an umbel; if overstayed the seed heads shatters the seeds readily in the field. Harvesting is done by hands. When heads are cut, they should be supported in the palm of hand and held between the fingers to avoid seed shattering. The harvested umbels are heaped for a few days drying before threshing the seed. But heap should not exceed 20-30 cm and should be turned each day.

Seed threshing, cleaning and drying

The dry umbels are gently mowed and winnowed to separate the seeds from chaffs. Over drying may damage the brittle seed. Seeds can also be threshed through rolling, threshing machine or combines. The cleaning is achieved with an air screen machine followed by passing through the gravity separator or by floatation. The winnowed and unclean seed be put in a bucket and soaked with clean water and left for not more than 3 minutes in the water, heavy seeds sinks
and poor quality seeds and chaffs floats. The pure seed settled in a container should be taken immediately and dried under the morning and late afternoon sun or under shade for 3-4 days; should not be dried in the sun during noon time.

**Seed Storage**

The final seed lot must be dried down to moisture content not exceeding 12% or lower depending on the method of storage and packaging. When seed has to be packed in porous containers (cloth bag/paper bag) then seed moisture should not be >8% whereas, packaging in moisture proof containers, the seed moisture should be 5-6%.

**Post-harvest managements for improved germination and vigour**

High seed germination and seed vigor are directly or indirectly related to the success of crop establishment and its further productivity. The quality seeds having good germination may help in reducing the seed rate per hectare from the existing 7-8 kg to 4-5 kg.

De-Souzaa et al., 2014 investigated the effects of pre-sowing magnetic treatments on germination, emergence, growth and yield of onion (cv.Red Creole) plants under field conditions. In field experiments, the treatments led to a significant increase in seedling emergence, root length, seedling height, seedling dry weight and leaf area per plant. Also, at the vegetative stage, the leaf and root relative growth rates of plants derived from magnetically treated seeds were greater than those of the control plants. At the bulb forming stage, bulb relative growth rates from magnetically exposed seeds were greater than those of controls. At the bulb maturity stage, all magnetic treatments significantly increased mean bulb weight, bulb yield per area, number of tunics per bulb, bulb diameter and dry bulb weight in comparison to the controls.

Since the onion seed losses its viability and vigour rapidly thus the role of seed moisture and packing material is more vital for good productivity of crops.
Accordingly, Tripathi and Lawande (2014) studied the effect of different moisture levels i.e. 5, 6, 7 and 8 percent and packing materials i.e. cloth bags, polyethylene bags, laminated aluminum bags and laminated aluminum bags with vacuum packing and stored at ambient condition for 27 months. The results indicated that germination percent and seed vigour Index were higher in seed having 5% moisture than seed having 8% moisture. Among the packing materials, lower seed germination and viability was recorded in cotton cloth bags. The seed packed in cloth bags lost their complete viability and vigour within 18 months of storage. The highest seed germination was observed in laminated aluminum bags with vacuum packing. The seed packed in aluminum laminated bags remained viable for 27 months. Among the various treatments combinations seed having 5% moisture and vacuum packed in aluminums laminated bags remain viable for longer period with percent germination was 61.7% germination 27 months of storage. The seed vigour index was also higher in this treatment than other treatments.

Abdullah et al., 2011 stored onion seeds under a wide range of temperature (5, 15, 25 and 35°C) and relative humidity (RH) (11.3, 22.5, 32.5, 43.2, 58.4, 75.3 and 84.3%) conditions for various storage periods (1, 3, 6, 9 and 12 months) and recorded seeds stored at 5°C had the highest seed germination percentage(SGP) in shortest mean germination time (MGT). whereas, seeds stored at 35°C had the lowest SGP and the longest MGT. RH up to 58.4% had no significant effect on SGP while higher levels of RH significantly lowered SGP and MGT. The highest RH levels (75 and 84%) showed an obvious decrease in seed quality by lowering SGP and increasing MGT.

Makus, 2004 inoculated onion cultivars Granex 1015Y and Terlingua with mycorrhizae through seedling at transplanting and obtained improved bulb yields and accelerated maturation. Bulbs from mycorrhizal-treated plants were more uniform in diameter. Further, Bulbs stored at 13.2°C for 120 days suffered less soluble solids and weight loss if they were from mycorrhizal-treated plants.
Gabriel et al., 1997 determine combined effects of the seed size (2.000, 2.375 and 2.750mm dia.) and the gravimetric classification on seed quality and yield components in onion cultivar and observed seed germination increased linearly as seed diameter was greater. Other crop variables such as plant height, commercial yield of bulbs and the percentage of bulb classes 5 and 6 also increased curvilinearly as seed diameter was greater. In the same way, the time from emergence till harvest shortened when seed diameter increased. In addition, the diameter of the bulb neck at harvesting was smaller as the seed diameter increased. According to these results, it is concluded that the performance on onion can be improved classifying the seed lots regarding the seed diameter.

**Inset-pest and diseases management**

Among the diseases, purple-blotch, Stemphyllium-blight and Anthracnose causes severe losses, whereas, downy mildew prevalent in temperate regions and, pink-rot and *Fusarium* basal-rot also cause damage in onion growing areas. The severity of the diseases is influenced by the seasonal effect, variety and growing conditions.

**Purple blotch** (*Alternaria porri*)

It requires 22-25 °C temperature and 90-100% RH for sporulation and infection. It forms small, water-soaked areas on leaf or seed stalk and turns brown. The enlarged spot becomes zonate and more or less purplish. The margin is a shade of purple or red and surrounded by yellow halo that extends upwards and downwards for some distance. It can cause up to 80% yield losses under Indian conditions.

**Stemphylium leaf blight** (*Stemphylium vesicarium*)

It occurs at same time and even on same plant as of purple blotch and forms the diseases complex. Its symptoms start with small, yellow to brown purple, water soaked lesions. These lesions elongate, become spindle shaped to ovate-elongate and turn into diffusive spot, often extending to leaf tips. The spots
frequently coalesce into patches blighting leaves. As conidiophores and conidia develop on the lesions, turn light brown to tan purple at the center, and later dark olive-brown to black.

**Anthracnose** *(Colletotrichum)*

It mainly shows white sunken-oval lesions, which turns into pale yellow water soaked spots and cover whole leaf in later stage. In severe cases pseudo-stem twists and show abnormal elongation. The favorable conditions for conidia germination and infection are high humidity and 23-30°C temperature. It is more prevalent in *Kharif* crop.

**Downy mildew** *(Pernospora destructor)*

It is highly destructive under cooler and humid regions and develops white to purplish downy growth first on entire surface of the older leaves. The affected parts become pale-green, yellow and collapse. The fungus requires cool moist nights and moderately warm days for best development. The conidia produced in humid atmosphere between 4-25°C with optimum at 13°C. Cloudy days favour most, as 8 hour of light kills the conidia.

Above fungal diseases can be managed by following clean cultivation, crop rotation, raised bed planting and proper drainage. Seed treatment with Bavistin (0.1%) and hot water (50°C for 20 min), high rates of calcium, phosphorus and potassium also reduce diseases infection. Foliar sprays of Mancozeb @ 0.25%, Tricyclazole @ 0.1% and Hexaconazole @ 0.1% effectively controls the diseases.

**Pests**

Among the large number of insects including viz. thrips, leaf miner, leafhopper, psyllid, beet army worm, curt worm, gram borer, red spider mite, onion maggot and nematodes that attack onion;

**Thrip** *(Thrip stabasci)* is wide spread and cause damage not only by feeding and oviposition, but as a vector of tospo viruses. Thrips can be managed with regular monitoring of inner-most whorl of the leaves. Thrip nymphs and adults are visible on plant, eggs laid inside the plant, while pre-pupal and pupal stages occur in the soil and debris. Time of planting, crop rotation, barrier crops,
irrigation, fertilization, intercropping, deep ploughing, weed control, reflective mulches and clean management followed for cultural control of thrip. Chemical insecticides belonging to organophosphate (malathion), carbamate(Rogor) and pyrethroid(cypermethrin) groups are widely used for controlling the trip in tropical onion.

References:
Tomar, B. S.; Singh, Balraj; Hassan, M. 2004. Effect of irrigation methods on seed yield and seed quality in onion cv. Pusa Madhavi. Seed Research. 32(1)
India is the second largest populous country after China with an estimated population of 1.31 billion. It is estimated that Indian population will be the highest (1.7 billion) in the world by 2050. In India the per capita land resources (0.121 hectare) are decreasing due to the pressure of the population growth, therefore, it is very important to enhance the production and productivity per unit area. India is the second largest producer of vegetables with annual production of 162.9 million tonnes (NHB, 2015) but as compared with China we are still far behind in production and average productivity. The higher productivity in these countries is due to the coverage of maximum area under hybrids unlike open pollinated varieties in India. The major reason for lower productivity in India can be attributed to the limited availability of high quality seeds of released hybrids. In order to increase productivity, the seed availability of released hybrids at lower price is a prerequisite. Hence, in order to feed ever growing population there is a need to enhance the vegetable productivity (17.3 MT/ha) which is less than the average world vegetable productivity (19.6 MT/ha) (NHB, 2015).

Therefore, hybrid varieties can play a vital role in increasing total production and productivity due to their high yield potential, early maturing, superior quality, disease and pest resistance. The rapid increase in productivity per unit area can be achieved by the use of quality seeds with built in inbred and hybrid vigour along with the application of improved vegetable cultivation technologies and government policies. Therefore, growing of hybrid vegetable varieties is one of the better options because the complete potential of hybrids in
vegetable crops has not been utilised. The major reason behind low productivity in vegetables and less commercialization of hybrids in India is may be due to the non availability of quality seed of released improved hybrids. The another reason could be very high cost of hybrid seed of vegetables like chilli, capsicum, tomato, cucumber, musk melon, cabbage, cauliflower etc.

**Development of F₁ hybrids in major vegetables in India:**

In India the first F₁ hybrid ‘Pusa Meghdoot’ of bottle gourd was developed by IARI in 1971. In 1973, Indo-American Hybrid Seed Company from the private sector developed its first hybrid Karnataka in tomato and Bharat in capsicum. The major emphasis has been given in the development of hybrids and their testing under the All India Coordinated Improvement Project on vegetables during mid 1980’s. This has resulted in the identification and release of several F₁ hybrids in various vegetables. There are number of F₁ hybrids developed by public sector organization are popular among farmers and seeds of these are multiplied by NSC at national and SSC at state level (Table 1).

**Table: 1 Public sector hybrids in vegetable crops**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Crop</th>
<th>Available Hybrids</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Tomato</td>
<td>Pusa Hybrid-1, Pusa Hybrid-2, Pusa Hybrid-4, Pusa Hybrid-8, Pusa Divya (Kt-4)</td>
<td>IARI, Delhi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arka Rakshak, Arka Ananya, Arka Samrat, Arka Shreshta, Arka Vishal, Arka Vardan, Arka Abhijit</td>
<td>IIHR, Bengaluru</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kashi Abhiman</td>
<td>IIHR, Varanasi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pant Hybrid-1, Pant Hybrid-2, Pant Hybrid-10, Pant Hybrid-11</td>
<td>GBPUAT, Pantnagar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rajashree, Phule Hybrid-1</td>
<td>MPKV, Rahuri</td>
</tr>
<tr>
<td></td>
<td>Crop</td>
<td>Varieties</td>
<td>Institute</td>
</tr>
<tr>
<td>---</td>
<td>--------------</td>
<td>---------------------------------------------------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>2.</td>
<td>Brinjal</td>
<td>DBHL-20, Pusa Hybrid-5 (Long), Pusa Hybrid-6 (Round), Pusa Hybrid-9,</td>
<td>IARI, Delhi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pusa Anupama (Kt-4)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Arka Navneet</td>
<td>IIHR, Bengaluru</td>
</tr>
<tr>
<td>3.</td>
<td>Chilli</td>
<td>CH-1, CH-3</td>
<td>PAU, Ludhiana</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arka Meghana, Arka Harit, Arka Sweta</td>
<td>IIHR, Bengaluru</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kashi Early, Kashi Surkh</td>
<td>IIVR, Varanasi</td>
</tr>
<tr>
<td>4.</td>
<td>Sweet pepper</td>
<td>Pusa Deepti, KTCPH-3</td>
<td>IARI</td>
</tr>
<tr>
<td>5.</td>
<td>Cucumber</td>
<td>Pusa Sanyog</td>
<td>IARI</td>
</tr>
<tr>
<td>6.</td>
<td>Bitter gourd</td>
<td>Pusa Hybrid-1, Pusa Hybrid-2</td>
<td>IARI, Delhi</td>
</tr>
<tr>
<td>7.</td>
<td>Bottle Gourd</td>
<td>Pusa Hybrid-3</td>
<td>IARI, Delhi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kashi Bahar</td>
<td>IIVR, Varanasi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pant Sankar Lauki 1</td>
<td>GBPUAT, Pantnagar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Narendra Sankar-1</td>
<td>NDUAT, Faizabad</td>
</tr>
<tr>
<td>8.</td>
<td>Muskmelon</td>
<td>Pusa Rasraj,</td>
<td>IARI, Delhi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Punjab Hybrid-1,</td>
<td>PAU, Ludhiana</td>
</tr>
<tr>
<td>9.</td>
<td>Pumpkin</td>
<td>Pusa Hybrid-1</td>
<td>IARI, Delhi</td>
</tr>
<tr>
<td></td>
<td>Vegetable Type</td>
<td>Name/Description</td>
<td>Institute</td>
</tr>
<tr>
<td>---</td>
<td>--------------------</td>
<td>-------------------------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>9</td>
<td>Summer squash</td>
<td>Pusa Alankar</td>
<td>IARI, Delhi</td>
</tr>
<tr>
<td>10</td>
<td>Watermelon</td>
<td>Arka Jyoti</td>
<td>IIHR, Bengaluru</td>
</tr>
<tr>
<td>11</td>
<td>Cauliflower</td>
<td>Pusa Kartik Sankar, Pusa Hybrid-2, Pusa Snowball Hybrid-1</td>
<td>IARI, Delhi/R.S Katrain</td>
</tr>
<tr>
<td>12</td>
<td>Cabbage</td>
<td>Pusa Cabbage Hybrid-1</td>
<td>IARI, Delhi</td>
</tr>
<tr>
<td>13</td>
<td>Carrot</td>
<td>Pusa Vasudha, Pusa Nayanjyoti</td>
<td>IARI, Delhi/R.S Katrain</td>
</tr>
<tr>
<td>14</td>
<td>Onion</td>
<td>Arka Lalima, Arka Kirtiman, Arka Bhima</td>
<td>IIHR, Bengaluru</td>
</tr>
<tr>
<td>15</td>
<td>Okra</td>
<td>Kashi Bhairav</td>
<td>IIHR, Varanasi</td>
</tr>
<tr>
<td>16</td>
<td>Ashgourd</td>
<td>Pusa Shreyali and Pusa Urmi</td>
<td>IARI, Delhi</td>
</tr>
</tbody>
</table>

**Breeding systems in vegetable crops:** The successful seed production of vegetable crops depends on knowledge of breeding system (self-pollinating, cross-pollinating and often cross-pollinating), life cycle (annual, biennial and perennial), sex form (hermaphrodite, monoecious, dioecious) and compatibility (self-fertile, self-incompatible) of these vegetable crops (Table 2).
**Table: 2 Breeding system, sex form life cycle and compatibility of Vegetable crops**

<table>
<thead>
<tr>
<th>Breeding system</th>
<th>Sex form</th>
<th>Life cycle</th>
<th>Compatibility</th>
<th>Vegetable crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-pollinating</td>
<td>Hermaphrodite</td>
<td>Annual</td>
<td>Self fertile</td>
<td>Brinjal, Chilli, Sweet pepper, Tomato, Cowpea, Lettuce, hyacinth bean</td>
</tr>
<tr>
<td>Often cross-pollinating</td>
<td>Hermaphrodite</td>
<td>Annual</td>
<td>Self fertile</td>
<td>Okra, Lima bean</td>
</tr>
<tr>
<td>Highly cross-pollinating</td>
<td>Hermaphrodite</td>
<td>Annual</td>
<td>Self fertile</td>
<td>Palak, Amaranth, Chenopodium, coriander</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Biennial</td>
<td>Self-incompatible</td>
<td>Cauliflower, cabbage, Knol-Khol, Broccoli, Brussels Sprouts, Kale, radish, Beet root, Turnip</td>
</tr>
<tr>
<td></td>
<td>Hermaphrodite</td>
<td>Biennial</td>
<td>Self fertile</td>
<td>Carrot, onion, celery</td>
</tr>
<tr>
<td></td>
<td>Hermaphrodite</td>
<td>Perennial</td>
<td>Self fertile</td>
<td>Artichoke</td>
</tr>
<tr>
<td>Type</td>
<td>Life Cycle</td>
<td>Self Fertile</td>
<td>Hybrid Crops</td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>------------</td>
<td>--------------</td>
<td>------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Monoceious</td>
<td>Annual</td>
<td>Self fertile</td>
<td>Cucumber, Bitter gourd, Bottle gourd, Luffa, Pumpkin, Squash, Watermelon, Round melon</td>
<td></td>
</tr>
<tr>
<td>Andromonoecious</td>
<td>Annual</td>
<td>Self fertile</td>
<td>Muskmelon</td>
<td></td>
</tr>
<tr>
<td>Gynoecious</td>
<td>Annual</td>
<td>Self fertile</td>
<td>Cucumber, Bitter gourd</td>
<td></td>
</tr>
<tr>
<td>Dioecious</td>
<td>Perennial</td>
<td>Self fertile</td>
<td>Pointed gourd, Ivy gourd, Asparagus</td>
<td></td>
</tr>
<tr>
<td>Dioecious</td>
<td>Annual</td>
<td>Self fertile</td>
<td>Spinach</td>
<td></td>
</tr>
</tbody>
</table>

*Source: Vishnu Swarup (2006). Vegetable Science and Technology in India*

**Principles of hybrid seed production in vegetable:**

**A. Isolation Distance:** For successful hybrid seed production the field must be isolated from other varieties of the same crop, cultivated species and their wild relatives if any to make sure the production of genetically pure seeds. Many of these crops are highly cross pollinated; hence isolation distance for both foundation and certified seed production should be maintained as per the seed production standard. The isolation distance between cross compatible varieties can be achieved by the following ways.

**1. Time isolation:** It will allow the seed production of different varieties of the same crop at the same place each year. If the season is too long enough to allow two production cycles of the cross compatible crops then they too...
are isolated by time. For example, early and mid maturity group of cauliflower grown for seed production can be isolated by time.

2. **Distance isolation:** The isolation distance for self-pollinated varieties is comparatively less but, for cross-pollinated varieties the isolation distance from other variety should be relatively more. The isolation distance also varies with the direction of insect flight (in case of insect pollinated varieties) or the direction of winds (in case of wind-pollinated varieties).

B. **Selection of suitable season and areas for seed production:** For seed production the crop should be grown in areas where dry seasons prevail at the time of seed maturity and extraction. The locations are also important in seed production to enhance seed yield with better quality. Punjab, Haryana, U.P., Jalana (Aurangabad) in Maharashtra, Ranibenur and around Bangalore in Karnataka, Nandyal Valley in A.P., are the main areas of seed production for muskmelon and cucumber in India.

C. **Roguing:** Roguing is the removal of individual plant which do not confirm to the distinct limits of a particular variety. Therefore, rouging is a technique that is used in seed production to maintain genetic purity of the variety. The off-types may occur in a crop due to a variety of the morphological types within a crop. The cross-pollinated vegetable crops like Cole crops, Cucurbits and Onion) shows high morphological diversity than self-pollinated) crops (e.g. Peas, Tomato, Fenugreek). Therefore, the varieties of self-pollinated crops are generally more uniform and stable than varieties of cross pollinated crops.

**Different stages of rouging:**

1. **Before flowering:** On the basis of vegetative characters (plant growth, foliage morphology, colour etc.) the off types are removed from seed production field.

2. **At flowering:** The early and late varieties can be easily identified on the basis of curd maturity and sex expression in cauliflower and cucurbits respectively, and flower initiation time in solanaceous crops.
3. **At fruit development:** Trueness to type of developing fruit (Fruit shape, size, colour, colour of ripen fruit (green, yellow, red) is checked and on the basis off -type plants are rouged out.

4. **At maturity:** The plants showing late maturity of fruits in the early variety and vice versa should be removed immediately from seed production field.

**D. Threshing and seed extraction:** It varies from crop to crop. Threshing can be done by hand or machines. Threshing machines should be properly cleaned to avoid admixture. Generally, seeds should be extracted from dry fruits or from fruits in which the seeds are wet at the time of extraction.

**E. Seed Standards:** It refer to the field inspection of the harvested produce as well as the manner of harvesting, transporting, processing and packing. Unless, a seed certification agency keeps track of harvested produce until it is packed and sealed the identity of the lots cannot be assured. It is, therefore, necessary that the seed certification agency should lay down standard for processing plants. In addition, field and seed standards, such as isolation distances, inseparable other crop seeds, weeds, plants affected by seed borne diseases, genetic purity, percentage of pure seed, other crop and weed seeds, inert matter, moisture content, germination and insect damage, should be prescribed for successful accomplishment of the certification.

**Methods/Techniques of hybrid seed production in vegetables:**

The manual pollination method of seed production on commercial scale is only feasible in the development of hybrids of vegetables like tomato, eggplant, and cucurbits (bottle gourd, watermelon, pumpkin etc.) where large number of F₁ seeds can be obtained per pollination. The advance hybrid seed production techniques like, use of functional male sterility in tomato and brinjal, use of stable genic and sporogenous male sterility with marker character in watermelon and muskmelon can be utilized in these vegetables to reduce cost of F₁ seed production. The functional male sterility has been exploited for hybrid seed production of tomato cv. Pusa Divya
under poly house condition by Manjunath (2009). Hybrid seed in tomato, brinjal, capsicum and chilli are produced through hand emasculation and pollination (Table 4). The hybrid seeds of bottle gourd, bitter gourd and pumpkin through protection of female flower and hand pollination (Flemine, 2010; Jat, 2011; Behera et al., 2015); cucumber through natural pollination in case of gynoecious seed parent (Munshi et al., 2015); onion, cabbage and cauliflower by utilizing the CMS and SI system respectively. The hybrid seeds of summer squash are produced by use of ethephon for inducing the staminate flower and natural pollination. Cryopreservation of pollen in liquid nitrogen at -196°C offers many advantages to the hybrid seed production of vegetables. This method can provide a constant supply of viable and fertile pollen and can also allow supplementary pollinations for improving seed set.

**Table 4: Method/systems of hybrid seed production used in vegetable crops**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Hybrid seed production mechanism</th>
<th>Commercially exploited crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Hand emasculation and manual pollination</td>
<td>Tomato, Brinjal, Sweet pepper, Okra, Chilli</td>
</tr>
<tr>
<td>2.</td>
<td>Pinching of staminate flowers and hand pollination</td>
<td>Bitter gourd, Bottle gourd, pumpkin</td>
</tr>
<tr>
<td>3.</td>
<td>Removal of staminate flower + emasculation + hand pollination</td>
<td>Watermelon and muskmelon</td>
</tr>
<tr>
<td>4.</td>
<td>Functional male sterility and hand pollination</td>
<td>Tomato, Brinjal</td>
</tr>
<tr>
<td>5.</td>
<td>GMS + bee pollination</td>
<td>Chilli</td>
</tr>
<tr>
<td>6.</td>
<td>CMS + natural pollination</td>
<td>Capsicum, onion, cabbage, carrot, radish</td>
</tr>
<tr>
<td>7.</td>
<td>Self Incompatibility and natural pollination</td>
<td>Cauliflower, broccoli</td>
</tr>
</tbody>
</table>
8. Gynoecism and natural pollination  | Cucumber, bitter gourd
9. PGR and natural pollination  | Squash’s
10. Detasseling + wind pollination  | Sweet corn, baby corn

**Source: Tomar et al., (2017)**

**Mechanisms for hybrid seed production in vegetable crops:**

1. **Gynoecious sex form:** The hybrids of cucumber are produced mainly by crossing gynoecious lines with monoecious lines. The other systems of producing gynoecious hybrid seed are gynoecious × gynoecious but gynoecious × monoecious hybrids are still widely grown hybrids because this offers advantages like earliness (Jat et al., 2015), high degree of female sex expression (Jat et al., 2016; Jat et al., 2017), with uniform and concentrated fruit formation, which was especially advantageous for mechanical harvest (Robinson 1999, 2000).

2. **Use of growth regulators for maintenance of gynoecious lines in cucurbitaceous crops:** Gynoecy is most important sex form which has made phenomenal exploitation of hybrid vigour in cucumber, bittergourd and muskmelon (Munshi et al., 2017). The gynoecious inbreds could self reproduce if a growth regulator is applied to induce male flowers (Robinson, 1999). The gibberellic acid (1500-2000 ppm) is used for induction of male flower in cucumber. (Peterson and Anhder (1960) but different gynoecious lines vary in response to GA application and the number of induced male flowers are not sufficient for hybrid seed production, cause excessive stem elongation or malformed male flowers (Robinson, 2000). Therefore, the application of silver compound such as silver nitrate (250-400 ppm) is done to induce male flowers. These ions inhibit ethylene action and promote male flower induction in gynoecious cucumber lines (Beyer, 1976). However, due to phytotoxic effects of silver nitrate such as burning of plants, now a day’s silver thiosulphate (400 ppm) is widely used by seed producers for the maintenance of gynoecious cucumber lines. It induces
male flowering of cucumber plants over a longer period and is less phytotoxic compared to silver nitrate.

2. Male sterility system: Genetic male sterility systems have been utilized for commercial hybrid production in muskmelon (Punjab Hybrid-1). The female and male are grown in 4:1 ratio. However, to maintain the good plant population in female rows it is suggested that seed parent should be sown with double seed rate. It is also advised that female line seedling should be raised in polythene bags and transplanted at flower appearance in order to avoid the fertile plants in female rows. The pollination is done by honey bees. The male sterile line is maintained in heterozygous form by crossing with maintainer line under adequate isolation distance or under cover. Among the genetic emasculation tools, both genetic male sterility (GMS) and cytoplasmic genetic male sterility (CGMS) have been employed in hybrid seed production of chillies. Using these male sterile lines, hybrid cultivars (Kashi Surkh from IIVR, Varanasi; Arka Meghana, Arka Sweta and Arka Harita from IIHR, Bangalore) were identified for commercial exploitation.

1. Use of chemicals for sex modification of cucurbits for hybrid seed production: Specific chemicals are known to induce female and male flowers in cucurbits as desired. Ethrel (2-choloro-ethyl-phosphonic acid) 200-300 ppm at two and four true leaf stage and another at flowering is useful for inducing the pistilate flower in bottle gourd, pumpkin and squash for F1 seed production. The row of male parent is grown side by the side of female and natural cross pollination is allowed. The complete suppression of male flowers in squash can be achieve at higher concentration of (400-500 ppm) of ethrel and nearly 56% of total squash seed produced in USA is of F1 hybrid. The other chemicals like GA3, (10-25 ppm) in cucumber, MH-(100 ppm), ethephone (600 ppm) in squash induces female flowers.
Protected conditions: an option for quality hybrid seed production of vegetables

The lack of sufficient isolation, insect’s vector, diseases and a virus free environment in the production of disease free, healthy and genetically pure seed for commercial cultivation are the major challenges in quality hybrid seed production of vegetable. Compared to open filed condition, protected cultivation can fetches higher seed yield with better quality (Tomar and Jat, 2015). Insect’s vectors and viral diseases are the most devastating problems for quality seed production in most of the vegetable crops grown under open fields, and if the insect vectors are checked by protected structures the use of pesticides will automatically reduce. The seed production in summer season is affected by sudden increase in temperature and severe infestation of mottle mosaic virus and other insect pests in rainy season; against which still there is no effective and reliable management measure. The change in climatic conditions like unseasonal rains during April- June, increased temperature drastically reduced the seed yield and quality even in the summer season crop. Raising seed crop in insect proof net house can overcome these problems by protecting the crop from various insect vectors and unfavourable climatic conditions. It also provides an option for quality and off season seed production. Insect proof net house which is the most suitable and low cost protected structure for quality hybrid seed production of open pollinated varieties in large number of vegetables. The major interest is to grow virus free seed crops and protection against major insect/pests. Insect proof net house is suitable for hybrid seed production of tomato, sweet pepper, chilli, okra, brinjal and cucurbits as compared to open field condition (Jat et al., 2015; Jat et al., 2016). Semi-climate controlled greenhouse is suitable for hybrid seed production of indeterminate type varieties and hybrids of standard tomato, cherry tomato, sweet pepper, bitter gourd and parthenocarpic cucumber varieties. Seed yield of such crops can be 3-4 times more compared to their open filed cultivation (Kaddi., 2011; 2014; Kalyanrao et al., 2012; Jat et al., 2017). Similarly, naturally ventilated green house is also suitable for hybrid seed production, where the seed yield is usually 2-3 times
more over open field, but the cost of seed production is only 1/3 of the seed produced under semi-climate controlled green house condition (Kalyanrao et al., 2014; Singh and Tomar, 2015).

The major advantages of hybrid vegetables seed production under protected conditions are:

1. Higher seed yield (generally 2-4 times more) and seed quality as compared to open field
2. Requirement of isolation distance in cross pollinated vegetables can be minimized.
3. Problem of synchronization of flowering can be minimized.
4. Maximum plant population can be maintained.
5. Seed production under adverse climatic conditions is possible.
6. Training, pruning and hand pollination practices are very easily manageable under protected conditions compared with field seed crop.
7. Emasculation of female parents is not required as there are no insect pollinators.
8. Seed crops will not be damaged by un-seasonal rains at the time of their maturity.
9. Seed viability and seed vigour could be extended through better nutrient management in seed crops under protected conditions.

**Seed extraction methods in vegetables:** There are two methods of seed extraction in vegetable crops.

1. **Dry Method:** The fully matured and dried fruits are harvested and kept under sunlight for 2-3 days. After removal of seeds, these are dried under sunlight between 8.00-11.00 Am and 2.00-5.00 PM to reduce the high moisture content. The seeds of Chilli, Okra, Sponge gourd and Ridge gourd etc are extracted by dry method. The seeds of Radish are harvested when pods become brown and parchment like when the seeds are near maturity. (Tomar et al., 2016). The harvesting of carrot umbles should be done where the secondary umbel is fully ripe and third under umbles have started to
turn brown. For high quality seed, primary and secondary umbles should harvest and rest should be avoided. (Tomar et al., 2016).

2. **Wet Method:** This method is used for seeds extraction of tomato, brinjal, cucumber, muskmelon, watermelon, ash gourd, bitter gourd, round melon and long melon. There are two methods of seed extraction under wet method:

i) **Acid Method:** The fully ripened matured fruits are harvested and crushed along with pulp. The pulp is taken in plastic container or wooden container and the commercial HCL added. The acid and pulp are mixed thoroughly and kept for some time. The corrosiveness of the acid removes the mucilage adhering to the seed and makes the seed free of pulp. The seeds are washed 4-5 times thoroughly with water to make free of acid. The seed extraction is quicker in this method. Seed are also bright in colour with good germination ability and free from fungal attack.

ii) **Fermentation Method:** The fruits are crushed in a non-metalic container and kept as such for fermentation for 2-3 days. During fermentation the seeds get detached from the adhering pulp and settles to the bottom of the container. The seeds are separated, washed thoroughly and dried under shade to the desired moisture level. The seeds become dull coloured due to fermentation of the pulp and also due to the fungal load in the seeds.

iii) **Alkali Method:** Fully ripened matured fruits are harvested and crushed to make pulp. In Tomato, to hasten the fermentation process 0.5% sodium bicarbonate (500 g dissolved in 10 lit. of warm water is added to the pulp and allowed to remain for a day. Then, the seeds are separated and washed free of alkali with water.

**Genetic purity testing of hybrid seed:**

To evaluate the genetic purity of hybrid seed, grow-out-trails (GOTs) have been widely used. It involves the comparison of morphological traits of plants raised from seeds of test sample, with that of genuine samples throughout the crop’s growing season but it is time consuming, laborious and depends on season, which delays seed certification program. Hence, biochemical markers
(Isozymes) have been utilized for seed genetic purity testing but these are limited in number, influenced by environment, plant type and stage. Hence, an accurate and competent method is required for rapid and cost effective hybrid seeds testing. The alternative to this is the DNA marker, which detect the level of admixtures in a seed lot on the basis of established variations between the cultivars at the level of nucleotide sequences. These differences are not affected at different growth stages, seasons, locations and agronomic practices making varietal identification and genetic purity testing more accurate and reproducible. In recent times, various molecular marker systems including RFLP (Restriction Fragment Length Polymorphism), RAPD (Random Amplified Polymorphic DNA), AFLP (Amplified Fragment Length Polymorphism), ISSR (Inter-Simple Sequence Repeat) and SSR (Simple Sequence Repeat) have been widely in use for genetic purity testing of seed in many field crops but SSR markers are generally used for assessing the purity of hybrid in many crop plants because of many reasons like simplicity, rapidness, reproducibility and cost effectiveness as compared to other markers. The co-dominant nature of SSRs have advantages of determination of, heterozygosity of the hybrids by the presence of polymorphic parental alleles, which make them suitable marker for testing the hybrid purity against the admixture of selfed seeds as well as off types. The SSR markers have been widely used for assessing seed purity in vegetables like cabbage (Liu et al., 2007a), tomato (Liu et al., 2007b), chilli (Mongkolporn et al., 2004), melon (Liu et al., 2006), squash (Ferriol et al., 2003), cauliflower (Zhao et al., 2012), bunching onion (Tsukazaki et al., 2006), and artichoke (Bianco et al., 2011). Molecular markers are becoming vital tools for cultivar identification and seed quality control in many crops because of time saving, precision, less labour-consumption.
REFERENCES:


Improving Planting Value of Vegetable Seeds by Physical and Physiological Methods

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High quality seed is basic input for successful vegetable production system. Poor seed quality affects seedling emergence, growth and marketable yield. Quality seed insures better germination, rapid and uniform emergence and vigorous growth. These attributes result in a good stand and increased yield and quality. Poor quality seed results in “skips”, excessive thinning or yield reduction due to overcrowding, all of which decrease the profitability of the growers. Seed quality upgradation techniques using physical, physiological and biochemical treatments are performed on seeds after harvest and before sowing to improve its field performance. After harvest seed processing based on screen (size) and density (weight) grading based on physical parameters of seed are useful techniques in improving planting value of seed. In addition, physiological treatments like seed priming and coating are currently used commercially for seed quality enhancement.

SEED PROCESSING

The basic objective seed processing is to achieve maximum physical purity, germination and uniformity of seed size in an economical way. Wide range of seed processing equipment is available to upgrade vegetable seed quality based on the principal involving physical differences between good seed and material or seed to be removed.

Pre- cleaning:

The most commonly used pre- cleaning machine used is a scalper. The operation is normally used to rough clean various kind of trash or plant debris from the seed lot. It may also be used to break up seed clusters during processing. The seeds which are relatively smaller fall through a vibrating or rotating sieve. This
separation is usually accompanied by an air flow that removes dust, chaff and other materials which are lighter than the seed crop undergoing pre-cleaning.

**Basic cleaning:**
The basic cleaning is the main cleaning of a seed lot. Two main principals involved in basic cleaning are screening and pre-cleaning. The air screen machines combine both these features. It uses a combination of air flow and perforated metal or wire screens to separate seed on the basis of size. Air screen machines have at least two vibrating screens, the upper screen removes impurities larger than the seed while the lower screen separates out any seed or impurities smaller than the optimum seed size of the crop. An aspirating air flow removes impurities and empty seed which are larger than the optimum. Screens used in an air screen machine are constructed in either perforated sheet metal or woven wire mesh on a wooden frame. Metal screen openings are either round, oblong or triangular while openings in a wire mesh screen are either square or rectangular. These screens can be easily changed and almost hundred sizes are available. It is important that appropriate set of screens are available for the specific crop seed to be cleaned.

**Gravity separator:**
The specific gravity separator removes undesirable seed and inert contaminants that are so similar in size, shape and seed coat characteristics to the crop seed that cannot be removed in any other way. This is the best machine available for upgrading seed quality. For example, deteriorated, mouldy or decayed seed which are usually similar in size and shape to good seed but have a lower specific gravity can be removed by this machine. Insect damaged seed, empty seed or other seeds that have defects that decrease their specific gravity can be separated on this machine. The gravity separator consists of a base, plenum chamber or perforated vibrating deck, a feed hopper and a seed discharge system. Seed are introduced from the feed hopper on the porous metal deck, where the combination of shaking and air flow up through the deck causes them to stratify seed according to specific gravity. Thus heavier particles walk close to the deck surface and move towards the top of the deck where they ultimately fall off and
are collected. The lighter particles tend to float on the air cushion above the heavier seeds following the path of least resistance and drift to the lower end of the deck where they fall off and are discharged. Seeds in medium specific gravity ranges called *middlings* can be collected in the middle area.

**Indented cylinder separator:**
The indented cylinder separator operates by lifting short seeds out of a mixture containing long and short seed or other particles. This machine is especially used for separating pieces of stem or stalk from lettuce seed.

**Electronic colour separator:**
Colour separator makes it possible to separate seeds that cannot be separated by any other method. This type of separation may be necessary on occasions when well graded seed lot contains some discoloured seeds which are known to be of lower potential germination or vigour.

**SEED PRIMING**
Differences in seed quality within and between seed lots arise from the presence of different proportion of immature, mature and over-mature seeds. Occasionally these differences are associated with colour or some other physiological characteristics such as size, which allow physical techniques like seed processing to separate seed into different viability classes.

Another approach is to try to improve seed quality of the poorer seeds in the seed lot by physiological treatments. In the mid-1970’s, Walter Heydecker in U.K invented a technique called priming. Heydecker (1973) defined seed priming as a presowing treatment in which seeds are soaked in an osmotic solution that allows them to imbibe water and go through the first stage of germination, but does not permit radicle protrusion through the seed coat. The seeds then can be dried to their original moisture contents and stored or planted by conventional techniques. Priming has the ability to improve the mean performance of a seed-lot and also reduces variation within a seed-lot for a wide range of species.
HOW DOES THE TECHNIQUE WORK?

Seed physiologists recognize three main stages during germination (triphasic uptake of water).

- **Stage 1**: This stage is recognized with a rapid initial uptake of water that is usually completed in 6-24h depending on the species. All seeds, even dead ones, take up water rapidly during this stage.

- **Stage 2**: This is the plateau phase of water uptake during which there is initiation of nucleic acid and protein synthesis in preparation for the emergence of the radicle. This stage may last two or three times as long as stage one.

- **Stage 3**: This is a stage characterized by the rapid uptake of water, cell expansion and the protrusion of radicle through the seed coat.

The stage 3 is relatively short and the differences in the times of germination between the seeds of a population are associated with differences in the duration of stage 2. Thus ‘good’ seeds germinate earlier than the ‘poorer’ seeds. Regulating the availability of water to the seed and preventing it from entering stage 3 can reduce this variation. This enables ‘good’ seed to be held back, allowing ‘poor’ seeds in the lot to catch up the development. The hydration of the seeds can be regulated using osmotica (osmopriming), salt (halopriming) and inorganic or organic carriers (solid matrix priming).

Primed seeds emerge faster and grow vigorously. In this process controlled hydration of seed is done to a level that permits pre-germinative metabolic activity to proceed, but prevents actual emergence of the radicle. Different methods are adopted for priming seeds.

**Hydropriming**: Prior to sowing, seed is soaked in water for a specified duration depending upon crop and variety. After completion of soaking period, surface dry them either by drying them with cloth or placing in sun. Farmers can hydroprime their own seed if they know the safe limits. These safe limits are calculated for
each variety so that germination will not continue once seeds are removed from water.

**Osmopriming:** Seeds are osmotically primed by soaking in -0.5 to -1.0MPa Polyethylene glycol 6000 solutions in a test tube or cylinder. Aeration during the priming is provided through a glass tube connected by a rubber pipe to an aquarium pump. Priming is done at a constant temperature (20 to 25°C) for a period ranging from 2 to 7 days. Distilled water is added to test tube as needed to maintain constant volume and thus constant water potential of the solution. After the completion of priming period, seeds are removed from the solution and rinsed with water and surface-dried immediately.

**Halopriming:** Seeds are haloprimed by soaking them in salt solution for a specified duration at constant temperature. Salts like potassium nitrate, calcium nitrate and magnesium nitrate at 10 to 30mM concentration are generally used. After the completion of soaking period, seeds are removed from solution and surface-dried.

**Solid matrix priming:** For solid matrix priming 100g seed is mixed with 200g vermiculite to which 250ml of water is added. The vermiculite and seeds are mixed thoroughly, sealed in a plastic bag and incubated at constant temperature for a specified period. After completion of incubation period, seeds are sieved out and dried to original moisture content.

After drying seed to original moisture content, the primed seed can be used for sowing. Occasionally in case sowing is delayed, the primed seed can be stored in dry place for several days.

**EFFECT OF SEED PRIMING ON SEEDLING GROWTH AND DEVELOPMENT**

The benefits from priming treatments include increased germination, uniform emergence, germination under optimal and sub optimal environments and improved seedling vigor and growth (Pandita and Nagarajan, 2000; Khan et al., 1992; Penzola and Eira, 1993). Seed priming modify embryonic axis growth and
subsequent seedling development. The response varies according to the species and priming conditions. Priming did not modify embryo volume and cell number of leek and onion but under similar conditions, carrot embryo volume increased almost 50% and the number of cells increased by two-fold. Generally, the major effects of seed priming on growth has been observed as early more uniform emergence and not accelerated growth, per se, of the species. Osmopriming of freshly harvested and aged seed of tomato seed improved germination, speed of germination, field emergence and vigor of seedlings (Pandita et al., 2003). Seed priming did not modify the number of basal and lateral roots and taproot length of 14 days old pepper seedlings (Stoffella et al., 1992). Root length of primed lettuce seeds germinated at 35°C was greater than that of nonprimed seeds (Wurr and Fellows, 1984). Pill (1986) reported that primed parsley seeds yielded 52% more fresh weight compared to non primed seeds 24 days after sowing. Priming of carrot seeds resulted in 36% increase in dry weight of one-month old seedlings compared to nonprimed seeds (Nagarajan et al., 2003). The differences in root and shoot growth between primed and nonprimed seeds is more evident under stressful conditions. Hydration of bittergourd seed in wet muslin cloth for 48h improved emergence, seedling length and dry weight significantly under low temperatures (Pandita and Nagarajan, 2004). Root growth from perennial rye grass seeds germinated at low temperature was greater in primed seeds than in nonprimed seeds, but no differences were observed at 25°C (Danneberger et al. 1992).

**EFFECT OF PRIMING ON YIELD AND QUALITY**

Seed priming promoted early growth of brinjal, pepper, cucumber, and muskmelon plants, but no differences were detected in early and final yield between primed and nonprimed seeds (Passam et al. 1989). However, Alvarado et al. (1987) reported that flowering was early in primed tomato seeds, but fruit maturation, yield or fruit soluble solid content were unaffected. Under stressful conditions, priming increased early seedling growth and marketable yield in
tomato (Odell et al. 1992). Beneficial effects of priming on yield and quality have been reported in crops growing under stressful conditions. Pandita et al. 2010 reported that solid matrix priming alone or in combination with *Trichoderma viride* significantly improved final marketable pod yield under sub-optimal temperature but there was no such improvement under optimal temperatures. Priming had no effect on the number of pods per plant and pod yield per plant under either environment.

There is no doubt about the beneficial effects of priming on the rate and uniformity of seed germination. However, priming treatments are influenced by complex interaction of factors including plant species, osmoticum, duration, temperature, seed vigor and storage conditions following priming.

**PHYSIOLOGICAL AND MOLECULAR BASIS OF PRIMING**

It is important to understand physiological and molecular basis of seed priming for further refinement of this process to obtain better and more consistent benefits. A number of studies have reported on these effects but the biochemical mechanism of priming remains largely unelucidated. Lettuce seeds primed in PEG 6000 had increased activities of acid phosphatase and esterase and reduced time for RNA and protein synthesis than nonprimed seeds (Khan et al., 1978). Coolbear et al.(1990) reported large increase in nucleic acid content during priming process. The activities of peroxidase and dehydrogenase markedly increased in osmoprimed seed of carrot (Nagarajan et al., 2003). Solid matrix priming improved emergence in chilli seed under suboptimal temperatures were attributed to increased activity of glyoxylate cycle enzymes (Pandita et al. 2007). Nascimento et al.(2000) found that during priming of a thermosensitive lettuce genotype endo-ß-mannanase activity was induced after 24 h. After drying and immediately upon reimbibition, endo-ß-mannanase levels were high, leading to rapid germination at 35°C. A connection between priming, thermotolerance and endo-ß-mannanase activity has finally been established (Cantliffe et al., 2000).
Membranes play an active role in seed hydration and dehydration mechanism, but their role during and after priming has not been studied extensively. Basra et al. (1988) reported changes in quantity and quantity of membrane phospholipids during and after priming. Parera and Cantliffe (1991) demonstrated that SMP primed sweet corn had less solutes leakage and reduced water uptake rates during early imbibition than nonprimed seeds.

MORPHOLOGICAL CHANGES IN PRIMED SEED

Morphological changes in primed seeds of ‘Minetto’ lettuce seeds were studied by Guedes et al. (1981) under electron microscope. They found that the outer layer of endosperm cells were gradually loosened after 9 h of priming and this loosening weakening of cell wall, possibly is one of the mechanism of priming enhanced seed germination. Osmopriming of tomato seeds showed large free space between embryo and endosperm under X-ray radiography (Pandita et al., 2003, 2007). The occurrence of free space in primed seeds has been suggested to play a role in accelerating germination rate by facilitating uptake of water (Argerich and Bradford, 1989). During priming the embryo expands and compresses endosperm tissue at a location opposite to radicle tip (Liptay and Zariffa, 1993). Both the compression forces of embryo and hydrolytic activities on the endosperm facilitates protrusion of roots upon rehydration (Liu et al., 1996)

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Vegetable breeding programme results in the production of improved cultivars in vegetable crops. At the time of variety release a small quantity of seed is available with the breeder. The relatively small amount of seed of improved cultivar needs to be multiplied and made available to farmers as quickly as possible. During seed multiplication, varietal purity and identity needs to be maintained. Each multiplication cycle starts from the ‘breeder seed’. If the breeder seed is not of high purity, the contaminants present get multiplied several times in the succeeding generations of foundation and certified seed production. The presence of contaminants may even lead to complete loss of the improved features of the cultivar. Prevention of contamination is at the heart of a successful breeder seed production programme.

**Variety Maintenance**

During seed multiplication process, several factors may reduce the genetic purity of seed. The maintenance of genetic purity is largely dependent on the genetic makeup of the cultivar. The diversity of morphological types is normally greater in predominantly cross pollinated crops like brassicas, cucurbits, onion etc than self- pollinated crops like garden pea, vegetable cowpea, fenugreek, tomatoes, etc. Genetic variation may appear within a seed stock for a number of reasons including mechanical contamination, hybrids resulting from undesirable pollination, recombination, residual segregation, and mutation. These factors ensure that no cultivar is likely to retain the precise frequencies established by the breeder without continuous intervention through maintenance breeding techniques. The occurrence of contaminants during seed
multiplication process occurs due to:

1. **Out-crossing**: Out-crossing vegetable crops such as onion, brassicas, cucubits, onion have substantial outcrossing percentage and even self pollinating crops like common beans show a low percentage of out crossing. In each generation many new genetic combinations appear due to uncontrolled open-pollination. These new genotypes recombine and segregate into a range of new genotypes, thereby enlarging the genetic variations within a cultivar.

2. **Residual segregation**: Some characters have not been selected during breeding or in subsequent purification and production may remain in a population in a range of states. Exposure to new environments may allow expression of states of selected characters not detected previously. For example, in red beet (*Beta vulgaris* L.) maintenance of bolting resistance is strongly influenced by environmental conditions. To maintain such cultivars, a strong selection pressure for that (bolting) attribute is required.

3. **Volunteer plants**: Volunteer plants may arise from vegetative pieces or dormant seed remaining from previous crop grown on the same field. If the volunteer plants are of the same crop to which the cultivar to be maintained belongs will enlarge the genetic variation once harvested together - For example volunteer plants are seen in Indian spinach beet, tomato etc.

4. **Mechanical mixture**: Mechanical mixing with seed from another cultivar of the same crop may occur during sowing, harvesting, threshing, cleaning, storage, bagging, etc.

5. **Mutation**: During maintenance and production spontaneous mutations do occur and may reduce the agronomic value of the cultivars. The mutation rate is generally low but increases significantly after long periods of seed storage. Since mutations are usually micro mutations and recessive, they are often difficult to detect. However, mutations are probably the least important degrading factor contributing to genetic contamination.

6. **Seed borne pathogens**: Pathological contaminants occur due to infection with seed borne diseases, which are exclusively transmitted through
seeds. Pathogens like viruses in tuber crops or anthracnose in beans can spread rapidly, if not contained. Pathological contaminants result in loss of yield and quality of cultivars and also gradual loss of tolerance of the cultivar to specific seed borne diseases.

The above mentioned factors collectively result in genetic variation and these changes accumulate over the years resulting in loss of varietal identity and genetic gain.

**Maintenance of a cultivar**

Once a cultivar is released for cultivation, the breeder usually supplies a small quantity of seed for further multiplication and maintenance. The responsibility of breeder seed production centre is to produce breeder seed and varietal maintenance. In order to release seed of an improved cultivar to farmers, it has to be multiplied. Each multiplication cycle has to start from its basic seed stock, ‘Nucleus Seed’.

Our basic objective of cultivar maintenance is to maintain the purity and identity of a cultivar. The maintenance procedures are in fact the extension of the normal breeding process. The difference is that during maintenance breeding, selection process is relatively mild and our aim is not improvement but to keep the identity unchanged. Selection should maintain the plant type, its uniformity and freedom from diseases. The maintenance procedures for self pollinating vegetable crops like garden pea, cowpea, fenugreek, tomato etc with a substantial amount of out-crossing are slightly different from cross-pollinating crops. In cross pollinating crops like cauliflower, cabbage, onion, carrot, etc the important characters are assessed before flowering. The fields where plants and progenies are to be assessed should be uniform. Essentially these should be grown under optimal growing conditions.

**Cultivar maintenance in self-pollinating vegetable crops**

**Plant to row method:** The maintenance procedure starts with a small plot raised from the parental material received from the breeder or uniform seed multiplication field in case of established cultivars. A fair number (300-500) of
healthy plants typical of the cultivar are selected and marked for progeny testing. The seeds of the marked true-to-type plants are harvested separately. The seeds of each plant are planted in a 3m long progeny row. These progeny rows are assessed critically several times during the growing season. Progeny rows that deviate in one or other characteristics are discarded and entire plant progeny rows is rejected. The plant progenies that are uniform and true to type are selected and bulked together as nucleus seed stage-I. This nucleus seed is used for planting larger breeder seed plots. If the breeder seed requirement of a particular cultivar is more, then another cycle of nucleus seed production is followed.

In this case the true-to-type individual plant progenies are harvested and thrashed separately. Seed of each selected plant-row progeny is now sown in a small plot called plant-row progeny plot. The second cycle of nucleus seed production provides another opportunity to eliminate any plant row progeny showing segregation or off-type plants. The plots with required uniformity and plant type are bulked together to produce nucleus seed stage-II. The product of this second cycle of progeny testing is sufficient to meet the higher requirements of breeder seed particularly in garden pea, vegetable cowpea, etc.

Many modifications of this scheme are possible. For example in garden pea, where 150 typical plants are selected from seed multiplication plot. These plants are harvested and threshed separately. Next season 150 progeny-rows are planted and critically examined for cultivar characteristic during the entire growing season. The off-type rows and less promising lines about 20% are discarded. Among the remaining 120 progeny rows, the 30 best progeny rows are selected. Ten best plants showing better production are selected from each of the 30 best plant progeny rows. Out of these 10 plants, five best plants showing higher number of seeds per pod are selected. These 5 X 30 plants are used to produce plant progeny rows next year. The remaining seed of 30 best progeny rows is harvested separately and planted as 30 bulk plots next season.
Plate 1: Nucleus seed production (stage 1) in garden pea cv. Pusa Pragati

Plate 2: Plant row progeny plots for nucleus seed production (Stage 2) in garden pea cv. Pusa Pragati
**Cultivar maintenance in cross-pollinating vegetable crops**

The risk of genetic contamination through pollen of other cultivars is more in cross pollinating crops and therefore, large isolations are necessary. Cross pollinating cultivars cannot be maintained unchanged for a prolonged period unless proper and systematic maintenance selection procedures are followed. In these cultivars plant selection is of vital importance because of the inherent genetic variation within the crop. However, too stringent selection can shift the cultivar type as much that a different type is produced if reference to original description is not maintained. The methods used for maintenance of such cultivars are

**Negative mass selection:** Part of the basic seed field is given special attention. The undesirable premature bolters and diseased plants are removed. Any doubtful plant not conforming to cultivar description should also be removed. Isolations from related crops should be maintained. The left over plants are harvested and bulked together and is utilized for breeder seed production. In this method, there are chances of cross contamination from off-type pollen grains from undesirable plants. In case of melons nucleus seed is produced by mass selection based on fruit quality in respect to fruit shape, flesh colour and TSS. In watermelon fruit scoring 10% and above TSS are selected where as in muskmelon fruits showing TSS above 12% are selected for nucleus seed. This process has helped us to maintain the fruit quality in melons. A better method is rest seed method.

**Rest seed method:** From the basic seed plot, select 300-500 true-to-type plants based on the cultivar characteristics. The selected plants are harvested and threshed individually. Next year a small part of each progeny (about 200 best plants) is planted in rows and the remaining seed of each progeny is stored. Each plant-row progeny is critically examined for cultivar characteristics and rows showing off type plants are marked and rejected. The remnant seed of the true-to-type plant rows is bulked to form the nucleus seed and is used to raise
the breeder seed plots next year. All off-type plants are removed from the progeny rows before flowing until harvest. Again 300-500 best plants are selected for next maintenance cycle. Repeated maintenance, selection results in a continued improvement over time provided the number of progenies is kept fairly large.

**Vegetable Seed Production Technology**

Quality seed is one of the important inputs for increasing vegetable productivity. Seed is the basic starting point of most of our vegetable crops although some are propagated vegetatively from cuttings of tubers. The vegetable seed is, therefore, basic for all inputs such as fertilizers, crop protection, irrigation, harvesting and marketing. Thus, it is essential that seed of highest possible quality may be made available to the farmers. Quality of seed includes; genetic purity, physical purity, germination potential and freedom from pest and diseases. To produce seed with all these quality attributes, a systematic seed production is must. During the seed multiplication process, the following points are to be kept in mind for obtaining high yields of quality seed with low cost of production.

1. **Environmental Requirements**

Vegetable crops for seed production should be grown under best possible conditions. Best seed yield and quality is obtained when crop is grown in correct season and in an area where the crops’ reaction to appropriate environment can be observed. The regions with abundant sunshine should be selected for seed production. The flowering in many crops is controlled by the light duration (Photoperiodism). For example lettuce and spinach require long day conditions for flowering and seed setting. Some species require a low temperature stimulus to initiate flowering (vernalization). Many temperate vegetables like cabbage, cauliflower, beet root, European type radish and carrot also require vernalization. Avoid areas of high rainfall as it may reduce seed viability and increase need for artificial drying. Excessive wind will increase water loss, prevent activity of pollinators, carry wind borne pollen over long distances and increase seed shattering.
2. Land Requirements

The field selected for raising a vegetable seed crop should be free from ‘volunteer’ plants. Volunteers mean the plants originating from the seed/plant material of the previous market or seed crop. In vegetables volunteer plants are seen in palak, tomato etc. The land should be leveled with proper drainage and should have sufficient organic matter. The cultural operations of vegetables for seed production are similar to the operation on market crop but seed crop is to be maintained beyond the stage of commercial market harvest. Therefore, the control of diseases, pests and weeds should be continued over a longer period.

3. Pollination Requirement

Vegetable crops like tomato, garden pea, fenugreem, cowpea are self pollinated and majority of other vegetable crops like okra chillies, cucurbits, brassicas are cross pollinated.

Table. Natural cross-pollination (NCP) and pollination agents in vegetable crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>NCP (%)</th>
<th>Pollination agent</th>
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<tbody>
<tr>
<td>Tomato</td>
<td>0.00-5.00</td>
<td>Honey bees/ solitary bees</td>
</tr>
<tr>
<td>Potato</td>
<td>0.00-20.00</td>
<td>Bumble bees</td>
</tr>
<tr>
<td>Brinjal</td>
<td>0.70-15.00</td>
<td>Insects</td>
</tr>
<tr>
<td>Capsicum</td>
<td>7.00-37.00</td>
<td>Honey bees/ insects</td>
</tr>
<tr>
<td>Carrot</td>
<td>97.6-98.90</td>
<td>Insects / bees</td>
</tr>
<tr>
<td>Radish</td>
<td>Highly CP</td>
<td>Bumble bees/ honey bees</td>
</tr>
<tr>
<td>Cabbage</td>
<td>73.0</td>
<td>Honey bees/ bumble bees</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>40.0-50.0</td>
<td>Honey bees/ bumble bees</td>
</tr>
<tr>
<td>Onion</td>
<td>95.0-100.0</td>
<td>Insects</td>
</tr>
<tr>
<td>Muskmelon</td>
<td>85.0-95.0</td>
<td>Honey bees</td>
</tr>
<tr>
<td>Cucumber</td>
<td>65.0-70.0</td>
<td>Honey bees/ solitary bees</td>
</tr>
</tbody>
</table>

The natural insect population is normally sufficient under open conditions to ensure satisfactory pollination but high plant population grown for seed in a concentrated area, there is a possibility that natural insect population may be
insufficient to ensure proper seed set. Therefore, the introduction of supplementary bee hives will improve pollination and seed set. However, care must be taken to ensure that pest protection chemicals are not used in a way to harm useful pollinating insects. Spray of chemicals should be avoided at peak pollination insect activity and should be done in the late afternoon.

4. Isolation Requirements

Satisfactory isolation of seed crop helps to maintain purity in three ways:

a) Cross-pollination does not occur between cross compatible crops
b) During harvesting seeds of different varieties of same crop are not mixed
c) The transmission of pest and diseases from alternative host crop are minimized

Proper isolation is thus essential to maintain genetic purity and health of a variety. Isolation between cross compatible varieties is achieved as follows.

Isolation by time
Isolation by time will allow seed of different varieties of the same crop to be produced at the same station each year. If the season is too long enough to allow two production cycles of the cross compatible crops, then they too are isolated by time. For example, early and mid maturity group of cauliflower grown for seed production can be isolated by time.

Isolation by distance
The mode of pollination is related to the degree of isolation necessary. In case of self-pollinated varieties, the isolation distance is relatively short but, in case of cross-pollinated varieties the distance from other variety should be relatively wide. The isolation distance also depends on the direction of insect flight (in case of insect pollinated varieties) or the direction of winds (in case of wind-pollinated varieties).
Table Minimum isolation requirements of vegetable seed crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Minimum isolation distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Foundation</td>
</tr>
<tr>
<td>Brinjal</td>
<td>200</td>
</tr>
<tr>
<td>Fenugreem</td>
<td>10</td>
</tr>
<tr>
<td>Tomato, beans, dolichos, cowpea</td>
<td>50</td>
</tr>
<tr>
<td>Cauliflower, cabbage, beet raidsh, turnip</td>
<td>1600</td>
</tr>
<tr>
<td>Carrot</td>
<td>1000</td>
</tr>
<tr>
<td>Bhindi, chilli, capsicum</td>
<td>400</td>
</tr>
<tr>
<td>Bottlegourd, muskmelon, watermelon, spongegourd, bittergourd, pumpkin</td>
<td>1000</td>
</tr>
</tbody>
</table>

**Roguing**

The vegetable varieties, which are produced for seed show genetic change over several generations. It is, therefore, necessary to exert control and keep the natural variation within the acceptable limits. This is achieved by inspecting the crops at various growth stages and removing individual plant which do not confirm to the defined limits of that variety. Thus rouging is a technique that is used in seed production to maintain genetic purity of the variety. Rogues or off-types may occur in a crop due to any of the following reasons.

- The diversity of the morphological types within a crop may be wide. This tendency is greater in predominantly cross-pollinated (e.g. cauliflower, cabbage, cucurbits and onion) than self-pollinated (e.g. peas, tomato, fenugreek) crops. This is why varieties of self-pollinated crops are generally more uniform and stable than varieties of cross-pollinated crops.

- The seeds that result from cross-pollination between the crop for seed production and other compatible varieties or wild plants. These are not always identified in the first generation and show up in the second.
• Some plants may display deviation from the normal type due to mutation.

• Seeds of other varieties may have been accidentally mixed in the seed stock during its production, processing or admixture via seed drill.

• Volunteer plants may arise from vegetative pieces or dormant seed of the previous crop grown in the same field.

It is always easier to conduct intensive rouging in breeder seed plots than in large commercial seed production plots. To obtain maximum benefits from rouging operation, we should follow the below mentioned practical points.

• The crop should be grown in such a way that plants can be seen individually. Paired row system of planting may be followed so that it is easy to walk between rows. This shall facilitate detection of dwarf undesirable plants.

• Walk systematically through the crop so that each plant is seen. Remove the whole off-type. Do not simply remove the fruits showing undesirable character because the remaining flowers on the off-type plant will still contribute to the material in the next generation.

• Inspect the crop with the sun behind you as it is difficult to examine plants with the sun on your eyes.

• Do not delay field inspection. The undesirable plants should be removed before flowering as far as is possible. Remove cross-compatible weeds and wild relatives. Remove all diseased plants and related infected weeds also.

Variety description based on morphological characters like leaf shape, flower colour, fruit shape and colour generally from a good basis of rouging but some characters like leaf colour, plant height, earliness of flower are affected by environment.

**Harvesting, threshing and seed extraction**

The best time of harvesting vegetable seed crops is at a stage when the highest yield of best quality seed will be obtained. Seed has to be extracted from dry seed heads, or from dry fruits or from fruits in which the seeds are wet at the time of
extraction. Threshing can be done by hand, animal or machines. Care should be taken while transportation of material from the field to threshing floor. Both the trolley and the threshing floor should be clean from the seed/ plant parts of the other varieties of the same crop or weeds to avoid admixture at this stage. Threshing machines must be used with care in case of vegetables. They should be run at a reduced speed to avoid mechanical damage to the seed. Threshing machines should be properly cleaned to avoid admixture.

**Seed drying**
At the time of harvest, the seed contains frequently higher moisture content than the optimum for better germination and storability of seed. Seed from pulpy fruits like tomato, watermelon, muskmelon, cucumber and brinjal have high moisture content have high moisture content at harvest and absorb more during wet extraction. Other vegetable seeds like onion, brassicas, fenugreem and peas have relatively low moisture at harvest. Sometimes due to adverse climatic conditions, seed may also have high moisture content. The seed moisture should be reduced to optimum level before storage. For ambient storage seed moisture should be kept under 9-12% and for sealed storage it should be 6-8%. Natural and artificial methods are used in vegetable seed drying.

**Seed Quality control**
Seed quality reflects the overall value of the seed for intended purpose. Poor quality seed leads to loss of money and potential crop. Seed quality consists of physical purity, germination, potential, genetic purity and seed health.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Minimum limit of Germination (%)</th>
<th>Purity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cucurbitis</td>
<td>Ridgegourd, bittergourd, bottlegourd, tinda, spongegourd, muskmelon, watermelon, pumpkin</td>
<td>60</td>
</tr>
</tbody>
</table>

Table: Minimum Germination and Purity Limits of Vegetable Crops
<table>
<thead>
<tr>
<th>Vegetable Type</th>
<th>Genetic Purity</th>
<th>Trueness to Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brinjal, tomato, chillies, capsicum</td>
<td>70</td>
<td>98</td>
</tr>
<tr>
<td>Peas and beans</td>
<td>75</td>
<td>98</td>
</tr>
<tr>
<td>Sundry vegetables</td>
<td>65</td>
<td>99</td>
</tr>
<tr>
<td>Bulb crops</td>
<td>70</td>
<td>98</td>
</tr>
<tr>
<td>Cole crops</td>
<td>65</td>
<td>98</td>
</tr>
<tr>
<td>Leafy Vegetables</td>
<td>70</td>
<td>95</td>
</tr>
<tr>
<td>Root crops</td>
<td>60</td>
<td>96</td>
</tr>
</tbody>
</table>

**Genetic Purity:**
Trueness to type can be assessed by grow-out tests. In addition, biochemical and cytological methods can also be used to ascertain the variety purity. Seed Certification scheme can effectively control genetic purity of seed crops.

**Suggested Reading:**


Advances in seed production of vegetable crops

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University of Agricultural Sciences, Dharwad

Seed production in fruit vegetables

Brinjal
Seeds are sown in the nursery beds in the month of June and seedlings are transplanted in the field during July. Seedlings are transplanted at a spacing of 60 X 60 cm. The seed plots are isolated from other cultivars by 200 m distance. Off- type and diseased plants are removed at vegetative, flowering and fruiting stage to maintain genetic purity of the cultivar. Mature fruits are harvested in the month of October and November.

Chilli
Chilli seed is sown in well prepared nursery beds in the month of June and seedlings are transplanted in July. Seedlings are transplanted on ridges at 60 cm apart. An isolation distance of 400 m is maintained from other varieties including capsicum (Bell pepper). Proper rouging of off- type and diseased plants is undertaken during entire growing season. Mature red- ripe fruits are harvested and dried for seed extraction. Seed can also be extracted by wet seed method in an axil- flow seed extractor.

Seed Production in cole crops

Cauliflower
Seed of early and mid- season group of cauliflower is produced at IARI, Regional Station, Karnal. Seed is generally sown in July- August depending upon cultivar, in well prepared nursery beds. Seedlings are transplanted on ridges 60 cm apart. Since cauliflower is insect pollinated, an isolation distance of 1600 m
is required from other cauliflower cultivars and other varieties of *Brassica oleracea* L. Heading occurs in November – December. Roguing is done on the basis of leaf and curd characters. Very early and late bolting curds are removed. Only compact curds are left to bolt. Curds are left in the field for bolting and flowering during winter. Flowers are pollinated by bees and seeds are harvested in March- April.

**Seed Production in bulb crops**

**Onion**

Bulb-to-seed method is followed for onion seed production. Seeds are sown in nursery beds in the 1st week of November. Seedlings are transplanted in flat beds at 15 X 10cm by the end of December to first fortnight of January. Mature bulbs are lifted in May after the leaves have ‘toppled’ over and are left to dry in the field. The bulbs are further dried in shade and stored in well- ventilated store. Bulbs are taken out of store by the end of October. Bulb selection is done at this stage and only true- to – type bulbs are used for seed production. Bulbs are planted in the field by the end of October and 1st week of November. Onion crop flowers in March and pollination is aided by bees. Onion seed fields are isolated from other varieties by isolation distance of 1000 m. Roguing is done before flowering, after flowering and at maturity. Seeds are harvested when umbels are dry and black seed is seen in capsules. Harvesting of seed umbels is done in the month of May during morning hours. Harvested umbels are kept for drying on threshing floor and seed is extracted after one week of drying.

**Seed production in root crops**

**Carrot**

Carrot is an insect pollinated crop. Seeds are sown in the field on ridges in mid- September for root production. The roots are ready for lifting after 80-90 days after sowing. Proper selection of roots is done at the time of harvesting.
The stecklings are prepared by removing half portion of foliage and roots. The core colour of the roots is also taken into consideration while root selection. The true-to-type stecklings are transplanted in the field at a planting distance of 30 X 60 cm. seed plot field is isolated from fields of other varieties by at least 1000 m for breeder seed production. The plants flower during March- April and seed is ready for harvesting by the end of May. The primary umbels are harvested mainly during first picking while second picking mainly constitutes of secondary umbels. It is advisable not to harvest tertiary umbels in Asiatic carrots as they contain embryo-less seeds. The harvested umbels are left on threshing floor for 3- 4 days before seed extraction.

**Radish**

Seed of only Asiatic radish is produced at IARI, Regional Station, Karnal. Radish is cross-pollinated by insects. Seed is sown on ridges in mid- September to mid- October for root production. Roots are ready for lifting 40- 60 days after sowing depending upon the type of cultivar. The roots are selected on the basis of cultivar characteristics and stecklings are prepared by removing half portion of foliage and roots. The proper selected stecklings are transplanted in the field at 60 X 60 cm. seed plots must be isolated from fields of other cultivars by at least 1600 m. The plants flower in January- February and seed is harvested by April.

**Turnip**

Turnip is cross-pollinated by insects. The seed production plots must be isolated from other varieties and other species of genus Brassica by 1600m. Contamination must be avoided from Brassica napus, B. juncea, B. chinensis. B. nigra and B. alba. Seed is sown on ridges after mid September. Proper root selection is done at the time of root lifting and stecklings are transplanted in the field at 60 X 60 cm distance. Harvesting is done when haulms turn from green to brown parchment color. Harvesting should be done during morning hours to avoid loss due to shattering.
Seed production in cucurbits

The cucurbits are cross pollinated in nature and honeybees are major pollinators, thus for pure seed production an isolation distance all around seed field is necessary to separate it from fields of other varieties and fields of the same variety not confirming to varietal purity requirement. The isolation distance of at least 1000m is required for breeder seed production. Bittergourd also needs isolation from *Momordica balsamina* L., *M. cochinchinesis* (Kakrol), *M. dioica* (Jangli karela). Pumpkin needs isolation from winter squash, summer squash, *Cucurbita maxta* Pang. Watermelon needs isolation from wild watermelon (*Citrullus colocynthis* L.).

Seeds of cucurbits should be sown on raised beds. The plant spacing is 2-4 m between rows and 45-60 cm between hills is desirable depending upon crop and variety. In case of raised bed, 2-3 seeds per hill should be sown and after emergence only two seedlings per hill should be retained. Beehives should be placed in clusters around the periphery of field, with additional hives placed inside the larger fields. Rouging of off-types, diseased plants, objectionable weeds, plants of other crops and undesirable plants (wild type) should be conducted throughout the growing season. There are four stages of rouging. The first is done before flowering when vegetative characters are checked. The second stage is at early flowering when morphology of the ovary is checked. The third stage is when the developing fruits are checked for trueness to type, and the final rouging is confirming the external morphological characters of the fruits to be harvested. Field inspections for rouging should be based on the stable characters like leaf spot, length of peduncle, shape of peduncle, flaring of the peduncle, ovary shape, matured fruit shape and rind colour of the matured fruit.
Quality Seed Production of Vegetable Crops Under Protected Conditions

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Although cost of seed is only a fraction of the total cost of inputs involved in growing a vegetable crop but timely providing availability of good quality seed is the basic unit in increasing the production and productivity. Raising healthy seedlings through good quality seed, suitable cultural practices and optimum environmental conditions are pre-requisite for success in vegetable growing. Inadequate availability of quality seed is one of the major causes of low productivity and poor quality of vegetable produce. Thus, in order to enhance the production and productivity of vegetables, it is necessary to increase the production of quality vegetable seeds. Protected vegetable cultivation has been to increase the production of quality vegetable seeds for off-season and long duration commercial purpose. Raising seed crops of high value vegetable crops under protection can further enhance production and quality of seeds.

PROTECTED STRUCTURES AND VEGETABLE CROPS SUITABLE FOR SEED PRODUCTION

The protected structures may be climate controlled greenhouses, semi-climate controlled greenhouses, naturally ventilated greenhouses, insect proof net-houses, walk-in-tunnels, low cost poly-houses and plastic low tunnels etc. Greenhouses, mainly the climate and semi-climate controlled are also used for seed production of high value vegetables as the crops get very short crop season under open field conditions. The high value vegetables include slicing tomatoes,
cherry tomatoes, sweet peppers, parthenocarpic cucumbers etc. The major constraint for using this type of structure is that the basic or initial cost of fabrication and running cost of such greenhouses is very high which increases the seed cost as compared to seed produced under other structures or under open field conditions, but yield and quality of seed under such structures is always very high.

Naturally ventilated greenhouses can be used for seed production of tomato, sweet pepper, cucumber including parthenocarpic cucumber, summer squash, muskmelon etc. but the duration for seed crop and the seed yield are less compared to climate controlled or semi climate controlled greenhouses.

The insect proof net-houses can be used commercially for seed production of sweet pepper, tomato, brinjal and other vegetables like cucurbits etc. These structures can be used to protect the crop against viruses and other insects like fruit bores during rainy and post rainy season but the seed yield is always less compared to all kind of greenhouses including cost of seed production, which is also very less compared to greenhouse. Walk-in-tunnels can be used commercially for seed production of cucurbits like muskmelon, watermelon, summer squash, bottle gourd, bitter gourd etc even during off-season but these structures can only be used peak winter months to protect the crops against low temperature injury (Dec-mid Feb) in north Indian plains. Walk-in-tunnels, plastic low tunnels and even rain shelters are suitable for raising seed crops of onion, French bean, leek, garden pea etc. especially in hills where their seed maturity coincides with the rains.

Plastic low tunnels can be used commercially for off-season seed production of cucurbits. The basic purpose is to advance the seed crops which is not possible under open field conditions of northern plains of India.
TRAINING AND PRUNING

Source-sink relationship affects the growth habit, fruit bearing pattern and seed yield in cucurbits and solanaceous vegetables. In tomato, the growth habit can be indeterminate, semi-determinate or determinate. The indeterminate varieties/hybrids are preferred for hybrid seed production inside the greenhouse. Such plants can be grown over a long period and produce a number of fruit trusses. Seed production of determinate or semi determinate varieties is less popular and not preferred under greenhouse conditions. Usually first to fourth cluster at each branch are selected for emasculation in case of hybrid seed production. The training and pruning is a regular process in greenhouse tomato crop, hence a careful attention is always helpful in high seed yield.

**Kind of protected structures and vegetable crops suitable for seed production and duration of seed production under northern plains of India**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Protected structure</th>
<th>Suitable vegetable crops for seed production</th>
<th>Duration of seed crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Climate controlled greenhouses</td>
<td>Tomato, cherry tomato, sweet pepper, cucumber</td>
<td>10-12 months</td>
</tr>
<tr>
<td>2</td>
<td>Semi-controlled greenhouses</td>
<td>Tomato, cherry tomato, sweet pepper, cucumber</td>
<td>9-11 months</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10-11 months</td>
</tr>
<tr>
<td>3</td>
<td>Naturally ventilated greenhouses</td>
<td>Tomato, sweet pepper, cucumber</td>
<td>8-9 months</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7-8 months</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9-10 months</td>
</tr>
</tbody>
</table>
Pruning in sweet pepper is normally limited to the shoots that grow on the stem below first branching, or to some of the weak side shoots. Pepper leaves have a rather low level photosynthetic efficiency and consequently a large area of active leaves is necessary to produce sufficient dry matter. Pruning is done only in few cases where the growth is luxuriant.

Under protected cultivation, the stem structure of pepper is often too weak to take the load of the plant, hence there is a need to train the plant. Pepper plants should be trained upright by allowing two main branches after removal of first terminal bud in a way to expose the leaves to the maximum light, the canopy must always be ventilated. The eggplant has an upright growth habit; hence horizontal strings fixed on either side of the plant row are enough to support them. A good pruning system consists of removing the side shoots up to the

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>
| 4 | Insect proof net houses | musk melon
|   |   | summer squash |
|   |   | 8-9 months |
|   |   | 6-7 months |
| 5 | Walk in tunnels | Tomato
|   |   | sweet pepper |
|   |   | 6-7 months |
|   |   | 7-8 months |
|   |   | 6-7 months |
| 6 | Plastic low tunnels | cucumber
|   |   | 4-5 months |
|   |   | 4-5 months only for off-season production during winter months

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 4 | Tomato
|   | sweet pepper |
| 5 | Muskmelon, watermelon |
|   | and other cucurbits |
| 6 | All cucurbits |
|   | 4-5 months only for off-season production during winter months |
position of the first flower appearance, allowing two branches to develop from the terminal flower node, followed by periodic removal of shoots from the inner part of the plant and removal of the oldest suffice to allow good air exchange and a balanced framework of plants.

Cucumber requires a supporting system in order to grow vertically by means of its tendrils. Plastic or fibre strings are useful for training. They hang down from wire stretched at height of 1.5 to 2.0 m.

**Long fruited cultivars**

The side fruits on the main stem are removed up to a height of 60-70 cm. The fruits are then allowed to set on the main stem up to a height of 2 or 3 meter. Side shoots up to 2 m length are not allowed. Above 2 m length, 3 branches are allowed to develop. The fruits are allowed to set up to first 2-3 nodes. De shaped fruits and old leaves are removed in order to improve fruiting.

**Short fruited cultivars**

The fruits and side shoots of the main stem are removed up to a height of 40-50 cm. Further pruning is done in one of the following ways:

1. The side shoots are pruned to 1 fruit/leaf. The fruits on the main stem are also removed.
2. The side shoots are pruned to 1 fruit and 2 leaves. The fruits on the main stem are also removed.
3. The side shoots are pruned to 1 fruit and 2 leaves. The fruits on the main stem are allowed to develop.
4. The side shoots are pruned to 1 fruit and 2 leaves up to 1 m. Then pruned to 2 fruits and 3 leaves up to 2 m. The fruits on the main stem are removed.
**Parthenocarpic varieties**

In gynoecious or parthenocarpic cucumber varieties, one single stem is allowed from the beginning of the plant and fruits are allowed on the main stem only. Three seed crops of such varieties are possible under greenhouse are muskmelon, watermelon and summer squash.

**Muskmelon**

In muskmelon single stem training is the common set system. The plants are trained upright. All branches below 6-8 nodes are removed. Female flowers are retained on branches emerging from 9 to 16 nodes on the main stem. After fruit set the tips of the branches are pinched off retaining 2-3 leaves per branch. The top of the main stem is pinched off after 25 nodes. In double stem training system, the main stem is pinched off at the second leaf stage and the plants are trained upright with 2 main branches. The secondary branches appearing on each of the 2 main axis may be pinched off after the first fruit set or two leaves afterward. Maximum 3 to 4 fruits are allowed per plant for optimum growth. The tips of the two main branches are pinched off up to 20 to 25 nodes. The middle portion of the plant should be allowed to retain the fruits. After harvesting first 3 to 4 fruits, further fruits may be allowed to set. In muskmelon, the duration of seed production can be doubled by this way to increase the seed yield.

**Watermelon**

In watermelon, the main stem is trained upright along with 3-4 strong branches with the help of plastic strings. The first female flower, if it develops below 8-10 nodes on the main stem, is pinched off. In the middle portion of the plant 2-3 fruits are allowed to develop between 12 to 25 nodes. The growing tip of each branch after 2nd or 3rd node is pinched off. For small-fruited varieties, 4 fruits are allowed to develop per plant. The developing fruits are provided a support using nylon net bags if insect pollination has been used in the protected structures.
SUMMER SQASH

In summer squash, the main stems and branches are short, thus making the plant bushy and such do not required any training and pruning. The older leaves are, however, removed for proper areartion. The winter squash has long vines and needs upright training. The main stem is pinched off at 4 nodes allowing two strong branches to develop. Two fruits are allowed to set on each branch between 12-16 nodes. The main branches are pinched off at 30 nodes. Each developing fruit is provided with a support using a nylon net bag.

EMASCLULATION AND POLLINATION

Flowering period in male and female parents is synchronized the sowing time. In solanaceous vegetables, the emasculation of the perfect flower on the seed parent is done a day prior to anthesis, leaving the petals intact. Such petals turn yellow (in tomato), purple or white (in brinjal) and white (in sweet pepper) on the day of anthesis. Flowers with under developed inverted stigmas are pinched off. Fresh pollen from several plants of male parents is collected by a vibrator on the day of anthesis. Since only ripen pollen are shed by a vibrator on the day of anthesis. Since only ripen pollen are shed by vibrating the flower, such pollen have the highest viability. Pollen are collected in a small cup attached to a finger ring or other container as per need. Pollination is done by dipping the stigma into the pollen mass. Half of the calyx of pollinated flowers is removed to distinguish it from un pollinated flowers. In eggplant, the stigma is quite receptive a day prior to anthesis which is quite successful. Since the bees do not visit simultaneously, a day prior to anthesis which is quite successful? Since the bees do not visit the emasculated flowers in solanaceous crops, gagging of emasculated flower is not necessary. Pollen grains can be stored for a long period i.e. 1 to 2 months at 0 °C using silica gel for their proper drying.

The sex expression in cucurbits is mainly monoceious, andromonoceious and gynoceious. The perfect flower on the seed parent in muskmelon and cucumber are emasculated a day prior to anthesis which is not required in
parthenocarpic varieties. The perfect flowers of the watermelon on the other hand are not emasculated, as the anthers do not produce the viable pollen, the emasculated flowers are bagged in order to avoid chance self-pollination. In monoceious plants, the female flower is bagged a day prior to anthesis. The male flowers are either collected in the evening a day prior to anthesis and are kept in a moist polythene bag or collected early in the morning on the day of anthesis. Pollination is done on the day of anthesis by dusting pollen on the stigma of the main flowers. Pollination work commences at 7 am and completed by 9.30 am. Pollinated flowers are re-bagged to avoid contamination by visiting bees.

Pollination work continues upto 15 days in muskmelon and cucumber and up to 10 days in watermelon and squash. Emasculation and pollination work requires 20-25 laborers/day/acre. Insect pollinators like honey bees are largely used in cucurbitaceous vegetables under protected seed production but proper and careful management of the pollinators is required to avoid pollinators’ destruction. Similarly, in case of tomato, bumble bees are best pollinators among insects but they are not available in India. Hence, only option left is to use electric bee or vibrators or hand pollination in open pollinated varieties.

**Harvesting in fruit/vegetable crops:**

The mature fruits in different vegetable crops are harvested at different times after pollination. The stages of harvest in some of the important crops are as under

**Stage of harvest in different vegetable crops:**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>VEGETABLE CROPS</th>
<th>SEED YIELD (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Brinjal</td>
<td>50-55 days after pollination. Fruit skin colour yellow/yellowish brown.</td>
</tr>
</tbody>
</table>
2. Cucumber 30-35 days after pollination. Fruit skin colour – yellow or brown.

3. Muskmelon Full slip stage or when cracks develop at the junction of fruit peduncle

4. Pepper 60-65 days after pollination. Fruit skin colour – red or yellow.

5. Squash 40-45 days after pollination. The peduncle is dried upto the base

6. Tomato 60-65 days after pollination. Fruit colour complete red

7. Water melon 1. 55-65 days after pollination
   2. The tendrils nearest to the fruit is dried upto the base
   3. The fruits also produce dull sound when tapped with knuckles.

**Fruit curing:**

The fruit need to be cured prior to seed extraction. Duration of curing in different crops

<table>
<thead>
<tr>
<th>S.N.</th>
<th>VEGETABLE CROPS</th>
<th>CURING PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Brinjal</td>
<td>10 days after fruit harvest</td>
</tr>
<tr>
<td>2.</td>
<td>Cucumber</td>
<td>7-10 days after fruit harvest</td>
</tr>
<tr>
<td>3.</td>
<td>Muskmelon</td>
<td>7-8 days after fruit harvest (non slipping varieties)</td>
</tr>
</tbody>
</table>
4. Squash 20 days after harvest-summer squash; 30 days after harvest-winter squash

**SEED EXTRACTION:**

In Tomato, Cucumber, Watermelon and Muskmelon, the seeds are extracted by fermentation method. Under warm condition, the fermentation process is completed in 24 hours. At 25°C Cit requires 2 days for the completion of the fermentation process. The pulp is stirred several times in a day to maintain uniform rate of fermentation and to avoid discolouration of seeds. Fermentation methods of seeds extraction also control the seed borne bacterial canker in tomato. The seeds are washed thoroughly with excess of clean water. Tomato seeds are also extracted using 10 cc of 36% HCL of NaOH is added to 4.0 kg of tomato pulp. The treatment is given for a period of 15 minutes, and then washed with clean water. In eggplant and bell pepper, the ripe fruits are crushed and washed. In squash, the seeds are separated from the placental material using rice bran and then washed. Seed drying is done using dry air at 28-30°C

**EXPECTED SEED YIELD IN DIFFERENT VEGETABLE CROPS**

**Seed yield in different vegetable crops under protected conditions**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>VEGETABLE CROPS</th>
<th>SEED YIELD (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Brinjal</td>
<td>200-400</td>
</tr>
<tr>
<td>2.</td>
<td>Cucumber</td>
<td>450-500</td>
</tr>
<tr>
<td>3.</td>
<td>Muskmelon</td>
<td>250-300</td>
</tr>
<tr>
<td>4.</td>
<td>Pepper</td>
<td>150-200</td>
</tr>
</tbody>
</table>
5. Squash  
6. Tomato  
7. Water melon

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>Squash</td>
<td>500-700</td>
</tr>
<tr>
<td>6.</td>
<td>Tomato</td>
<td>150-200</td>
</tr>
<tr>
<td>7.</td>
<td>Water melon</td>
<td>200-300</td>
</tr>
</tbody>
</table>

The seed yield, though, varies depending upon the crop or variety, protected structure and crop management in different vegetable crops but with good management 100-700 kg seed can be harvested from one hectare in different vegetables.

**Advantages:**

1. Off-season seed production is possible in several vegetables, especially in cucurbits.
2. Seeds of vegetables can be produced all the year round by avoiding the season.
3. High seed yield can be obtained from small area of a protected structure.
4. Production of virus free quality seed is possible even during rainy or post rainy season.
5. Provides the best opportunity for organic seed production in vegetables.
6. Uniform establishment of seed crops leads to quality seed production.
7. Early fruiting leads to advancement in seed production.
8. More fruit setting due to congenial climatic conditions under protection provides long duration for fruit setting.
9. Different cross pollinated crops/varieties belonging to same family/crop can be grown in adjacent greenhouses for seed production without any problem of isolation distance.
10. Handling is very easy during winter season.
11. Seed production is possible even if soil salinity is high soil-less media for cultivation.
12. Seed in case of parthenocarpic varieties of cucumber is only possible under protected conditions.

13. Several seed crops are possible under a protected structure in duration of one year.

14. Crop is protected from heavy rains and viral disease transmitted by insect vectors like white flies etc.

15. The protected area is always kept neat and clean so objectionable weed or diseased plants etc. under check.

**Constraints:**

1. Normally the cost of seed production is high.
2. The seed production job is highly labor intensive and technical.
3. Difficulty in the maintenance of the pollination under protected conditions.
4. Soil borne fungus sometimes becomes a severe problem for crop production.

**REFERENCES**


Advances in Production of Quality Planting Material of Ginger

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Department of Vegetable Science
YSP University of Horticulture and Forestry
Nauni 173230 Solan, Himachal Pradesh

Ginger (*Zingiber officinale* Rosc. 2n=2x=22), a monocotyledonous plant belonging to the family Zingiberaceae is an important cash crop and one of the principal spice crop all over the country and world. India is the largest producer with more than 50% of the world production and exporter of ginger besides domestic consumption. In India it is grown in a area of 1 32 620 ha with a production of 6 55 060 t i.e. productivity of 4.94 t/ha mainly in the states like Kerala, Meghalaya, HP, WB, Odisha, AP, Karnataka, UK, Sikkim, MP, Mizoram, Manipur, TN, Bihar, Tripura, Gujarat, Nagaland, Assam, J&K, Andaman and Nikobar Islands. Kerala contributes maximum dry ginger i.e. sounth which is marketed internationally under the trade name “Cochin Ginger”. Jamaica and India produce the best quality ginger followed by West Africa. Chinese ginger is usually not exported as a dried spice but preserved in sugar syrup or converted into ginger candy. It has low pungency and aroma and hence can not be used for distillation. Japanese ginger possesses a certain amount of pungency but lacks characteristic ginger aroma.

In HP, the State Department of Agriculture started giving attention to step up the Production of quality ginger and stress was made on investigations on the crop in early sixties at Dadahu in the heart of ginger growing areas of Sirmour district on various aspects of production and breeding. The systematic research work on ginger was also conducted at Kandaghat and Solan (Shimla Hills) under AICRP on Spices. In HP, the ginger is grown in the area of 3230 ha with a production of 7640 t i.e. productivity of 2.37 t/ha. It is a cash crop of mid and low hills and more than 3/4th of the area and production is mainly from Sirmour
district. The other ginger growing areas are Solan, Bilaspur and Shimla and 90% of ginger produced in the state is exported as fresh to the adjoining states like Punjab, Haryana, Delhi, UP and Chandigarh and generate a good income to the farmers of the state. It is marketed in different forms such as raw ginger, bleached ginger, ginger powder, ginger oil, ginger oleoresin, ginger ale, ginger candy, ginger beer, brined ginger, ginger wine, ginger squash, ginger flakes etc. It is useful in gastric, cold and cough.

In hilly areas especially Himachal Pradesh, the economy of the farmers depends on this crop. It is propagated through rhizomes which can be carried easily in living state from one place to other and actually forms the seed. Normally, the seed ginger is used in bulk and forms 40-45 per cent of the total expenditure. For raising next year’s crops, tonnes of seed ginger are required which is stored in pits (locally called khaties in Himachal Pradesh) for 4-5 months as the future crop depends on proper storage till it is sown. Thus, the poor farmers have to pay very high price for the seed ginger at peak sowing season if not stored of his own; sometimes it may not be available because of its perishable nature.

Botanically the underground stem i.e. rhizomes forms the seed vegetatively propagating material for ginger. Seed ginger is one of the major inputs for ginger production. The seed ginger requirement per hectare ranges from 15-20 quintals depending upon the size of rhizomes. The smaller is the size of the bits (pieces) lesser the seed rate per unit area and vice versa. The normal practice is that the farmers retain their own seed ginger every year. The rhizomes reserved for seed purposes remain in the pits/ground for about another 40 days. The healthy rhizomes selected for seed are sorted from the harvested ginger from the field having healthy crop stand and is free from rhizome rot and ginger yellows and insects etc. during December-January depending on the elevation and other topographical factors. Mostly the seed retained is always from the irrigated fields, however, in mid-hills, the seed ginger is also retained from rain-fed crops. Proper
selection is done on the basis of size, shape and colour of the plant and rhizomes, free from diseases, insect-pests, deformed or undersized, etc. should be eliminated.

Rhizomes of a particular variety are selected from a healthy field. Normally the selected rhizomes of resistant better varieties should be developed and grown on commercial scale which has great demand in the international market as per the requirement of the importing countries. The selected rhizomes having two buds need to be used for planting on a still larger area to meet the increasing demand both in domestic and export markets. The planting methods and other operations followed for production of seed is the same as for fresh mature ginger consumption.

**Seed production technique:**

In ginger production seed rhizomes account for single largest cost item or investment of the total cost of production. Therefore, for the production of quality seed ginger and its maintenance the optimum land/field and seed standards followed in potato/vegetable seed production should be taken into consideration in ginger seed production also. At present the land/field and seed standards are also not followed properly in our country with the result ginger crop has been severely affected by rhizome rot disease growth in storage and in fields, and ginger yellows in the standing crop as the disease and insects (maggots) inoculum is either carried through rhizomes so prevalent in the store with previous remains of the rhizomes or in the soil. Thus, the yields are greatly affected and in some places the losses are 100%. It will be better to explore the possibility of identifying new areas/belts which are disease and insect free is the need of the day. Because the disease is transmitted through seed. Therefore, the movement of seed ginger should be restricted from one place to another and if required to be carried, it should be done after proper certification. Because there is every likely-hood of transmission of inoculums of serious diseases and insect-pests carried along with the seed ginger. The seed ginger pockets should be first
identified and isolated on the basis of the standards fixed by the certifying agency for seed purpose and then only it should be procured from the disease and insect-pest free zone or pockets and supplied to other areas. In addition, seed ginger multiplication should be got done in new non-traditional areas where there is no infestation. Moreover, the farmers of these areas should be encouraged to take up the seed multiplication programme on large scale and provided with the necessary incentives like subsidies on inputs, loans, insurance cover, etc. and made easily available the technology for seed production of quality ginger seed.

**Cultural Requirements:**

Other package and practices are the same as for the normal ginger crop.

**Climatic requirements:** Ginger requires tropical, subtropical, humid climate for its commercial production. The favourable temperature range is 19-28°C, temperature lower than 13°C induces dormancy, higher than 32°C can cause sunburns and poor relative humidity is also unfavourable. The optimum soil temperature for sprouting is 25-26°C and for growth 27.5°C at increased day length (10-16 hours) vegetative growth is enhanced while it is inhibited and rhizome swelling promoted as the day length decreased (16-10 hours). It thrives well under partial shade hence can be grown as an intercrop.

**Soil requirements:** Ginger can be grown in all types of soils but the ideal one is sandy loam soil, light, loose, friable, well drained and at least 30 cm depth and new soils rich in humus are the best having 5.5-8.5 pH however, rhizome growth is better in slightly acidic soils (pH 6.0-6.5) than neutral soils.

**Site selection:** The site should be flat with sufficient slope to avoid water stagnation, well drained, rich in humus, organic matter and free from diseases and insect pests. Partial shade conditions are preferred. Ginger crop should not be grown on the same field for at least three years to avoid infection of rhizome disease a serious problem in ginger industry.
**Varieties:** Differential performance of the varieties in different locations is observed. The cultivars released by AICRP on Spices Varda, Mahima and Rajetha by IISR, Calicut; Surubhi, Suruchi and Suprabha by HARS, Pottangi and Himgiri by UHF Solan, mostly for local state cultivation.

**Planting time:** It is planted in the month of April, delay in sowing decreases the yield, the early sowing makes sufficient growth that withstands rains and grows rapidly when there are heavy rains during July-August. In West coast of India, the best time for planting ginger is during the first fortnight of May with the receipt of pre-monsoons. In eastern India planting is done in March. Sowing in HP is according to the altitude i.e. April-May in mid and high hills and May-June in low hills. Burning of surface soil and early planting with the receipt of good summer showers consistently gives higher yield and reduces the disease incidence.

**Land preparation:** The land is ploughed 3-4 times or dug to bring the soil to a fine tilth. Compost or well rotten FYM should be applied at the time of field preparation and mixed thoroughly. Beds of convenient size about 3 m long, 1 m wide and 15 cm raised are prepared with channels of 30-45 cm to avoid stagnation of water. The alignment of the channels should be in such a way that during rainy season these should act as drains for excess water and before and after rainy season as irrigation channels.

**Propagation:** Preserved seed rhizomes are broken or cut into small pieces i.e. bits of 2.5-5.0 cm long weighing 20-30 g each having at least one or two good buds/eyes or growing points. While preparing the seed bits, the hands or the knives used should be washed with detergent powder and the knives be sterilized after some interval to avoid transmission of disease inoculums to the healthy rhizomes of seed ginger.
<table>
<thead>
<tr>
<th>Variety/year of release</th>
<th>Pedigree/parentage &amp; plant type</th>
<th>Institution/University</th>
<th>Yield t/ha (fresh)</th>
<th>Salient features</th>
<th>Recommended state/region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suprabha 1988</td>
<td>Clonal selection from Kunduli Local</td>
<td>HARS Pottangi, (OUAT Odisha)</td>
<td>16.6 (22.8)</td>
<td>Plumpy rhizome, less fibre, wide adaptability, suitable for both early and late sowing, duration 229 days, 8.9% oleoresin, 4.4% crude fibre, 1.9% essential oil and 20% dry recovery.</td>
<td>Odisha and adjoining states</td>
</tr>
<tr>
<td>Suruchi 1990</td>
<td>Clonal selection from Kunduli Local</td>
<td>Odisha</td>
<td>11.6 (23.5)</td>
<td>Profuse tillering, bold rhizome, suitable for rainfed/irrigated conditions, duration 218 days, 10.9% oleoresin, 3.8% crude fibre, 2% essential oil and 23.5% dry recovery.</td>
<td>Odisha, Central and South India</td>
</tr>
<tr>
<td>Surabhi 1991</td>
<td>Induced mutant of Rudrapur Local</td>
<td></td>
<td>17.5 (23.0)</td>
<td>Plumpy rhizomes, dark skinned yellow fleshed, suitable for rainfed/irrigated conditions, duration 225 days, 10.2% oleoresin, 4.0% crude fibre, 2.1% essential oil and 22.5% dry recovery.</td>
<td>Odisha</td>
</tr>
<tr>
<td>V&lt;sub&gt;3&lt;/sub&gt;S&lt;sub&gt;1&lt;/sub&gt;-8</td>
<td>Sodium azide mutant</td>
<td></td>
<td>29.0</td>
<td>A mutant line moderately tolerant to diseases and pests. Having 10.8% oleoresin, 3.2% crude fibre, 1.3% essential oil and 22.2% dry recovery, suitable for green and dry ginger, wide ecological adaptability, suitable for both hills and plains</td>
<td>Odisha, AP, WB, MP, UP, Bihar</td>
</tr>
<tr>
<td>V&lt;sub&gt;1&lt;/sub&gt;E&lt;sub&gt;8&lt;/sub&gt;-2</td>
<td>An EMS mutant</td>
<td></td>
<td>32.9</td>
<td>A high yielding mutant with moderate tolerance to disease and pests. Contains 10.8% oleoresin, 3.5% crude fibre, 1.8% essential oil and 21.4% dry recovery, suitable for green ginger, late planting under rainfed conditions in hills and plains</td>
<td></td>
</tr>
<tr>
<td>Himgiri 1996</td>
<td>Clonal selection from Himachal Pradesh</td>
<td>Dr YSPUHF Solan HP</td>
<td>13.5 (20.6)</td>
<td>Best for green ginger, less susceptible to rhizome rot disease, suitable for rainfed condition, duration 230 days, 4.29% oleoresin, 6.05% crude fibre, 1.6% essential oil and 20.2% dry recovery.</td>
<td>HP</td>
</tr>
<tr>
<td>Variety</td>
<td>Selection from germplasm</td>
<td>ICAR, IISR, Calicut, Kerala</td>
<td>22.6</td>
<td>High yielder, high quality bold low fibre content (3.29% to 4.50%), essential oil 1.7%, oleoresin 6.7% and dry recovery 19.5%, tolerant to disease, maturity 200 days</td>
<td>All over India</td>
</tr>
<tr>
<td>-------------</td>
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</tr>
<tr>
<td>Varada 1996</td>
<td>Selection from germplasm</td>
<td>ICAR, IISR, Calicut, Kerala</td>
<td>22.4</td>
<td>High yielder, plumpy and bold rhizome, 6.3% oleoresin, 4.0% crude fibre, 2.35% essential oil and 20.8% dry recovery, maturity 200 days</td>
<td>Kerala and Karnataka</td>
</tr>
<tr>
<td>Rejatha 2004</td>
<td>Selection from germplasm</td>
<td>ICAR, IISR, Calicut, Kerala</td>
<td>33.2</td>
<td>High yielder, plumpy bold rhizome, 4.5% oleoresin, 4% crude fibre, 1.32% essential oil and 20% dry recovery, maturity 200 days</td>
<td>Kerala and adjoining states</td>
</tr>
</tbody>
</table>
Seed rate: Seed rate vary with the size or weight of the seed bits and may be 18-20 q/ha. Seed bits of 20-25 g having 2-3 eyes are generally recommended. The use of high seed rate may be advantageous if to compensate the high seed cost involved at the time of sowing the farmers can recover the healthy mother rhizomes.

Seed treatment: Treat the seed before sowing with a mixture of Dithane M-45 (0.25%) + Bavistin (0.10%) + Chloropyriphos (0.2%) for 60 minutes and dry in shade for 24 hrs as a safeguard against soft rot and to induce early sprouting. Rhizomes for seed are also treated in hot water at 48°C for 20 minutes before planting. Soaking seed rhizomes in water for 24 hours 10 days prior to planting results in good sprouting.

Spacing: Depending on the seed rhizome size and weight, agro-ecological situation etc. the spacing ranges 15-20 x 20-30 cm between plants and rows. Generally, closer spacing produces the higher yields. Under AICRP on Spices, general recommendation of spacing for whole of the country is 20 x 25 cm. Seed bit is placed 3-5 cm deep in the soil.

Manures and fertilizers: The general recommendation given by the AICRP on Spices is 100, 50, 50 kg NPK/ha. The FYM is applied either by broadcasting or by putting in the hole over the seed and cover with soil. Full dose of P and K applied at the time of field preparation, however, K can also be given in two splits, first half at the time of field preparation and second half 90 days after sowing. N is applied in three splits, first 1/3 at the time of field preparation, second 1/3 one month after germination and third 1/3 one month after second split. The beds are to be earthed up after each top dressing with the fertilizers. In ginger the total period of growth is categorized into three phases: active vegetative growth (90-128 days after planting; slow vegetative growth (129-180 days after planting) and phase approaching senescence (181 days onwards). Marked uptake of NPK is during active growth.

Mulching: Preferably locally available material like green or dry grass/ leaves, paddy straw, cane trash, banana leaves, mango leaves, oak leaves, pine
needles, FYM etc. can be used. One or two applications can be given; one at the time of sowing and the second 6-8 weeks after sowing. A range of 5-30 t/ha has been tried by different workers and generally 20-25 t/ha is recommended. The first mulching is done at the time of planting or just after planting in 4-5 cm thick uniform layer with green leaves @ 10-12 t/ha or dry leaves @ 5-6 t/ha. Mulching is to be repeated @ 5 and 2.5 t/ha green and dry leaves, respectively, at 40 and 90 days after planting, immediately after weeding, hoeing, earthing up and application of fertilizers. An increase in yield with mulching may be 50-100%. Under low shade mulching may be reduced without affecting the yield.

**Inter-cropping and cropping systems:** Ginger can be planted in young citrus and forest plantations/orchards up to 5-6 years of mango, litchi, citrus, apple, peach, pear, plum, coconut, coffee, areca nut etc. These also provide shade as it prefers partial shade. Annual crops like maize, chilli, okra, *Colocassia*, amaranths, gram etc are also found to be the best companion crops. Commonly rotated with turmeric, onion, garlic, chillies, other vegetables and maize; and groundnut in irrigated conditions. In NE States, ginger is grown under *jhoom/ shifting cultivation system*, where ginger rhizomes are planted on a virgin land after preparation and shifting to the new site to make use of the forest land rich in organic matter.

**Shade requirement:** Crop under 25% shade performed better. Maize growing in alternate inter row space has been found beneficial in comparison to sole cropping in terms of tillering and yield. Shade tolerance varies from cultivar to cultivar.

**Irrigation:** The total water requirement of ginger crop ranges between 1320-1520 mm during the complete crop cycle. The rhizomes from rain fed crop has more fibre than irrigated one raised under lower elevations. Studies have shown that sprouting, rhizome initiation (90 DAP) and rhizome development (135 DAP) are critical stages of irrigation.
**Drainage:** The excess water in the field whether it comes from over irrigation or from natural source or rain/snow water accumulation need to be immediately removed from the field to ensure normal crop growth.

**Earthing-up:** At least two earthing-ups one after 45-90 days and another after 135 days after planting should be done.

**Weed management:** Weeding is done just before fertilizer application and mulching, 2-3 weedings are required depending on the intensity of weed growth. The use of chemical weedicides like Simazine @ 1.5 L/ha or Basalin @ 2.0 L/ha or Attrazine applied immediately after planting as pre-emergence have been reported effective in controlling most of the weeds.

**Recovery of mother rhizomes:** The mother or seed rhizomes utilized as planting material can be removed or detached from ginger sprouts of 4-6 cm height without adversely affecting the further growth of the plant. Separated rhizomes can be used for spice purpose.

**Seed Certification:** The seed ginger produced in the new disease and insect-pests free pockets can be got produced by the respective State Departments of Agriculture of each state and made available to the farmers of the infested/prone areas. The Field and seed standard are not followed properly. With the result, recently the ginger crop has been severely infested with rhizome rot disease both in storage and fields and ginger yellows in the standing crop. Thus the fields are greatly affected and in some places the losses are 100%. Identification of new pockets which are disease free, need to be exploited for seed raising. Because the disease is transmitted through seed and the movement of diseased seed should be restricted. The seed ginger produced in the new disease free pockets can be procured and used in the infested areas and the farmers of both the pockets are benefited i.e higher returns from seed ginger and disease free, healthy seed ginger, respectively. Thus, keeping in view the above situation in the country, the growers should follow the production technology of quality seed ginger as under:
i. The rhizome used for seed shall be quite clean apparently, healthy, from apparently healthy field(s), plants, bold firm and shall confirm to the varietal characteristics of the variety. The seed rhizomes not confirming to the varietal characteristics shall not exceed 0.10% and 0.20% (by number) for foundation and certified seed classes, respectively.

ii. Cut, bruised, diseased, injured rhizomes or those damaged by maggots shall not exceed more than 0.20% (by weight).

iii. Maximum tolerance limit of rhizomes showing visible symptom caused by diseases-rhizome rot, ginger yellows and ginger maggots should be none for foundation and certified seed classes.

**Isolation:** There is no problem of crossing in ginger as it is vegetatively multiplied and normally there is no true seed set at all the places. It is better to provide an isolation distance of 10-15m between two varieties grown to avoid chance of mechanical admixture which not only contaminate the variety but also reduces the quality seed yields in the seed production programme.

**Rouging:** Rouging is an important operation done in ginger seed production. The removal of off-type plants and plants of other variety and weeds from the seed production field is known as rouging. Any plant(s) which are outside the acceptable limit of varietal variation are termed as off-type. Even some plants which confirm to the varietal characteristics may not be acceptable due to some undesirable traits/features are also known as undesirable plants. Generally, for maintaining purity of seed in ginger seed production, 3 or 4 rouging are done thoroughly before the crop maturity. First rouging is done after 2 months of sowing of crop to remove all the off-type plants. Keeping in view true to typeness of the plants viz. leaf colour, shape, size, diseases (soft rot, giner yellows and leaf spot) and insect pests attack. Second rouging should be done after 2 months of the first for the same characteristics. The third should be done just before lifting of the rhizomes for size, shape, colour disease (rhizome rot) and insect infestation etc. The rhizome rot infestation can be visually seen by breaking the rhizomes and seen that if there is yellowish ring formation below the corky cells such rhizomes should be discarded and others having grayish colour may be retained for seed.
Normally, the healthy fields may be irrigated or rain-fed prior to harvesting should be marked for seed ginger and eliminate the infested plants/ field. However, the fourth rouging is carried at the time of lifting of the rhizomes or before storage for size, shape, colour, designated disease (rhizome rot), insect infestation and injury, etc. The off-type rhizomes and old mother rhizomes should be culled.

**Post harvest handling of seed crop**

**Harvesting and yield:** The maturity of the seed crop is indicated by yellowing of foliage and there drooping down. The pseudo-stem get dried and falls down which indicates the maturity of rhizomes for seed purpose. Depending on the time of planting, management of the crops and the situations prevailing in the ginger growing areas, the seed crop normally get ready within 7-8 months. In hilly areas, particularly in Himachal Pradesh, the seed ginger crop gets ready for harvesting in November-December. The rhizomes are harvested/ uprooted carefully by spade or any other implement without injury to the rhizomes on small scale, but on large scale the ginger fields are ploughed with furrow turning plough in such a way that a minimum damage is done to the rhizomes. Then the healthy rhizomes are collected and kept in shade. The daughter rhizomes are separated from the mother rhizomes carefully without injury. The mother rhizomes are either consumed or sold and the daughter rhizomes are retained for seed after thorough screening. Maximum yield to the tune of 30-40 t/ha has been reported, however, 12-15 t/ha is generally obtained depending upon the variety and locality.

**Curing:** The selected healthy rhizomes retained for seed purpose are subjected for curing for at least 5-6 days in shade in a thin layer. Immediately after harvesting, the ginger rhizomes are kept in shade either in the field under trees and covered with the plant remains (pseudo-stems or tree leaves, etc.) or also may be kept in verandah or any other room till it is properly cured. During this period, these are freed from soil, roots, root hairs, stems etc. The excess moisture is also eliminated and more so if there is some cut, injury or damaged rhizomes get healed up because of suberisation process. The injury,
etc. may be caused during harvesting operation and while preparation for seed. These may be kept in a thick layer of not more than 10-15 cm. If the thickness is more than this, these may get rotted or loose their viability and become unsuitable for seed purpose. After proper curing, these may be checked thoroughly for any rhizome rot cured properly or is dry or wrinkled or diseased should be culled and then are stored properly.

**Storage of rhizome:** Conventionally the storage is done above or below ground. In above ground, the rhizomes are kept in heap on sand layer or paddy husk and covered with dry leaves and plastered with cow dung. In below ground, pits of size l x l x 1 m or as per requirement are made under shade/ shed. The walls of this pit are plastered with cow dung with a layer of sand at the base. Healthy and disease free rhizomes treated in solution of Dithane M-45 + Bavistin + Chloropyriphosph are placed loosely. Filling is done up to 10-15 cm below from the top. This top is covered with dry grass. The pit is closed with the help of wooden plank. Plaster the space between the planks with soil or cow dung. Keep or place a perforated PVC pipe of 2 inches diameter in the centre of the pit for removal of gases. The material is stored for 3-4 months and taken out from the pits at least 20-25 days before sowing.

Fully mature, big, plump rhizomes, free from diseases are selected after harvesting and treated before storage. A drum of 200 litres capacity is filled with 100 litres of water. Few litres of water is taken in a bucket added with 250 g Dithane M-45+100 g Bavistin+200 ml of Chloropyriphosph and mixed thoroughly. Then 80 kg rhizomes are steeped in the drum for 30 minutes. Solution is drained off and rhizomes are dried under shade and stored. Rhizomes are best stored by pit method.
References


Quality Seed Production of High Value Cucurbitaceous Vegetables for High Economic and Remunerative Returns

Ramesh Kumar Bhardwaj, Reena Kumari and Ankita Sharma
Department of Vegetable Science
YSP University of Horticulture and Forestry
Nauni 173230 Solan, Himachal Pradesh

Cucurbitaceous vegetable crops belong to family *Cucurbitaceae*, which primarily comprised of species which are consumed as food worldwide. The family consists of 118 genera and 825 species. Although most of them originated in old world, many species originated in the New World and at least seven genera in both hemispheres. There is tremendous genetic diversity within the family, and the range of adaptation for cucurbits species includes tropical and subtropical regions, arid deserts, and temperate regions. The genetic diversity in cucurbits extends to both vegetative and reproductive characteristics and considerable range in the monoploid (x) chromosome number including 7 (*Cucumis sativus* L), 11 (*Citrullus* spp, *Momordica* spp, *Lageneria* spp, *Sechium* spp and *Trichosanthes* spp), 12 (*Benincasa hispida, Coccinia cordifolia, Cucumis* spp other than *Cucumis sativus* and *Praecitrullus fistulosus*), 13 (*Luffa* spp), and 20 (*Cucurbita* spp). Cucurbitaceous vegetable forms the largest group of summer vegetables. The cucurbits are tender and thrive only in hot weather and do not withstand frost. These are grown for their fruits either used as salad (cucumber, gherkin and long melon) or for cooking (all the gourds), for pickling (gherkin) or as desert fruit (muskmelon and watermelon) or sweet preserved (ash gourd and pointed gourd). Most of the members of *Cucurbitaceae* family contain cucurbitacin a bitter glucoside. Though, this bitter principle is not poisonous but even its slight presence affects the taster and quality. There are different types of cucurbits such as:

1. **Annual cucurbits**: Cucumber

**Gourds**: Bottle gourd, bitter gourd, sponge gourd, ridge gourd, round gourd, snake gourd, wax gourd.

**Melons**: Muskmelon, watermelon, Long melon, Snap melon
**Pumpkin and squashes:** Pumpkin, Summer squash, Winter squash

**II. Perennial cucurbits:** Pointed gourd, Chayote, Kakrole, Kartol, Ivy gourd or little gourd.

Almost all cucurbits are mainly propagated by seeds except pointed gourd, little gourd, kakro and kartoli which are propagated by vegetative means.

**Floral Biology of different cucurbits:**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Anthesis time</th>
<th>Anther dehiscence</th>
<th>Stigma receptivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muskmelon</td>
<td>5.30-6.30 am</td>
<td>5.00 to 6.00 pm</td>
<td>2 hrs before anthesis and 3 hrs after anthesis</td>
</tr>
<tr>
<td>Cucumber</td>
<td>5.30-7.00 am</td>
<td>4.30-5.00 am</td>
<td>12 hrs before anthesis and 7 hrs after anthesis</td>
</tr>
<tr>
<td>Watermelon</td>
<td>6.00 – 7.30 am</td>
<td>4.45 – 6.30 am</td>
<td>2 hours before and 3 hour after anthesis</td>
</tr>
<tr>
<td>Bottle gourd</td>
<td>5.00-8.00 pm</td>
<td>1.00-2.30 pm</td>
<td>Up to 60 hrs of anthesis</td>
</tr>
<tr>
<td>Bitter gourd</td>
<td>5.00- 10.30 am</td>
<td>7.00-8.00 am</td>
<td>1 day before anthesis and 1 day after anthesis</td>
</tr>
<tr>
<td>Pumpkin and squashes</td>
<td>7.00-9.00 am</td>
<td>6.30-8.30 am</td>
<td>2 hours before and 2 hours after anthesis</td>
</tr>
</tbody>
</table>
## Soil, climate and other requirements of cucurbits:

<table>
<thead>
<tr>
<th>SN</th>
<th>Crop</th>
<th>Soil</th>
<th>Climate</th>
<th>Time of sowing</th>
<th>Seed rate</th>
<th>Manures and fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cucumber</td>
<td>Light to heavy soils</td>
<td>Warm season</td>
<td>Feb-March, May-June, <strong>In hills-</strong> April-August</td>
<td>4-5 Kg/h a</td>
<td>N-25 Kg P- 40 Kg K-40-60 Kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with pH 5.5 to 6.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Bottle gourd</td>
<td>Light soils pH 6.0-7.0</td>
<td>Summers and rainy season</td>
<td>Feb-March, June-July and Oct-November</td>
<td>6-8 Kg/h a</td>
<td>N-40 Kg P-40-60 Kg K-60-80 Kg</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Bitter gourd</td>
<td>Sandy loam soil</td>
<td>-do-</td>
<td>Plains-Jan- Feb, rainy season-June-July</td>
<td>4-6 Kg/h a</td>
<td>FYM-20-50t N- 20 Kg P- 30 Kg K- 30 Kg</td>
</tr>
<tr>
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</tr>
</tbody>
</table>
4. **Sponge gourd**  
Wide range  
Subtropical and tropical  
Jan- Feb for summer and June-July for rainy season  
4-5 Kg/h a  
FYM-10-15t  
N- 20-30 Kg  
P-30-40 Kg  
K- 30 Kg

5. **Round gourd or Indian squash**  
Sandy loam soils  
Warm season  
Plains- Jan-Feb, and May – June in hills  
3-5 Kg  
FYM-10-15t  
N- 40 Kg  
P-30 Kg  
K- 30 Kg

6. **Sanke gourd**  
Wide range  
Subtropical and tropical  
April-July and Oct- Nov.  
5-6 Kg  
FYM- 10-15t  
N- 40-60 Kg  
P-30-50 Kg  
K- 30-40 Kg

7. **Wax gourd**  
Sandy loam  
Warm season  
Feb-March on the river bed cultivation  
6-8 Kg  
FYM- 15-20t  
N- 40-60 Kg  
P-50-60 Kg  
K- 60-80 Kg
<p>| | | | | | |</p>
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>8.</td>
<td>Muskmelon</td>
<td>Sandy loam</td>
<td>pH 6-6.8</td>
<td>Hot and dry atmosphere</td>
<td>Dec. to March</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>9.</td>
<td>Watermelon</td>
<td>Sandy loam</td>
<td>pH 6.5-7.0</td>
<td>-do-</td>
<td>-do-</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>10.</td>
<td>Snap Melon</td>
<td>Wide range</td>
<td>Warm season</td>
<td>June-July</td>
<td>2-3 Kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Pumpkin</td>
<td>Heavy and light soils</td>
<td>Warm season</td>
<td>Summer and rainy season</td>
<td>6-8 Kg/ha</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>12.</td>
<td>Winter squash (Halwa kadu)</td>
<td>Light soils</td>
<td>Mild climate</td>
<td>Jan-April, Oct-November</td>
<td>4-6 Kg</td>
</tr>
<tr>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>
### 13. Chayote (Chow-chow)

- **Wide range**
- **Tropical and subtropical**
- **Late monsoon to early winter**
- **FYM**: 10-15 kg + 100g Urea + 100g SSP + 50g MOP

### 14. Kartoli Light medium or medium black soils

- **Rainy season**
- **FYM 10-15t**
- **N,P 40-60 Kg**

### 15. Ivy gourd Sandy loam

- **Warm and moist**
- **June-July or Feb-March**
- **FYM 10-15t**
- **N- 60 Kg P-80 Kg**

---

**Breeding Objectives:**

- Earliness
- High female: male sex ratio
- Short vine length with short internodes
- Light green, green and white skin colour
- Cylindrical fruits without crook neck
- Few or no spines, preferably white
- Few soft seeds at edible stage
- Fruits free from bitterness
- Edible fruits without carpel separation
- Higher yield, longer fruit duration and more number of fruits per plant
- High TSS (11-13%) and flavor of melons
- Resistance to various biotic and abiotic stresses
Variety/Hybrid Developed by different Breeding methods:

**Introduction:**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Introduced from</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cucumber</td>
<td>Japanese Long Green</td>
<td>Japan</td>
</tr>
<tr>
<td></td>
<td>Straight Eight</td>
<td>USA</td>
</tr>
<tr>
<td></td>
<td>Poinsette</td>
<td>USA</td>
</tr>
<tr>
<td>Water melon</td>
<td>Asahi Yamato</td>
<td>Japan</td>
</tr>
<tr>
<td></td>
<td>Sugar Baby</td>
<td>USA</td>
</tr>
<tr>
<td></td>
<td>Improved Shipper</td>
<td>USA</td>
</tr>
<tr>
<td>Summer Squash</td>
<td>Patty Pan</td>
<td>USA</td>
</tr>
<tr>
<td></td>
<td>Australian Green</td>
<td>USA</td>
</tr>
</tbody>
</table>

**Selection:**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Selection from</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muskmelon</td>
<td>Pusa Madhuras</td>
<td>Local Collection of Rajasthan</td>
</tr>
<tr>
<td></td>
<td>Hara Madhu</td>
<td>Local Collection of Haryana</td>
</tr>
<tr>
<td></td>
<td>Arka Jeet</td>
<td>'Bati” strain of UP</td>
</tr>
<tr>
<td>Cucumber</td>
<td>Sheetal</td>
<td>Local material of MH</td>
</tr>
<tr>
<td>Watermelon</td>
<td>Durgapura Meetha</td>
<td>Selection from local material</td>
</tr>
<tr>
<td></td>
<td>Durgapura Kesar</td>
<td>Selection from local material</td>
</tr>
<tr>
<td>Bitter gourd</td>
<td>Pusa Visesh</td>
<td>Local variety of Hapur, UP</td>
</tr>
<tr>
<td></td>
<td>Priya and Preethi</td>
<td>Local germplasm of Kerala</td>
</tr>
<tr>
<td></td>
<td>Arka Harit</td>
<td>Germplasm collected from Rajasthan</td>
</tr>
<tr>
<td>Bottle gourd</td>
<td>PSP Long and PSP Round</td>
<td>Local germplasm</td>
</tr>
<tr>
<td></td>
<td>Arka Bahar</td>
<td>Local cultivar of Karnataka</td>
</tr>
<tr>
<td>Variety</td>
<td>Parentage</td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>----------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Samrat</td>
<td>Local germplasm of Dahanu district of MH</td>
<td></td>
</tr>
<tr>
<td>Summer Squash</td>
<td>Inbred from segregating local variety of Punjab</td>
<td></td>
</tr>
<tr>
<td>Pumpkin</td>
<td>Germplasm of Rajasthan</td>
<td></td>
</tr>
<tr>
<td>Pusa Viswas</td>
<td>Local line ‘CM 10’</td>
<td></td>
</tr>
</tbody>
</table>

**Hybridization followed by selection (Pedigree method)**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Parentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muskmelon</td>
<td>Pusa Sharbati</td>
<td>Kuntana x Resistant No. 6</td>
</tr>
<tr>
<td></td>
<td>Punjab Sunheri</td>
<td>Hara Madhu x Edisto</td>
</tr>
<tr>
<td></td>
<td>Punjab Rasila</td>
<td>WMR 29 x Hara Madhu</td>
</tr>
<tr>
<td>Cucumber</td>
<td>Himangi</td>
<td>Poinsett x Kalyanpur Ageti</td>
</tr>
<tr>
<td></td>
<td>Phule Shubhangi</td>
<td>Poinsett x Kalyanpur Ageti</td>
</tr>
<tr>
<td>Watermelon</td>
<td>Arka Manik</td>
<td>IIHR 21 x Crimson Sweet</td>
</tr>
<tr>
<td>Bitter gourd</td>
<td>Phule Green</td>
<td>Green Long x Delhi Local</td>
</tr>
</tbody>
</table>

**Heterosis breeding**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Parentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muskmelon</td>
<td>Pusa Rasraj</td>
<td>Monoecious 3 x Durgapura Madhu</td>
</tr>
<tr>
<td></td>
<td>Punjab Hybrid</td>
<td>ms 1 x Hara Madhu</td>
</tr>
<tr>
<td>Cucumber</td>
<td>Pusa Sanyog</td>
<td>Japanese Gynoecious line x Long Green Naples</td>
</tr>
<tr>
<td>Watermelon</td>
<td>Arka Jyoti</td>
<td>IIHR 20 x Crimson Sweet</td>
</tr>
<tr>
<td>Bottle Gourd</td>
<td>Pusa Meghdoot</td>
<td>PSP Long x Sel. 2</td>
</tr>
<tr>
<td></td>
<td>Pusa Manjari</td>
<td>PSP Round x Sel. 11</td>
</tr>
</tbody>
</table>
Summer Squash Pusa Alankar EC 207050 x Sel. 1

**Mutation breeding: Bitter gourd: MDU 1:** Gamma irradiation (50Kr) on local selection MC 103

**Polyploidy breeding: Watermelon: Tetra 2:** Diplodisation of chromosomes of a local cultivar through 0.2% colchicine treatment. This line was used as parent in evolution of Pusa Bedana, a triploid female variety.

**VARIETAL IMPROVEMENT WORK AT DEPARTMENT OF VEGETABLE SCIENCE, UHF, NAUNI, SOLAN**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Varieties</th>
<th>Varietal descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cucumber</td>
<td>Khira 75</td>
<td>Local selection, prolific growth, fruits are well filled up to end, smooth, light green, cylindrical and 10-15 cm length. Ready for picking after 75 days.</td>
</tr>
<tr>
<td></td>
<td>Khira 90</td>
<td>Local selection, vigorous vines. Fruits are well filled up to end, smooth, light green, cylindrical, 15-20 cm long. Ready for picking after 90 days.</td>
</tr>
<tr>
<td></td>
<td>KH 1</td>
<td>Gynoecious based early maturing F&lt;sub&gt;1&lt;/sub&gt;, bears 10-12 cm long fruits, ready for harvesting in 65 days, yields 30-40 t/ha.</td>
</tr>
<tr>
<td></td>
<td>KH 2</td>
<td>Gynoecious based F&lt;sub&gt;1&lt;/sub&gt;, vines reach up to 5m with 4-5 lateral branches, and fruits are cylindrical, 20-23 cm in length, black spine. Average yield 55-60 t/ha. Suitable for low temperature areas.</td>
</tr>
<tr>
<td>Bitter gourd</td>
<td>Solan Hara</td>
<td>Fruits are 20-25 cm length and 4-5 cm thick, green, white fleshed and spongy with high keeping quality. Ready for harvesting in 75 days, yields 15-17.5 t/ha.</td>
</tr>
<tr>
<td></td>
<td>Solan Safed</td>
<td>Fruits are 22-25 cm length and 4-6 cm thickness, takes 80 days for maturity, yield 17.5 t/ha.</td>
</tr>
</tbody>
</table>
Pumpkin
Solan Badami

| Pumpkin | Solan Badami | Vigourous vines, early, prolific bearer (40-50 t/ha), orange coloured medium sized fruits having thick flesh and good keeping quality. |

**Seed Production:** Cucurbits seed are variable in size, shape and structure, traits which are used in family classification. The high economic value of some species including cucumber, melons and squash increase the importance of studying their optimal seed production. Most seed production in the Cucurbitaceous crops is directed for propagation. However, in some parts of the world cucurbits seed (Mainly watermelon and squash) are produced and consumed as snack food because their nutritive value is high. For quality seed production the following major basic requirements must be taken into consideration:

**Requirement of seed production:** The basic requirement of seed production is availability of improved varieties/hybrids and their demand among the farmers. Preferably the variety should be released and notified for certified seed production; however, any kind/variety can be multiplied for Truthfully Labeled Seed (TFL).

**Land selection:** The land selected should be free from volunteer plants, wild species and objectionable weeds. The land should be fertile with good drainage facility.

**Seed selection and treatment:**

Selection of seed is the first step in production of quality seed. This involves selection of seeds with the right genetic make-up of the variety chosen to be produced. Seeds must be from an approved source. This is possible if the seed is got from the breeding firm / university research station or from the breeder himself. Verify if the seed brought for sowing has breeder seed tag (for producing foundation seed); foundation seed tag (for production of certified seed). Further, the seeds must be free from pest and diseases. Rotten, dull colored, black spotted seeds must be removed. Seeds of uniform size and
shape alone must be used for sowing. Certified seeds should be obtained from an authorized source. Seeds should be healthy and free from disease and pest infection. Remove the broken, colored seeds and use uniformly graded seeds. Seeds should be soaked in a solution of cow’s urine (1 part cow’s urine + 5 parts of water) for 30 minutes prior to the sowing. This will inhibit the seed borne diseases. Treat the seeds with *Trichoderma viride* @ 4 gms/kg of seeds. Treated seeds should be sown in the main field ploughed for 3 – 4 times. Seeds are sown at 2 cm depth and the field should be irrigated before seed sowing. Seedlings of more than three are thinned out 15 days after sowing.

**Nutrient management:** Farm yard manure or compost is applied @ 10 tones/acre (25 tones/ha) before last ploughing and incorporated into the soil. In each sowing pit, farm yard manure or compost @ 1 kg mixed with 100 gms of neem cake is applied as basal manure. One month after sowing apply 500 gms of vermicompost per plant as top dressing. The flower drop in the crop can be controlled by spraying *Asafoetida* solution (125 gms of *Asafoetida* in 1 litre of water) over the plants.

**Weed management:** Weeding is most important during all growth stages of the crop. The field should be maintained clean by frequent hand weeding. Periodical removal of objectionable weeds should be done.

**Irrigation:** First irrigation is done before sowing. Subsequent irrigation should be done once a week or depending upon the rains. Irrigation during flowering and fruit setting stages are very crucial.

**Pest and disease management:** Cucumber is commonly affected by pests like fruit fly, aphids and diseases like powdery mildew and downy mildew at different growth stages.

**Isolation requirements:** The cucurbits are cross pollinated in nature and honeybees are major pollinator, thus for pure seed production an isolation distance all around seed field is necessary to separate it from fields of other
varieties, fields of the same variety not confirming to varietal purity requirement. The isolation distance of 400 m for C.S. and 800 m for F.S. and at least 1000 m isolation is required for breeder seed production.

**Crossable species**
- Muskmelon from snap melon and long melon
- Cucumber from Indian wild cucumber (*C. sativus* var. *hardwickii*)
- Watermelon from round melon and wild sp. (*Citrullus colocynthis*)
- Bitter gourd from wild species (*M. charantia* var. *muricata*)
- Bottle gourd from wild species (*Lagenaria sphaerica*)
- Pumpkin from squashes

**Choice of season and areas of seed production:** Seed crop should be raised in such a season which remain dry at the time of seed maturity and seed extraction. Rainy season is preferred over summer season for raising seed crop.

Locations are also important in seed production with reference to seed yield and quality of seed. To harness the advantage of climate, private sector seed companies are organizing their seed production in these areas. The Jalana (Aurangabad) in Maharashtra, Ranibenur and around Bangalore in Karnataka, Nandyal Valley in A.P., are the main areas of seed production.

**Major cucurbits seed production regions in India**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Areas</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muskmelon, Longmelon</td>
<td>Punjab &amp; Haryana</td>
<td>Northern Region</td>
</tr>
<tr>
<td>Bittergourd</td>
<td>Eastern UP, Faizabad and Jaunpur</td>
<td>Northern Region</td>
</tr>
<tr>
<td>Cucumber and Muskmelon</td>
<td>Azamgarh, Ballia and Gonda in UP,</td>
<td>Northern Region</td>
</tr>
<tr>
<td></td>
<td>Jalana (Maharashtra)</td>
<td>Central Region</td>
</tr>
<tr>
<td>Pumpkin and Ridge gourd</td>
<td>West Bengal (South West)</td>
<td>Eastern Region</td>
</tr>
<tr>
<td>Sponge gourd, Watermelon, Cucumber</td>
<td>Telingana, Karool and Vijayawada (North AP), Ranibenur (Karnataka)</td>
<td>Southern Region</td>
</tr>
</tbody>
</table>
Roguing: Seed crop is to be monitored at various stages of crop growth for removal of off-type and obviously should be carried out before flowering to avoid natural cross-pollination. However, fruit set and complete fruit development stages are also important.

The crop-wise main features described here under for effective rouging:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muskmelon</td>
<td>Fruit shape, colour, rind colour, skin (netted/plain), flesh colour (orange/red), TSS and cavity size.</td>
</tr>
<tr>
<td>Watermelon</td>
<td>Fruit shape, colour, rind colour, flesh colour (red/yellow/white).</td>
</tr>
<tr>
<td>Longmelon</td>
<td>Fruit shape, colour, bitterness.</td>
</tr>
<tr>
<td>Cucumber</td>
<td>Fruit shape, colour, presence of spines, spines colour, colour of ripen fruit (green, yellow, white or orange)</td>
</tr>
<tr>
<td>Pumpkin (Squash, summer)</td>
<td>Fruit shape, colour, flesh colour.</td>
</tr>
<tr>
<td>Gourds (Bottle gourd, Bitter gourd &amp; Luffa etc.)</td>
<td>Fruit shape, colour, stripe, neck etc.</td>
</tr>
</tbody>
</table>

Maturity of fruit: Cucurbits takes fairly long time to attain harvestable maturity. The maximum period is required in crops like pumpkin (*Cucurbita moschata*), ash gourd and watermelon, however, muskmelon, round melon and bitter gourd take relatively less time. The maturity also influenced by the environmental factors and crop management (trailing etc.). Besides days to maturity, some other parameters like change in color also used as criteria of maturity index.

**Cucumber and summer squash:** Fruit turn pale yellow to golden yellow and attached with plant.
**Pumpkin:** Fruit attain red colour and seeds inside the shell break readily from pulp.

**Muskmelon:** Full slip stage.

**Watermelon:** Fruits are ready for harvest when they reach edible maturity, fruit color change from green/white to pale yellow of underside of the fruit.

**Bitter gourd and snake gourd:** Fruit turn to bright yellow.

**Bottle gourd:** At maturity fruit color fade to straw green or pale yellow.

**Luffa:** Complete drying/fruit turn to gray color.

2. **Hybrid seed production of cucurbits**

Hybrid is produced by crossing between two genetically dissimilar parents. Pollen from male parent (Pollen parent) will pollinate, fertilize and set seeds in female (seed parent) to produce F1 hybrid seeds. For production of a hybrid crossing between two parents is important, the crossing process will results in heterosis.

**Hybrid development in cucurbits:** Hayes and Jones (1916) were the first to observe the heterosis in cucumber (*Cucumis sativus* L). The phenomenon of ‘hybrid vigour’ expressed particularly in the first generation (F1) following the crossing of cultivars or inbred lines, has been known for more than hundred years. The term heterosis, coined by G.H. Shull in 1909 suggests a mechanism based on heterozygosity and therefore is not fixable in the homozygous state of later generation progenies. Heterosis is the superiority of the F1 hybrid over the parents involved. While the heterosis in positive direction is useful for yield and component traits, the same in negative direction would also be a welcome feature for traits like maturity, disease incidence etc. The first F1 hybrid of watermelon was developed in 1930. The first F1 hybrid in public sector in Bottle gourd was Pusa Meghdoot, Pusa Manjari released by IARI, New Delhi. Hybrid cultivars are commercialized in selected cucurbits, which express desirable heterosis for yield.
Manifestations of heterosis

The superiority of hybrid over parents may be in yield, quality, disease and insect resistance, adaptability, general size or the size of specific parts, growth rate, enzyme activity etc.

1. **Increased yield**: Commercially this is of great importance since high yield is the top most priority in any plant breeding programme.

2. **Increase in size and general vigour**: The hybrids are generally more vigorous, i.e., healthier and faster growing and larger in size than their parents. The increase in size is usually a result of an increase in the number and size of cells in various plant parts.

3. **Greater resistance to diseases and pests**: Some hybrids show greater resistance to pests and diseases than their parents.

4. **Greater adaptability**: Hybrids are generally more adapted to environmental changes than the inbreds.

Adoption of hybrid cultivars favored because:

1. **Easy identification of male & female flower**: In HSP major problem for breeders to separate male and female reproductive organ. But in case of cucurbits we can easily identify female due to presence of swollen hypogynous ovary.

2. **Large size of flower**: Cucurbits have large size of flower so that hand pollination, emasculation, pollen collection become easy.

3. **High number of seeds per fruit**: Due to large size of fruits, by a single crossing we can obtain a large no. of seed.

4. **Relatively low number of seed required for establishment**: Less no of seed required as compared to open pollinated seed.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Hybrid seed rate (g/ha)</th>
<th>OP seed rate (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cucumber</td>
<td>375</td>
<td>2-3</td>
</tr>
<tr>
<td>Gourds</td>
<td>500</td>
<td>5-7</td>
</tr>
<tr>
<td>Melons</td>
<td>750</td>
<td>3-5</td>
</tr>
</tbody>
</table>
5. **Cost-efficient hybrid seed production**: Reduces labor cost by use of male sterile line, gynoecious line etc.

6. **Modification of sex form**: By the application of PGR we can modify the sex expression of cucurbits and used in HSP.

7. Pollen production capacity of male plant and longer duration of stigma receptivity.

**Three Steps in F1 Hybrid Seed Production:**

Three steps involved in F1 hybrid seed production are:

1. **Development of inbred line and their production**: The inbred lines developed through exploiting inbreeding depression and fixation of the desired traits in them. The seed of the developed lines are produced in isolation or by hand pollination.

2. **Testing of combining ability**: The combining ability (gca/sca) is tested by line x tester or diallel cross method. Successful exploitation of hybrid vigour depends upon combining ability (GCA/SCA) of parental line and technique used for economical HSP. It has been observed that some variety have better ability to transmit high yield & quality to their progeny. Sometimes there are also differences in reciprocal hybrids. SCA gives better predictive information than GCA of parents.

3. **Production of F1 hybrid seed**: Techniques have been developed and is variable for crop to crop.

**Techniques of Hybrid Seed Production:**

1. **Hand emasculation and hand pollination**:  
   This technique is applicable for limited scale production, since lot of trained labour are required in pinching, pollen collection and hand pollination.

2. **Hand emasculation and pollination by insect**:  
   The male flowers from female lines are pinched off day before of anthesis regularly, which honeybees and other insects (voluntary) uses as a pollinizer.
The male and female are grown in alternate rows. The planting ratio varies within the crops e.g. in summer squash it is 2:1 to 5:1 and 5:1 to 8:1 in muskmelon and in cucumber is 4:1, in Watermelon it is 5:1 to 6:1, and in Bottle gourd it is 1:1. The fruit set on female lines are of hybrid and harvested for seed extraction. The technique used in bottlegourd, pumpkin, muskmelon, cucumber, summer squash and bittergourd for hybrid seed production.

3. Use of genetic male sterility system: Genetic male sterility system has been utilized for commercial hybrid production in muskmelon (Punjab Hyb.-1). The genetic male sterility in muskmelon controlled by single recessive gene (msms). For hybrid seen production, the male sterile line used as female parent. Since genetic male sterile line is maintained in heterozygous forms, 50% fertile plants are to be removed at flowering. The other 50% having non-dehiscent empty anther are retained in female rows. The female and male are grown in 4:1 ratio. However, to maintain the good plant population in female rows it is suggested that seed parent should be sown with double seed rate. It is also advised that female line seedling should be raised in polythene bags and transplanted at flower appearance in order to avoid the fertile plants in female rows. The pollination is done by honey bees and 1 to 2 medium sizes hives are good enough to ensure the good pollination and fruit set at female row. The male sterile line is maintained in heterozygous form by crossing with maintainer line under adequate isolation distance or under cover.

4. Use of gynoecious sex form: The gynoecious sex form has been commercially exploited in hybrid seed production of cucumber (Pusa Sanyog) at IARI R.S. Katrain and in muskmelon (MH-10) at PAU, Ludhiana. For hybrid seed production female and male rows are planted in 4:1 ratio. The female (seed parent) bear only female flowers and pollination in done by insect (honeybee). To ensure the good fruit and seed recovery, the sufficient population of honeybee 1 to 1½ colony of medium size has to be kept at the boundry of seed production plot to boost the amount of crossing. The parental lines i.e. male parent maintained by selfing (mixed pollination) and rouge out undesirable plants before contamination take place. The female lines i.e. gynoecious lines maintained by inducing the staminate flower through the
sprays of silver nitrate 200 ppm at two to four true leaf stage and then selfing is carried out. It was observed that 10-11 male flowers appear per 100 nodes. The performance of gynoecious lines is unstable under high temperature and long photo period conditions because of their thermo-specific responses for gynoecious stability. That is why the gynoecious cucumber did not receive much attention in the tropical countries. However, few true breeding tropical gynoecious lines in cucumber and muskmelon have been developed at IARI. As a result of development of true breeding line, muskmelon hybrid Pusa Rasraj was developed. These homozygous gynoecious lines are maintained by using GA3, 1500ppm or silver nitrate 200-300 ppm or sodium thio sulphate 400 ppm to induce staminate flowers at two and four true leaf stage. Homozygous lines are planted in strict field isolation. The gynoecious lines are crossed with monocious male parent to produce F1 hybrid.

5. Pinching of male flower (Defloration): Production of hybrid seeds by this method is the most simple and economical and can easily be adopted by the grower who can identify male and female flowers. F1 hybrid production in gourds can economically be done on large scale by pinching all the male flowers before opening from the female parent and the male parent is allowed to grow side by side female parent for natural cross pollination in isolation. One row of the male parent can be sown after every three row of female parent for producing F1 hybrid seed on large scale in bottle gourd. All the fruit set in female parent would be necessarily through cross pollination by insects. For this, as a precaution, there should not be a single male bud in female parent as it will promote self or sib pollination with in the female parent. Anthesis of the flowers of bottle gourd is in afternoon, the pinching operation should therefore be done in the forenoon. As the male flowers in bottle gourd, pumpkin and squash are quite big, showy, having long pedicle, and less in number, the pinching operation can easily be performed. In _Luffa_, where the male flowers are produced in racemes, pinching off male buds will not be complete and effective. For maximum fruit set and seed yield, availability of
pollinator is prerequisite. One medium sized bee colony per hecatre would be enough in seed production block.

**6. Hybrid seed production through modification of sex expression:** The hybrid seed can also be produce in cucurbits by the application of PGR for attaining the sex of cucurbits. Specific chemicals are known to induce femaleness and maleness as desired. In cucurbits many type of sex forms have been reported.

**Different sex forms in cucurbits:**

<table>
<thead>
<tr>
<th>Sex form</th>
<th>Crop spp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hermaphrodite</td>
<td>Satputia cultivar of Ridge gourd and rare: Pumpkin and Summer squash</td>
</tr>
<tr>
<td>Monoecious</td>
<td>Cucumber, Musk and Watermelon, Round and Snap gourd, Pumpkin, Squash, Ash gourd, Bitter, Bottle, Ridge, Sponge and Snake gourd.</td>
</tr>
<tr>
<td>Andromonoecious</td>
<td>Muskmelon,Cucumber (var. Lemon) also reported in some breeding line of Watermelon</td>
</tr>
<tr>
<td>Gynoecious</td>
<td>Bitter gourd, Muskmelon and Cucumber</td>
</tr>
<tr>
<td>Gynomonoecious</td>
<td>Cucumber, Ridge gourd</td>
</tr>
<tr>
<td>Androecious</td>
<td>Ridge gourd, Cucumber and Muskmelon</td>
</tr>
<tr>
<td>Dioecious</td>
<td>Pointed gourd, Ivy gourd and Spine gourd</td>
</tr>
<tr>
<td>Trimonoecious / Gynoandromonoecious</td>
<td>Reported in some species of <em>Momordica</em> and <em>Cucumis melo</em>, rarely cucumber</td>
</tr>
</tbody>
</table>

**Sex ratio is affected by** – Environment, nutrient, photoperiodism, temperature.
• Short day with mild temp promotes pistillate flower.
• Long day with high temp usually promotes greater no. of staminate flower.

**Role of PGR in cucurbits:**

**General recommendations for sex modification through chemicals and PGRS**

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Chemical (s)</th>
<th>Conc. (ppm)</th>
<th>Crop(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For inducing staminate (male)</td>
<td>Gibberellic acid (GA$_3$)</td>
<td>1500-2000</td>
<td>Most monoecious cucurbits</td>
</tr>
<tr>
<td>flowers</td>
<td>Silver nitrate (AgNO$_3$)</td>
<td>200-300</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Silver thiosulphate (Ag$_2$S$_2$O$_3$)</td>
<td>300-400</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amino ethoxy vinyl glycine (AVG)</td>
<td>50-100</td>
<td></td>
</tr>
<tr>
<td>For inducing pistillate (female)</td>
<td>Tri-iodo benzoic acid (TIBA)</td>
<td>25-50</td>
<td>Watermelon</td>
</tr>
<tr>
<td>flowers</td>
<td>Ethrel</td>
<td>250-400</td>
<td>Bottle &amp; Bitter gourd</td>
</tr>
<tr>
<td></td>
<td>Ethrel</td>
<td>250-500</td>
<td>Rest all monoecious sp.</td>
</tr>
<tr>
<td></td>
<td>Napthalene Acetic Acid (NAA)</td>
<td>25-100</td>
<td>Ridge &amp; Sponge gourd</td>
</tr>
<tr>
<td></td>
<td>Maleic hydrazide (MH)</td>
<td>50-150</td>
<td>Most monoecious sp.</td>
</tr>
</tbody>
</table>

**Commonly utilized mechanism/methods for developing commercial hybrids:**

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Commercially exploited crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagging/protection of staminate &amp; pistillate</td>
<td>Bottle gourd, pumpkin, watermelon</td>
</tr>
<tr>
<td>flowers + MP</td>
<td></td>
</tr>
</tbody>
</table>
Pinching of staminate flowers +MP/NP | Bitter gourd, bottle gourd, pumpkin, watermelon
---|---
Gynoecism + NP | Cucumber, Muskmelon
PGR & pinching of staminate flowers + NP | Summer squash, winter squash

MP= manual pollination, NP= Natural pollination, PGR= plant growth regulator

**Important points to be considered for quality seed production:**

Different activities carried out for F1 hybrid seed production of cucumber, Squash, Muskmelon and Watermelon are given in table.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Cucumber</th>
<th>Squash</th>
<th>Muskmelon</th>
<th>Watermelon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trailing/Pruning</td>
<td>Single Stem</td>
<td>Top cutting</td>
<td>Trail upright</td>
<td>Pinching of lower &amp; upper female flower</td>
</tr>
<tr>
<td>Fruiting node</td>
<td>8th node</td>
<td>12-25th node</td>
<td>11-16th node</td>
<td>12 fruit middle node (12-15 node)</td>
</tr>
<tr>
<td>Duration of pollination</td>
<td>10-15 days</td>
<td>10 days</td>
<td>15 days</td>
<td>7-10 days</td>
</tr>
<tr>
<td>Harvesting (days after pollination)</td>
<td>35-50 days</td>
<td>40-45 days pollination</td>
<td>full slip stage</td>
<td>55-65 days (fully ripe)</td>
</tr>
<tr>
<td>Planting ratio</td>
<td>4:1</td>
<td>2:1 to 5:1</td>
<td>5:1 to 8:1</td>
<td>5:1 to 6:1</td>
</tr>
<tr>
<td>Curing of fruit</td>
<td>7-10 days</td>
<td>one month</td>
<td>7-10 days</td>
<td>7-10 days</td>
</tr>
<tr>
<td>Seed yield (ha)</td>
<td>300-500 kg.</td>
<td>350-500 kg</td>
<td>200-300 kg.</td>
<td>100-250 kg.</td>
</tr>
<tr>
<td>Seed extraction</td>
<td>fermentation</td>
<td>fermentation</td>
<td>fermentation</td>
<td>Fermentation</td>
</tr>
</tbody>
</table>

**Seed Extraction**

There are two method of seed extraction employed in cucurbits.

**1. Dry method:**

The dried fruits are cut from one side and the seeds comes out from the fruit e.g. sponge gourd, ridge gourd, snake gourd.
2. **Wet method:**

This method is employed for seeds extraction of cucumber, muskmelon, watermelon, ash gourd, bitter gourd, round melon and long melon. The fruit of cucumber and bitter gourd, summer squash and long melon are cut longitudinally and seed is scooped out while fruit of muskmelon and pumpkin are cut into two pieces and seed is scooped out from cavity. However, in case of watermelon and ash gourd whole central portion are manually scooped out and macerated to separate the seed from pulp. In wet method, the seed extraction done by three ways:

1. **Mechanical Extraction:** In this method the fruits are cut into pieces and macerated by machine. The seeds are separated out from pulp by floating with water. This method is quick, less expensive and seeds retain good lusture, but require good amount of water. This method is applicable in bottle gourd, watermelon, round melon and ash gourd.

2. **Natural Fermentation:** The scooped material kept in wooden/plastic or steel vessel for 48 hours at room temperature and stirred 2-3 times and then seed is washed thoroughly with water 2-3 times. The main problem with this method is discolouration and poor lusture of seed.

3. **Chemical Extraction:** 25-30 ml. of HCL or 8-10 ml. of commercial H2SO4 added per 5 kg of pulp and some quantity of water is mixed, stirring of pulp is done to enhance to separation and left for 30 minutes. The impurities will float and seed will sink. The seed should be washed thoroughly with clean water. This is quick method but accuracy of acid and time is important.

**Seed Yield**

Seed yield depends upon the crop, variety, location, season and management of the seed crops.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Days after pollination</th>
<th>Seed yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muskmelon</td>
<td>40-45</td>
<td>100-150</td>
</tr>
<tr>
<td>Cucumber</td>
<td>35-40</td>
<td>80-150</td>
</tr>
<tr>
<td>Watermelon</td>
<td>45-50</td>
<td>200-300</td>
</tr>
</tbody>
</table>
Bitter gourd  |  28-30  |  60-120  
Bottle gourd |  45-50  |  60-120  
Pumpkin      |  65-70  |  100-300 

Seed drying:
Immediately after seed extraction, it has to be properly dried, since seeds were extracted from 100% moist condition. The extracted seeds should spread on gunny bags in a thin layer and dried under shade for 8 to 10 hours for one or two days. Then, seeds can be dried under direct sunlight between 8 am to 12 noon and 3 to 5 pm. Avoid drying in between 12 to 3 pm since the rays emitting from sun and the heat may affect the seed viability. While drying care must be taken to avoid clogging. The extracted seed should not be dried directly under sun. Since seed possesses high moisture it may affect the germination potential. Similarly, while drying frequent stirring is more important otherwise it leads to clogging. This may result in improper drying, fungus growth and poor vigour.

Seed cleaning and processing
After proper drying seeds have to be processed. By removing the ill filled and small size seeds, vigour and viability are improved. For bitter gourd seed processing BSS 4 wire mesh sieve is to be used. After sieving, those seeds that are broken, fungal infected, seed coat damaged are removed.

Protecting seeds during storage
Producing quality seeds is only half of the job, the other half is protecting the seed during its storage that starts after processing till it is sown by the farmer. The major aspects that impart good storability are adequate seed moisture, seed treatment, mid storage correction and seed storage container.

Seed moisture
Seed moisture is the foremost seed physical attribute that contributes for storage life. Lower the seed moisture, longer the shelf life. Short term storage can be achieved by drying the seeds to 7-8% moisture content while
long term storage is possible by reducing the seed moisture even further to 6%. Under such low moisture content, seeds have to be stored in moisture proof bags made of thick polythene (700 guage).

**Seed treatment**

Prior to storage, seeds are treated with fungicide to ward off fungal pathogens. Seeds are mixed with Carbendazim 4g/kg. A novel technique called Halogen permeation treatment is also recommended now-a-days. Calcium oxy-chloride, commercially known as bleaching power and powdered calcium carbonate (lime stone) is mixed in equal ratio. This mixture is added to seed 5g/kg and stored.

**Seed container**

Apart from seed and seed treatment, the next most important aspect of seed storage is seed container. Container can be chiefly differentiated as moisture pervious and moisture impervious types. Cloth, paper and gunny bags are moisture pervious as the moisture from outside atmosphere can enter and exit freely. Hence, even if the seed is dried to safe moisture, but stored in humid climate, then seed gain moisture during storage and looses vigour. So, to safely store seeds in moisture previous bag, the outside humidity must be low. In Tamil Nadu, most of the months are hot and humid, hence after drying the seed to safe moisture limit, seeds can be safely stored in moisture impervious bag like thick polythene bags of 700 g or in tin / plastic containers that are sealed tightly. In case of short term storage (4-6 months) cloth or gunny will be sufficient.

**Seed certification:**

Seed certification will give guarantee for genetic purity and other qualities. It is a legally sanctioned system for quality seed production. The supply of improved varietal seed to the farmers with high genetic purity, physical purity and germinability are being the main objectives of the seed certification. Seed certification acts at different stages from sowing to issue the tags and sealing the bags. They start their function by verifying the seed source before the seeds are sown, then verifying the isolation distance
followed for that seed crop, taking field inspections at different stages viz., bagging operations. In addition to these operations, it is their duty to send samples to seed testing laboratory and after receiving the results, they will be issuing the certification tags. The seeds so produced will be issued certification tag only after meeting out the prescribed field and seed standards.

Hence, by registering the seed production fields under seed certification we could able to produce genetically as well as physically pure seeds. The private seed producers can also subject their seed production fields under seed certification for quality seed distribution.

**Minimum seed standards:**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Seed type</th>
<th>Pure seed (Min.) (%)</th>
<th>Inert matter (Max.) (%)</th>
<th>Other crop seed (Max/kg)</th>
<th>Weed seed (Max/kg)</th>
<th>Germination (Min) (%)</th>
<th>Moisture (%)</th>
<th>Normal</th>
<th>Vapour proof container</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cucumber</td>
<td>F</td>
<td>98.00</td>
<td>2.0</td>
<td>5</td>
<td>None</td>
<td>60</td>
<td>7.0</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>98.00</td>
<td>3.0</td>
<td>10</td>
<td>None</td>
<td>60</td>
<td>7.0</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>Bottle gourd</td>
<td>F</td>
<td>98.00</td>
<td>2.0</td>
<td>None</td>
<td>None</td>
<td>60</td>
<td>7.0</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>98.00</td>
<td>2.0</td>
<td>None</td>
<td>None</td>
<td>60</td>
<td>7.0</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>Bitter gourd</td>
<td>F</td>
<td>98.00</td>
<td>2.0</td>
<td>None</td>
<td>None</td>
<td>60</td>
<td>7.0</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>98.00</td>
<td>2.0</td>
<td>None</td>
<td>None</td>
<td>60</td>
<td>7.0</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>Watermelon</td>
<td>F</td>
<td>98.00</td>
<td>2.0</td>
<td>None</td>
<td>None</td>
<td>60</td>
<td>7.0</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>98.00</td>
<td>2.0</td>
<td>None</td>
<td>None</td>
<td>60</td>
<td>7.0</td>
<td>6.0</td>
<td></td>
</tr>
</tbody>
</table>

**References:**


**Advances in Quality Seed Production of Temperate Root Vegetables**

Ramesh K Bhardwaj, Ankita Sharma and Reena Kumari

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The temperate root vegetables occupying a significant position include mainly beet, temperate varieties of carrot, radish and turnip. Although all belongs to different families, but have similar cultural practices. These crops are also commonly known as European or biennial vegetables.

Production Technology: The improved cultural practices play a crucial role in realizing the maximum yield potential of a variety/hybrid chosen for growing. A brief package of practices for successful cultivation of different temperate vegetables has been summarized as below:

Varieties:

A lot of improvement work has been done, though all of these crops are introduced ones. Popularly grown varieties (open-pollinated) and hybrids (both from public and private sectors) are enlisted in table-1.

Table-1. List of popular varieties and hybrids

<table>
<thead>
<tr>
<th>Crop</th>
<th>Popular varieties</th>
<th>Popular hybrids</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carrot</strong></td>
<td>Chantenay, Denver, Nantes, Early Horn, Zeno, Early Gem Imperator, Pusa Yamdagini and Solan Rachna</td>
<td>Pusa Nayanjyoti (Katrain),</td>
</tr>
<tr>
<td><strong>Radish</strong></td>
<td>Japanese White, White Icicle, Rapid Red White Tipped (RRWT), Chinese Pink, Scarlet Globe, Scarlet Long and Pusa Himani</td>
<td>-</td>
</tr>
<tr>
<td><strong>Turnip</strong></td>
<td>Snow Ball, Golden Ball, Purple Top White Globe (PTWG), Pusa Swarnima and Pusa Chandrima</td>
<td>-</td>
</tr>
</tbody>
</table>
**Beet root** | Crimson Globe and Detroit Dark Red | -

**Advanced production practices:** All the root vegetables are sown directly in the field. Seeds are usually sown in the shallow furrows of 2 cm depth on ridges. After sowing the ridges are kept moist till the germination is completed. The seed of beet root is *multigerm* which produces 3-4 seedlings per seed ball, hence thinning is an important operation. Also remove the weak, diseased and insect affected plants to maintain proper distance between the plants with in the rows. Root crops can also be seeded precisely with mechanical seeders that prevent the need for subsequent thinning. Time of sowing of any root crop depends upon the type of the variety and location. Further, moisture stress can reduce the crop yields. Plants that wilt intermittently may produce smaller yields, while those which wilt frequently will often die due to irreversible cell damage. Most of root crops require irrigation prior to germination to prevent a crust from forming on the soil which impedes germination. After germination, irrigation is only necessary during drought or on typically dry soils such as sands. Both drip and overhead sprinkler irrigation systems are effective. Manure and fertilizer application is also an important step which decides the productivity potential and quality produce of any crop. Fertilizer program should be based on a soil test. Random soil samples should be collected from the entire field and nutritional status of the field should be checked out before planting any crop. Due to climatic conditions, differing cultural practices, varying soil conditions and other situations, the crop’s response to the fertility program may vary from region to region. Weeds pose a very serious problem in the early stages as growth of seedlings is very slow and they cannot compete with the weeds. Generally, one to two shallow weeding at early stages of crop growth keep the field free from weeds. Moreover, pre-emergence application of Fluchloralin (0.5-1.0 kg/ha) or Pendimethalin (1.0 kg/ha) is also effective to control the weeds in the field of root crops. Soil should be hoed time to time to allow proper
aeration. Beside this, organic mulches also help in keeping soil weed free and lower down the soil temperature (Table-3).

Table 2. Optimum temperature and soil requirements for proper growth and development of vegetative part of temperate root vegetable crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Temperature (°C)</th>
<th>Soil type and pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrot</td>
<td>16-21</td>
<td>Root crops prefer deep, loose, well drained, sandy loams or</td>
</tr>
<tr>
<td>Radish</td>
<td>20-25</td>
<td>loam soil having pH 5.5-7.0</td>
</tr>
<tr>
<td>Turnip</td>
<td>15-20</td>
<td></td>
</tr>
<tr>
<td>Beet root</td>
<td>15-21</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 Standard cultural practices for vegetative crop production in temperate root vegetables

<table>
<thead>
<tr>
<th>Crop</th>
<th>Sowing time</th>
<th>Spacing</th>
<th>Seed Rate</th>
<th>Manure &amp; fertilizers</th>
<th>Irrigation</th>
<th>Weed management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrot</td>
<td>Asiatic type: Aug-Nov European: Oct-Nov</td>
<td>25-30 × 8-10cm</td>
<td>8-10kg</td>
<td>FYM@ 20-30t/ha 120:60:60 kg NPK</td>
<td>At an interval of 5-7 days</td>
<td>Two weeding at 15-20 and 30-35 DAS. Linuron (0.5-1.0kg/ha) Nitrofen(1.0kg/ha)</td>
</tr>
<tr>
<td>Radish</td>
<td>Asiatic: Aug-Jan European: Sept-Mar.</td>
<td>25-30 × 8-10cm</td>
<td>Asiatic-10kg European 12-14kg/ha</td>
<td>FYM@ 26-30t/ha 50:100:50 kg NPK</td>
<td>6-7 days interval and root development and pod formation are critical stages</td>
<td>One weeding after 15-20 days, serious problem during early stage of growth, Fluchloralin @0.5kg/ha</td>
</tr>
</tbody>
</table>
### Turnip

<table>
<thead>
<tr>
<th>Region</th>
<th>Sowing Period</th>
<th>Planting Depth</th>
<th>Planting Rate</th>
<th>Fertilizer</th>
<th>Fertilizer Dosage</th>
<th>Irrigation</th>
<th>Plant Protection Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Indian plains</td>
<td>Sept- Dec</td>
<td>30-45 cm</td>
<td>3-4 kg</td>
<td>FYM@20-50 t/ha</td>
<td>30-40:50:50 kg NPK</td>
<td>At 8-10 days interval</td>
<td>Moderate and uniform moisture conditions</td>
</tr>
<tr>
<td>Lower hills</td>
<td>July-Oct</td>
<td>30-15 cm</td>
<td>3-4 kg</td>
<td>FYM@20-50 t/ha</td>
<td>30-40:50:50 kg NPK</td>
<td>At 8-10 days interval</td>
<td>Moderate and uniform moisture conditions</td>
</tr>
<tr>
<td>High hills</td>
<td>July-Sept</td>
<td>30-45 cm</td>
<td>3-4 kg</td>
<td>FYM@20-50 t/ha</td>
<td>30-40:50:50 kg NPK</td>
<td>At 8-10 days interval</td>
<td>Moderate and uniform moisture conditions</td>
</tr>
<tr>
<td>Turnip root</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Indian plains</td>
<td>Sept-Nov</td>
<td>30-45 cm</td>
<td>8-10 kg</td>
<td>20-25 t/ha</td>
<td>30-40:100-120:60</td>
<td>Field should be kept free from weeds during first 2 months of sowing.</td>
<td>Fluchloralin @1.5 kg/ha and Pendimethali @1 kg/ha</td>
</tr>
<tr>
<td>South Indian plains</td>
<td>July-Nov</td>
<td>30-45 cm</td>
<td>8-10 kg</td>
<td>20-25 t/ha</td>
<td>30-40:100-120:60</td>
<td>Field should be kept free from weeds during first 2 months of sowing.</td>
<td>Fluchloralin @1.5 kg/ha and Pendimethali @1 kg/ha</td>
</tr>
<tr>
<td>Hills</td>
<td>Mach-July</td>
<td>30-45 cm</td>
<td>8-10 kg</td>
<td>20-25 t/ha</td>
<td>30-40:100-120:60</td>
<td>Field should be kept free from weeds during first 2 months of sowing.</td>
<td>Fluchloralin @1.5 kg/ha and Pendimethali @1 kg/ha</td>
</tr>
</tbody>
</table>

**Plant Protection Measures:** It is in the interest of the farmers to keep the prevalent diseases and insect-pests under check in getting optimum yields of desired quality. In root vegetables, seed treatment with Captan or Thiram @ 3g/kg of seed before sowing and at an interval of 7-10 days is helpful to control Alternaria Blight in carrot. While, foliar application of copper fungicides or Zineb or Dithane Z-78 is effective against Leaf Spot or Cercospora Blight of carrot. In radish, application of Difoltan (0.3%), Dithane-M-45(0.2%) and Ridomil (0.1%) is advisable to control white rust disease. Mustard Sawfly in turnip can be controlled effectively by foliar application of Malathion or dichlorvos @ 0.05%. While in beetroot, Sclerotium Root Rot can be controlled by drenching the roots with bavistin (0.03%) solution.
**Seed Production of temperate root vegetables:**

Seed is one of the most critical inputs for production. A sustained increase in vegetable production and productivity has become dependent upon the development of new improved varieties/hybrids and supply of their quality seed to the farmers. Seed production is very systematic as well as technical programme involving set procedures. Good seed is the basic requirement of all growers. Thus seed producer stands in a position of great responsibility, and to fill his obligation satisfactorily he needs to understand thoroughly many factors which enter into production and processing of good seed.

On the basis of seed production, vegetable crops can be classified into two groups viz., ‘Tropical’ and ‘Temperate’. Seeds of tropical vegetable crops can be easily produced in plains and lower hills of India but the second group of vegetables includes biennial or European vegetables requiring temperate climate for successful seed production.

**Suitable areas for seed production**

Our country is gifted with a wide range of agro-climatic conditions, which enables the seed production of different vegetable crops throughout the country in one or the other part. The different pockets in the Hindukush Himalaya are suitable for seed production of temperate vegetables. In India, Humid Western Himalayan Region consists of states like Jammu and Kashmir, Himachal Pradesh, Uttrakhand and Humid Eastern Himalayan Region with Sikkim, Meghalaya, Manipur, Nagaland Mizoram, Tripura and Arunachal Pradesh. Likewise Pakistan Himalayan Region of Baluchistan, whole of Nepal and Bhutan are suitable for this purpose. The winter temperature of Kullu and Kashmir valleys is so congenial that neither protection from cold in the field nor provision of storage facilities for over wintering is required. The crops under these conditions can be left in the open for overwintering without any damage. Winter and summers suit to produce seeds of not only temperate vegetables, but also of summer’s vegetables. Besides the Kullu and Kashmir valleys, fulfilling the necessary requirement
for seed production of temperate vegetable, there are some other areas viz., Vegetable Research Station, Kalpa, Kinnaur where climatic conditions (severe winters and dry hot spring-summers) are quite congenial for quality seed production of temperate vegetable crops. These areas widen the scope for expending the seed industry not for indigenous consumption, but also for export to even some European and western countries, where seed production becomes expensive day by day with the increase in cost of labour.

**Specific requirements for seed production of temperate vegetables:**

It is greatly affecting the pattern of crop growth in various agro-climatic zones throughout the world, which in-turn is changing the socio-economic conditions of the people. Vegetable production is also not untouched by the changing climatic scenario, it has also affected the seed production of the various temperate root vegetables like European carrots, radish, turnip and beetroot, which have specific low temperature chilling requirements. Various marginal areas are becoming unsuitable for seed production of different vegetables *viz.*, late cauliflower, cabbage and other temperate vegetables due to increasing temperature. The problems arise from extreme events that are difficult to predict. More erratic rainfall patterns and unpredictable high temperature spells will consequently reduce crop productivity. Climate change is projected to increase the global temperatures, causes variations in rainfall, increases the frequency of extreme events such as heat, cold waves, frost days, droughts, floods etc. with immense impact on agriculture sector. Temperate vegetables require temperate climate especially during a specific stage of their growth for successful seed production. During this period these vegetables meet the vernalization (chilling) requirement, a pre-condition necessary for breaking dormancy of plant, thus stimulating the conversion of the vegetative phase into the reproductive phase *i.e.* induction of flowering and bolting.
Table-5. Special temperature requirement

<table>
<thead>
<tr>
<th>Crop</th>
<th>Edible part</th>
<th>Chilling temperature (°C)</th>
<th>Duration (Weeks)</th>
<th>Phases of Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrot</td>
<td>Root</td>
<td>4-7</td>
<td>4-6</td>
<td>2</td>
</tr>
<tr>
<td>Radish</td>
<td>Root</td>
<td>4-7</td>
<td>4-6</td>
<td>2</td>
</tr>
<tr>
<td>Turnip</td>
<td>Root</td>
<td>4-7</td>
<td>4-6</td>
<td>2</td>
</tr>
<tr>
<td>Beet root</td>
<td>Root</td>
<td>4-7</td>
<td>4-6</td>
<td>2</td>
</tr>
</tbody>
</table>

The seed production is taken in the hills for European types and in the plains for Asiatic types. European/temperate types require high chilling (4-7°C) for a specific period (about 4-6 weeks) in majority of cases as given in table-5. The mild summer and low rainfall of hills especially during flowering and seed setting stages are beneficial. The sowing time should be so adjusted that the roots become available and their stecklings could be set in before chilling months. In heavy snowfall areas where chilling period is long, the roots after uprooting are stored in trenches before the onset of winters and replanting is done in the month of March- April. In such case stecklings are prepared just before planting. The seed is ready for harvesting from July-August to September-October (high-hills) depending upon the weather, crop and cultivar.

Methods of seed production of temperate root crops

Seed production

Seed production of temperate or European types of root vegetables can only be under-taken in temperate regions comprising higher hills.

Methods of seed production in root crops

1. Seed-to-seed
2. Root-to-seed

Both seed-to-seed and root-to-seed methods are employed for seed production in root crops. The former method is not followed unless the seed is of the highest quality. In seed to seed method, the matured roots are left to
produce flowers and seeds in the place where seeds are sown initially. It is used for certified seed production alone. In root to seed method, roots at edible maturity should be uprooted and the roots of true to varietal characteristics should be selected and transplanted to the well prepared field after proper trimming of roots and shoots. Replanting method (root-to-seed) is preferred for producing nucleus and breeder seeds. Transplanted root to seed method is better since it gives an opportunity to rogue out off type roots at the time of transplanting thus maintaining only true to the type plants for seed production.

When the roots are fully mature, the crop is harvested, true-to-type roots are selected. The selection and roguing are done on the basis of foliage characters and root characters both external and internal (colour, shape, size, flesh colour, core size, pungency, indistinct rings etc.). Undesirable roots are discarded. After selection of true-to-type roots, their tops and tips are cut and transplanted in a well prepared field. The stecklings of roots can be prepared by giving one-third top (shoot) cut and one-fourth to one-half root cut to obtain higher yield of better quality seeds. In case of turnip and beet, after selection the tap root and tops of the roots are trimmed taking care not to injure the crown and planted in a well prepared field.

**Bolting, flowering and seed setting:** Exposure of plants to low temperature results in transformation of leaf-primordial into floral primordial. As discussed earlier the size of the plant exposed to low temperature is of considerable importance. The larger the plants at the vernalization, greater are their tendency to shoot to seed. The amount of flower-formation depends on temperature, the period of exposure to low temperature and to some extent on the rate of seed set because the plants with good seed-set cease to produce flowers early than the plants where less or no seeds is set. A single plant covered with a bag continues to flower for longer duration. Lower temperatures within the favourable range of 4°C-7°C for vernalization stimulate the plant in less time to bolt quickly and produce flowers in abundance and vice-versa. Number of flower-formation also depends on the
age of the plant. Low temperature treatment at the end of juvenile phase produces sparse flowering but when exposure to chilling temperature is subjected for 28-42 days or so profuse flowering takes place.

Rate of opening of flowers is decreased in rainy and cold weather. Moreover, pollination, fertilization and seed-setting are adversely affected. Sunny days are favourable for satisfactory flowering and seed-setting. Cloudy weather results in poor seed-set owing to poor bee-activity. Provision of 3-4 bee-hives/ha ensures good seed-set and thus increased seed yield. The favourable temperature range for flowering and seed-setting is 12.5\(^0\)C-18.5\(^0\)C. Spray of micronutrient formulations like McNelf, Agromin, Multiplex, etc. after the emergence of flower-stalk increases proper development of flower-buds and seed-setting. Proper moisture regime in the soil should be maintained for satisfactory setting, growth and development of seed. Ovules wither and dry under water-deficit conditions in early stages following fertilization. Dry conditions in the later stages of seed development cause shriveling of seeds and forced ripening of seeds with smaller size. Such type of ripening is however, not desirable from seed quality point of view due to sudden suppression of physiological processes going on inside the seed. This reduces the vigour of the subsequent crop. A huge population of aphids on the fully mature but green pods for few days before turning yellow leads to quick drying of branches and pods with the result seed become shriveled.

**Harvesting:** Harvesting is the last of various field-operations and is done at full maturity of the seed. It should neither be done too early to effect proper curing nor, be delayed to cause shattering and damage due to rainy season showers. Pre-harvest rains effect the viability during storage and its subsequent performance in the field. Harvesting should be done in 2-3 lots to avoid shattering losses. The seed crop of radish should be harvested when about 70% of pods on a branch have changed to yellowish-brown colour and seed turns brown it is cut whole with a sharp sickle. With a blunt sickle the plant is shaken and shattering of seed may occur. The shattering losses are
greatly reduced when harvesting is done in the morning or early part of the day or on cloudy days. Further, it is prevented by collecting the cut-seed stalks on a spreading cloth or hessian cloth to facilitate collection of fallen seeds from the dehisced siliques. In carrot the seeds are formed in umbels. The seed crop can be harvested when all the secondary umbels mature and tertiary umbels turn yellow. For high quality seed, primary & secondary umbles should be harvested and rest should be avoided. The seeds from primary umbels are heavier, more mature and of high quality. In turnip, the harvesting is done when the pods mature becoming brownish-red. The seed crops of beet root should be harvested when 80 per cent of the seed/seed balls on a plant get hardened and the base of the inflorescence turn brown.

Otherwise, there is possibility of shattering of seeds during harvesting.

**Curing, threshing and seed grading:** An ultimate seed quality is dependent upon the handling of the harvested crop and the care taken during curing, threshing, drying and storage conditions. The harvested crop is piled up in small heaps for curing either on a tarpaulin or cement floor and covered with a tarpaulin or hay to reduce rapid drying of branches. Curing with branches helps the unripened seed to ripen slowly as under normal conditions in the field. Seed ripens at the cost of water and food supply from the branches. Curing improves the colour of the seed, ripening during the process of curing and brings the colour at par with the seed that ripens on the plant under natural conditions. Curing also reduces shattering losses in the field. After 4-5 days the heap is turned upside down and allowed to cure for another 4-5 days. There should be no over or under-curing, otherwise the seed colour and quality will be impaired. If the heap is not turned for many days, the seed in the centre of the heap, germinates due to sufficient heat and moisture there. For this reason it is not advisable to pile in large heaps for curing. Threshing should be done on a clear day for once-over operation. Threshing does not present difficulties as the seeds are readily dislodged from the siliques because of the natural tendency of pods to dehisce. In the morning the crop is spread on a tarpaulin or concrete floor for drying and in the afternoon the seed is extracted by beating with sticks. Seed can be separated from chaff or
broken twigs either by winnowing or passing through coarse mesh sieve. Drying of seed to safe moisture levels (7%) should be done rather quickly to preserve vitality and vigour. Freshly harvested seed should not be kept packed in gunny bags for days together otherwise it will heat up due to high moisture in it. Rather the seed should be kept spreading or in small packs as long as it is moist. The other point to remember is that the moist seed should never be put into the bags when warm. It is to be cooled down before filling. Hand-grading of seed is laborious and takes lot of time. Seed-grading machines overcome this difficulty. Seed after grading should contain minimum of 98% pure seed with at least 60% germinability.

**Isolation and pollination**

All the root vegetables are cross pollinated owing to one or the other genetic mechanisms. Radish, carrot and beet do not cross with cruciferous crops belonging to genus Brassica. Turnips do not cross naturally with any other member of the sp. *Brassica oleracea* but cross easily with Chinese cabbage (*B. pekinensis* and *B. chinensis*) and *B. juncea*. Insects are the main agents to carry out pollination in these crops. Beet (*Beta vulgaris*) is pollinated by the agency of wind however, insects also visit the crop at flowering which may be a source of contamination. Garden beet crosses easily with sugar beet, spinach beet, swiss chard etc. The isolation distance for different classes of temperate vegetable crops are presented in **table-6**. If there are any chances of out-crossing it is better to cover the crop with isolation cages. Nucleus seed production should be carried out in the isolation chambers to ensure to effect pollination in case of carrot, radish and turnip whereas beet being wind pollinated, hand shaking of plants inside the chamber is practiced.

**Table-6. Isolation Distance for different temperate root vegetables**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Isolation Distance</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Breeder Seed</td>
<td>Foundation Seed(m)</td>
</tr>
<tr>
<td>Carrot</td>
<td>3000</td>
<td>1000</td>
</tr>
<tr>
<td>Radish</td>
<td>3000</td>
<td>1600</td>
</tr>
</tbody>
</table>
Rouging and Selection

Rouging and selection are the most important operations in seed production and must be carried out at specific stage of crop growth to remove off types and undesirable plants to maintain the purity of the variety. Root should be conformed to variety characters such as colour, shape, size and small, mis-shaped, forked, diseased and other undesirable roots should be sorted out. A minimum of 3 inspections and rouging are necessary to maintain the purity of a variety.

Pre-uprooting stage: Inspection at this stage can be made any time from root development stage but before pulling of the root from soil. Rouging based on foliage characters is made as the root parts cannot be examined at this stage. The amount of vegetable growth, size, shape, colour, and distinction of leaf-lamina are observed carefully. Diseased, unhealthy, weak or very vigorous plants should be discarded.

Uprooting and replanting stage: At this stage size, shape, colour, shoulder and typical shape of the root and root types (stumpy, semi-stumpy, tapering or globe) are examined critically. All the cracked, diseased hairy, deformed roots are discarded. The internal characters viz., pithiness, colour of flesh, core colour and size and presence/absence of blackish tissues in the core of the roots can be observed when stickling are prepared for replanting in case of root crops.

Bolting and pre-flowering stage: Consideration is given to remove very early and late bolters. Plants showing poor growth due to disease infection should be rouged out. This inspection should be done before flowering to avoid contamination with undesirable plants. Volunteer plants growing here and there need to be removed before their flowering.

Table-7. Average seed yield of important temperate vegetables

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Seed yield (q/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radish</td>
<td>Chinese Pink</td>
<td>6.00 to 8.50</td>
</tr>
<tr>
<td></td>
<td>Japanese White</td>
<td>6-50 to 7.50</td>
</tr>
</tbody>
</table>
RRWT | 8.50 to 9.50
---|---
Carrot | Solan Rachna | 5.50 to 7.00
| Early Nantes | 4.50 to 5.50
Turnip | PTWG | 6.50 to 8.0
Beetroot | Detroit Dark Red | 5.50 to 6.50
| Crimson Globe | 10.5 to 11.50

**Seed yield:** It is a function of various interacting factors. Besides agronomical and climatic factors, the yield contributing components of the plants are responsible for its overall seed-yielding potential. These characters are number of flowers produced (product of number of flowering branches and flowers per inflorescence), the percentage of flowers that produce seeded siliqua/pods and the number of seeds per pod, number of ovules per flower/ovary and the number of ovules that mature after pollination/fertilization. The final graded seed weight will ultimately determine the seed yield. The average seed yield of important temperate vegetables is presented in **table-7**.

### Minimum Seed Standards:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Seed type</th>
<th>Pure seed (Min.) (%)</th>
<th>Inert matter (Max.) (%)</th>
<th>Other crop seed (Max./kg)</th>
<th>Weed seed (Max./kg)</th>
<th>Germination (Min) (%)</th>
<th>Moisture (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Vapour proof container</td>
</tr>
<tr>
<td>Carrot</td>
<td>F</td>
<td>95.5 0</td>
<td>5.0</td>
<td>5</td>
<td>5</td>
<td>60</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>95.0 0</td>
<td>5.0</td>
<td>10</td>
<td>10</td>
<td>60</td>
<td>8.0</td>
</tr>
<tr>
<td>Radish</td>
<td>F</td>
<td>98.0 0</td>
<td>2.0</td>
<td>5</td>
<td>10</td>
<td>70</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>98.0 0</td>
<td>2.0</td>
<td>10</td>
<td>20</td>
<td>70</td>
<td>6.0</td>
</tr>
<tr>
<td>Beetroot</td>
<td>F</td>
<td>96.0 0</td>
<td>4.0</td>
<td>5</td>
<td>10</td>
<td>60</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>96.0 0</td>
<td>4.0</td>
<td>10</td>
<td>20</td>
<td>60</td>
<td>6.0</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Turnip</th>
<th>F</th>
<th>98.0</th>
<th>2.0</th>
<th>5</th>
<th>5</th>
<th>70</th>
<th>9.0</th>
<th>8.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>98.0</td>
<td>2.0</td>
<td>10</td>
<td>10</td>
<td>70</td>
<td>9.0</td>
<td>8.0</td>
<td></td>
</tr>
</tbody>
</table>

**Hybrid Seed Production**

Hybrid cultivars have the advantage of relatively uniform roots. In radish, the phenomenon of self-incompatibility and male sterility ease exploitation of hybrid vigour. Self-incompatibility system is of sporophytic type in which the papillae on the stigma surface disrupt the pollen tube penetration. Male sterility has been reported by Ogura (1968) in Japanese radish, which is governed by the interaction of a recessive gene ‘ms’ and S-cytoplasm. Single crossing, three way crossing and double crossing are three methods of hybrid seed production in radish. However, double-crossing method is, probably, the most effective means of hybrid seed production in radish.

In carrot hybrids have been produced by the use of two systems as described by Riggs (1987). The first system is with cytoplasmic male sterility (CMS) in which the pollen does not develop beyond the microspore stage, sometimes referred to as ‘brown anther form.’ The other type is petaloid form in which the five anthers are transformed into petaloid structures during their early development and do not produce early pollen. The final morphology of the petaloid anthers varies from petal-like to filamentous. According to Riggs, most commercial F₁ carrot hybrids are produced from the petaloid CMS. The number and arrangement of pollen parent plant rows relative to seed parent rows in fields varies depending mainly on inbred characteristics and grower practices. Generally, the ratio of female to pollinator rows as reported by Takahashi, 1987, is from 2:1 to 4:1. But a common male: female ratio is 4:1 which is often grown in an 8:2 arrangements with four two-row beds of female alternating with a single two-row bed of the pollen parent in an isolated field for production of F₁ hybrid seeds. The seeds are harvested from male sterile line and the pollinator plants are removed before collecting the seeds from the male sterile female parent.
For hybrid seed production in turnip the ratio of female to male parent is usually 1:1 while utilizing cytoplasmic male sterility as well as seed parents planted in case of self-incompatibility (Takahashi (1987).

In beet root sowing seed parent and pollen parent in 1:1 ratio can produce the commercial F1 hybrid seed in fields isolated from other compatible crops or varieties by at least 1000 m, since beetroot is an anemophilous. Zoning scheme can also be employed to confine seed production of different hybrids in separate geographical areas. Hybrid seed production in beetroot is feasible only if monogerm character and cytoplasmic male sterility (CMS) system is available.

A case study on early quality seed production of European carrots: It is well known that temperate carrot produces seeds commercially by ‘root to seed’ method in two cropping seasons. Roots produced in the first year require storage at low temperature/vernalization to induce seed stalk and flower initiation. These stored roots are planted the next year/cropping season. Therefore, this method takes 18-24 months for seed production.

The Defence Institute of High Altitude Research (DIHAR), the world's highest research laboratory working on agro-animal technologies’ under Defence Research and Development Organization, Leh-Ladakh has invented ‘rootlet to seed’, a new technology of high-quality carrot seed production within a year and at a low cost. In this method, seed is sown in November in nursery beds of a 10.0m×3.0 m × 1.0 m semi-underground passive greenhouse and it is covered with 200 mm thick translucent polythene from November to February. After germination, the plants are kept in this passive greenhouse up to February. During this period the plants received naturally available, low-temperature vernalization by manipulating the opening/covering time of the greenhouse by the polythene sheets. Very less irrigation and nutrients are provided so that the plants in the greenhouse just survive and produce small-sized roots called ‘rootlets’. These rootlets (about 12 g each) enter directly in the reproductive phase. The rootlets are harvested and transplanted in the field in March for commercial seed production. The
seed stalk and inflorescence induces 70-80 days after replanting and produced seeds in October during the same year. Therefore, with this technology one phase (root production phase) can be avoided completely using an eco-friendly method and high-quality seeds can be successfully produced in one year. Including the losses during handling and storage for the next season about 2.0 metric ton carrots can be made available for table purposes; otherwise, these would have been used for seed production in the ‘root to seed’ method.

Higher seed yield per hectare and quality were recorded with ‘rootlet to seed’ compared to ‘root to seed’ method, apparently due to the contribution of maximum seeds from first-and second-order umbels. However, higher seed yield per plant was observed in ‘root to seed’ method, and the third-and fourth-order umbels contribute in seed yield in this method. Seeds produced in the third-and fourth-order umbels are inferior in quality than first-and second-order umbels, because these small-sized seed contain higher levels of carotinal substance which inhibits germination and adversely affects the vigour. Therefore, high germination percentage and seed vigour were observed in the seeds produced using ‘rootlets to seed’ technology. With the adoption of ‘rootlet to seed’ technology development by DIHAR, food used for seed production as carrot roots (2.0 metric tonne/ha) can be saved and good quality seed can be produced in one year at almost one-third cost in comparison to the conventional method.

**Future strategies**

Promotion of modern technology and crop diversification should be tailored according to local conditions for effective and quality seed production. Efforts should be made to uplift the socio-economic condition of farmers through rigorous research and development. Researchers, extension personnel, gardeners and farmers should be trained on the issues of climate change. Temperate vegetable crops, which are tolerant to high temperatures, flooding, drought and soil salinity must be identified form the available resources. Uses of biotechnological interventions for introgression of important genes, which are adapted to climatic changes, have been widely
acknowledged. Some of simple, but effective adaptations strategies include change in the sowing date, use of efficient technologies like drip irrigation, soil and moisture conservations measures, fertilizers management through fertigation, change of crop/alternate crop, increase in input efficiency, pre and post harvest management of economic produce can not only minimize the losses, but also increase the positive impacts of climate change. All these measures can make the horticultural farmer more resilient to climate change. In conclusion, climate change will decrease crop yields in the long-term, unless one slows climate change and/or adapts new management practices and improved cultivars.

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Advances in seed pelleting and film coating in vegetable crops

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Seed enhancement is a value addition by technology. The motto is “Care with seed and Joy with harvest”. It is a new concept and growing very rapidly worldwide. The techniques improve germination, seedling growth and facilitate the delivery of seed and other material required at the time of sowing.

The coating and pelleting serve as delivery systems. The various methods of value addition are not mutually exclusive and several techniques can be combined together to obtain additive effect e.g. pelleting of primed seeds. So integration of selected techniques can be used to upgrade the quality of seed.
Why Seed pelleting?

- *Sigularization and precision placement*: Seed vary greatly in size, shape and colour. Seed size small and irregular making sigularization and precision placement difficult.
- *Protection/ value addition of seed* by the addition of insecticides/ pesticides/ nutrients/ growth-stimulants etc

History

- The technique is more than 2000 years old.
- Ancient Chinese coated rice with mud balls for better anchor of seed to avoid drifting in floating paddy field.
- In modern era coating was first developed for cereal seeds in 1930’s by Garmains, a British seed company.
- Large scale use of coating began in 1960s with precision sowing in Polyhouses in Europe.
- When California outlawed the short handle hoe in mid 1970’s, the use of coated seeds for precision field seeder increased.
- The combination of US field precision seeding and green house transplant production, created a demand for high quality coatings to achieve accurate sowing, satisfactory seedling emergence and stand establishment.
- Now the technology is widely used in vegetable, flower and field crops seeds.

What is seed pelleting?

- “Seed pelleting is a process of enclosing a seed into a small quantity of inert matter just large enough to produce a globular unit of standard size to facilitate precision planting.”
- The inert matter creates a natural water holding media. Water holding capacity of the pellet can be changed by altering the composition of filler
material by adding moisture attracting or repelling material to the pellet which creates a perfect seed with specific germination and moisture requirement.

- Bio-stimulants, microbial inoculants, micronutrients, pesticides, growth regulators can be added to the pellets to improve seed performance.
- Pellets should always be stable unit but should easily disintegrate to release seed.
- Hence the aim of seed pelleting is precision planting with added advantages of better crop establishment and increased productivity

**Materials used in pelleting and their selection criteria**

1. Adhesive material
2. Coating / filler material

**Adhesive material**

- The physical integrity of coating/ pelleting is decided by the types of adhesives and this highly influence the handling, transport and planting operations of pelleted seeds
- **Commonly used adhesives:** Gum Arabic, Methyl cellulose, Gelatin, Caesein, Plastic Resins, Poly Vinyl Acetate, Methyl Ethyl Cellulose, Poly Urethane, Poly Vinyl Alcohol, Polyelectrolyte or Dextran, Poly Ethylene Oxide and Carboxy Methyl Cellulose (CMC).
- Amongst these Carboxy Methyl Cellulose (CMC) is widely used due to ease of availability, low cost and low rate of application.
- **Concentrations of adhesives:**
  - Carboxy Methyl Cellulose 3 % W/V
  - Methyl Ethyl Cellulose 5% W/V
  - Gum Arabic 45%
  - Nitric Coat 4.3 % W/V in water
Some cheap and low cost binding materials are: Rice gruel, Maida gruel, Sago gruel, Starch gruel etc. These are used at concentration of 5 or 10% depending upon the filler material.

Selection criteria of adhesive

It is based upon selective purpose e.g.
- Plastic resins/ polyvinyl Acetate/ Insoluble Polyelectrolyte complexes are used to bind pesticides to seeds.
- Polyethylene Oxides are used to prevent erosion of surface sown seeds.
- Polyurethane is used to bind lime in a way that resists coat abrasion.
- Blends of Polyvinyl Alcohol and Polyvinyl Acetate is used to bind Vermiculite and Polyelectrolyte or Dextran to aggregate soil around the seed thereby improving the aeration of sown seeds.

Properties of Adhesives

- It must have affinity (combinability) for both seed coat and selected filler material.
- It should have the required degree of water solubility or insolubility for easy emergence.
- It should have the required strength and plasticity to prevent dusting and breakage.
- It should have the most appropriate viscosity for easy application.

Coating or filler material

- The material used as filler in pelleting must be beneficial and harmless to both seed and rhizo-sphere.
- Commonly used filler material:
  - Diatomaceous earth (a naturally occurring, soft, siliceous sedimentary rock that is easily crumbled into a fine white to off-
white powder), lime, gypsum, dolomite or rock phosphate, charcoal etc

- Other material used:
  - Vermiculite, blood, peat, poultry manure, moss, mucilage’s

- Botanical material used:
  - Low cost & environmental friendly
  - Leaf powders of
    - Arappu (*Albizia amara*)
    - Pungam (*Pungamia pinnata*)
    - Notchi (*Vitex nigundo*)
    - Neem (*Azadirachta indica*)
    - Moringa (*Moringa pterygosperma*)
    - Tamarind (*Tamarindus indica*)
    - Prosopis (*Prosopis juliflora*)
  - They are recommended @ 200-300g/ kg of seed
  - The fineness of the powder should be in such a way that it passes through muslin cloth.
  - These leaf powders contain auxin like substances which regulates the growth of seedling in initial establishment.

*Selection criteria for filler material*

- Must be porous to allow movement of air to the seed
- The coating must weaken or breakdown easily when it comes in contact with soil moisture to prevent any physical impedance to seed germination
- Should be non toxic to seed and rhizosphere
- It must be possible to apply the coating on commercial basis.
- Low cost
Methodology of seed pelleting

- The three basic steps are
  1. **Stamping**: Coating of seed with adhesive
  2. **Coating**: Filler material sprinkled on the coated seeds
  3. **Rolling**: Rolling of seeds - pellets - shade drying - packaging - transportation - storage - sowing

Types of pelleting/coating

Classified based on either bio-active chemical or filler material

1. Inoculant pelleting/coating
   - Biofertilizers (Rhizobium, Azotobacter, Azospirillium, Phosphobacteria PSB etc) or VAM as filler material

2. Protective pelleting/coating
   - Insecticides/fungicides
   - Bio-control agents – Trichoderma
   - Birds repellents – Methio-carb, Endrim or Thiram
   - Rodent repellents – Mestranol, Sesoreinal

3. Herbicide pelleting/coating
   - Herbicide antidote- 1,8 Naphthalic Anhydride (NA) is best for pelleting
   - The absorbant, Activated carbon

4. Nutrient pelleting/coating
   - Coating with micro and macro nutrients enhances germination & seedling growth
   - Makes nutrients more available to crop and less available to weeds and also avoid wastage
   - Micro-nutrients used – Zn So₄, FeSo₄, CuSo₄, KH₂PO₄, KCl, borax etc
• Dose – Nutrients  DAP (60g/ Kg seed), ZnSO$_4$ (300mg/ kg seed), Borax (100 mg/ Kg seed) added to the adhesive and are filled with filler material

5. Hydrophilic pelleting / coating
• Starch graft polymers (absorbs water 1000 times of their own weight) and Magnesium carbonate are capable of improving movement of air and water

6. Oxygen supplier pelleting / coating
• Seeds are coated with peroxides of Zinc or Calcium which aids in increased supply of O$_2$ to the germinating seeds
  – The seeds which has hard seed coats and impermeable to oxygen will be highly benefitted for enhancing germination
  – Sowing of seeds under water logging conditions

**Seed pelleting, encrusting, coatings- examples**

• Commonly pelleted crops include monogerm sugarbeet, lettuce/endive, carrot, celery, onion/leek, tomato, pepper, Brassicas, super-sweet corn, tobacco, petunia, Lisianthus, others.
• Encrusting is also employed in the above species and to
  – (1) pre-inoculate with rhizobia on small-seeded legumes (e.g.alfalfa or lucerne),
  – (2) reduce size variation in maize, sunflower, and
  – (3) add weight to avoid seed drift during sowing of low-density, chaffy turf grass seeds.
• Pelleting, etc. still an art; success dependant on operator. Ability to singulate seed is an acquired skill – new operators often practice with dead seed for months before actual seed lot runs allowed.
• Pellet types can be modified to disintegrate rapidly, or split after imbibition to expose the seed to adequate O$_2$ levels.
• Pellet/coating materials can be tailored to regulate seed water availability and gas exchange, thereby controlling timing of germination
and emergence (and potentially avoid poor environments for crop establishment).

- Water-attracting materials can be incorporated, aids to imbibition and increased seed-soil contact.
- Temp sensitive polymers/coatings can delay imbibition until a set temp is reached; avoid soaking injury in large-seeded legumes, high-sugar sweet corn; also useful for better nicking in hybrid seed production.
- Oxygen-generating materials (e.g. Ca or Mg peroxide) can be added to supply more O$_2$ in waterlogged environments.

**Process of coating/ pelleting of seeds**

- Seed coating and pelleting relies on technology developed by pharmaceutical industry to make medicinal pills.
- Commercial seed coating operation put seed in a rotating pan, mist with water and other liquid (adhesive).
- Gradually add fine inert powder or filler material to the rotating pan.
- Each misted seed becomes the centre of agglomeration of powder that gradually increase in size.
- The pills are smoothened by tumbling action in the pan. Tumbling action distributes, molds, blend to give good size distribution
- Tumbling also prevents formation of empty (seedless) pellets, or seeds sticking together.
- The coating powder is compacted by compression from the weight of the material in the pan.
- Binders are often also incorporated near end of the coating process to harden the outer layer of the pills. This reduces the dust produced by the finished product during handling, transportation and sowing.
- Wet-coated seed then dried with heated air, usually in separate equipment.
- Pelleting increases seed wt by ~2 to 50X (or more in tobacco seed); compared to an increase of only 0.1 to 2X for coatings/encrusting, and less than <0.1X increase for film coating.
• Size and uniformity after coating/ pelleting is a major criterion of quality

**Types of coats / pellets produced**

1. Dissolving or melt type
   - Dissolve when wet and gradually wash away from around the seed.
   - The melt coats often require more water to wash the coating material away from the seed and more time for the oxygen to reach the seed through saturated coating material.

2. Spilt types
   - Initially retain the shape when wet and by capillary action pass moisture through the pill to be imbibed by seed. The seed swells and cracks the pill by internal turgor pressure.
   - The spilt often permit germination with less water as they split, allow uniform, rapid oxygen access to the surface of the seed.

**Advantages of pelleting**

• Singulation of seed is achieved, helpful in precision planting in mechanized farming.
• Seeds with free wings enables aerial seeding by improving ballistic ability.
• Small seeds and irregular shaped seeds are made easy to handle.
• Accurate dosing of seed with chemicals is possible and wastage is prevented.
• Pelleting acts as inoculant, protective, nutrient, hydrophilic, oxygen suppliers.
• Lime pelleting of seeds, protect the multiplication of rhizobia in the rhizo-sphere of acid soils.
• Stress conditions can be overcome by pelleting even in low water holding capacity
• Chemicals/ fertilizers can be applied with seed
• Uniform field establishment and increased yield
• Protects seed from birds, animals and insects
• Increase seed size and reduce seeds rate
• Stimulation of germination
• Influence of micro-environment

Disadvantages of pelleting

• When seed is pelleted, its cost and weight is more than bare seed
• If proper pelleting techniques / machines is not used, there would be missing of seed during pelleting (blank pellet) or some times more than one seed may be there in a pellet (Doublets or triplets)
• Pelleted seeds require more moisture for germination since pellet must be dissolved first.
• Delayed field emergence at low moisture level.

Film coating

• “Film coating is a sophisticated process of applying precise amount of active ingredient alongwith liquid material, directly on the seeds surface without obscuring its shape and total weight may increase upto 10%.”
• Most film coating contain a colorant that helps in visual mentoring and placing accuracy during automatic seeding.
• Film coating can help to smoothen the rough surface of seed, allowing the seed to flow more evenly during automatic seeding due to reduced friction between seed and surface.
• Film coating may be performed as the final step after pelleting to generate dust free pellet.
• Fungicides and insecticides can also be added.
• It also provides strong identity to the treated seeds.
Primary Functions of Film Coating

- Binder and carrier for actives (pesticides & fungicides)
- Reduced dustiness
- Cosmetic improvement
- Improved flow ability
- Improved distribution of additives

Characteristics of a polymer

- An ideal polymer would not be permeable to water vapour but should be water soluble to allow the seed to imbibe sufficient moisture for germination without scarification i.e. The polymer should not disintegrate when exposed to heat or humidity and should not inhibit germination.
- Synthetic coats which restricts water entry may prevent deterioration
- It should be carried with minimal quantity of solvent to facilitate application and speed drying.
- Polymer used should be environmentally safe, non toxic to plants.

Requirements of film coating

- Seed
- Coating material i.e. actives
  - Crop protection chemicals (e.g fungicides/insecticides)
  - Biologicales (e.g. fungi/bacteria)
  - Nutrients
  - Growth regulators (e.g. gibberellins)
  - Repellents (e.g. birds)
  - Various (e.g. active carbon)
- Adhesives or polymers
• Solvents/ dilutants
  – Water, fevicol or any other organic solvent
• Equipments
  – Pelletizing pan or fluidized bed seed coating apparatus

**Advantages of film coating**

• Enables accurate and even doses of chemicals and reduce chemical wastage.
• It makes room for including all the required ingredients like inoculants, protectants, nutrients, plant growth hormones, hydrophilic substances, herbicides, oxygen suppliers etc.
• By encasing the seed within a thin film of biodegradable polymer, the adherence of the seed treatment to the seed is improved.
• It ensures dust free handling, making treated seeds both user and environmentally friendly.
• Addition of colourants helps visual monitoring of placement accuracy as well as identification of cvs.
• Coating results in more even seeding rate due to smooth flow of the seeds.
• Improves the appearance and quality of treated seed.
• Major benefits are safety and ease of handling
• Polymers acts as a temperature switch and protective coating which regulates the intake of water and subsequent germination of seeds.
• Better plantability and emergence of seeds.
• Hydrophobic seeds coatings are used to delay seed germination, enable synchronous flowering of male and female parental lines in hybrid seed production.

**Disadvantages of film coating**

• Coated seeds cost higher than the bare seeds.
• Proper coating equipments and solvents or dilutents are needed for effective coating
Seed colouring

- It is colouring of seeds with different colour natural or artificial dyes to enable brand identification and to give seeds a distinct and attractive look.

Objectives of seed colouring

- Improve marketability.
- Brand identity.
- Easy identification of varieties based on colour.
- Insects and birds repellent.
- In storage seed lots of different years can be identified easily.
- Mixing of seeds can be checked.
- Uniformity of application of seed treatment, coating and pelleting can be visually checked.

Dyes uses for seed colouring

Natural dyes
- Environmental friendly, non toxic to seed and most of them have medicinal and antimicrobial properties.
- Extracted from leaves, flower, fruits, seeds and roots of plants.
- Examples
  - Turmeric (Curcuma longa) - 1-2g/5g seeds
  - Heena (Lawsonia inermis) - 6-10 ml/5g seeds
  - Beet root (Beta vulgaris) - 4-10 ml/5g seeds
  - Basella rubra - 6-10 ml/5g seeds
  - Marigold (Tagetus erecta) - 5-15 ml/5g seeds
  - Hibiscus rosa-sinensis - 6-10 ml/5g seeds
  - Opuntia spp - 6-10 ml/5g seeds
  - Bixa orellana - 5-15 ml/5g seeds
• Jamum (*Syzygium cumini*) - 6-12 ml/ 5g seeds

**Artificial dyes**
- Dye powder is mixed with water and then seed are treated with it.
- Different dyes used
  - Congo red - 0.25-1.0%
  - Bromocersol green - 0.25-1.0%
  - Jade green - 0.25-1.0%
  - Sky blue - 0.25-1.0%
  - Turquoise blue - 0.25-1.0%
  - Pink - 0.25-1.0%

**Advantages**
- Prevents inadvertent mixing of seeds of other vars of same crop
- Gives protection to the seeds
- Seal the cracks on seeds coat
- Improve physical appearance of seeds
- Provides a smooth and even surface enhancing market and plantability of seeds
- Gives a distinct and attractive look to the seeds

**Disadvantages**
- Involves extra cost
- Time consuming
Perspectives of Organic Seed Production

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Organic varieties or seeds are required in organic production. However, limitations in the availability of organic varieties triggered policy makers to adjust and consider this gap. Conventional F1 varieties from private seed companies are allowed in organic production provided that seeds are produced for at least one generation under an organic system. However, it is observed that conventional varieties do not always perform well under organic conditions. This may be because conventional varieties are intentionally developed under optimum conditions but are not adaptable to low input conditions and an organic environment.

Basically, the concept of organic breeding is the same as conventional breeding, with Phenotype (P) = Genotype (G) + Environment (E) + Genotype × Environment (GE), wherein the performance of the variety (P) is dependent on the genetic trait (G), effect(s) of the environment (E), and the interaction between the variety and the environment (GE). However, varieties from conventional breeding may have traits that may be unsuitable for organic production systems, and some important traits for organic farming systems may not be found in the conventional varieties. Breeding under organic conditions may result in improved levels of stress tolerance and disease resistance in the resulting varieties. Hence, the evaluation and improvement of varieties through breeding under organic conditions at minimum levels of input application are essential for the development of the organic sector and for the quality of organic products.

Seed is too often overlooked as a fundamental piece of our food and agricultural systems. Yet this tiny resource has enormous impacts on how we farm and what we eat. When farmers plant their seed each spring, they rely
on the genetics contained within to help defend those plants from pests and diseases, and to withstand weeds and weather. In fact, organic farmers rely on seed adapted to their specific farm conditions and climates more than other farmers because they don’t use synthetic pesticides and fertilizers.

Seed also largely dictates the quality of our food – from appearance to flavor to nutritional content. In this way, seed holds endless potential for transforming our food system, especially when coupled with the principles that built the organic movement – the principles of health, ecology, and fairness.

Currently, the dominant seed system is controlled by a handful of chemical and biotechnology companies with no genuine interest in the success of organic agriculture. These players abuse intellectual property rights and fiercely protect them. They discourage farmers from participating in research and seed saving. And too often they put shareholder interests before those of the greater public.

The organic community has an opportunity to create a path for organic seed that’s very distinct from the dominant seed system. By establishing a shared vision and roadmap for developing organic seed systems, we can avoid the negative trends seen in the conventional seed sector while delivering high-quality organic seed for all regions, crop types, and farm scales.

Demand for organic food is only growing, with sales topping $39 billion in 2015 (an 11% increase compared to 2014). Organic farmers are required to use organic seed unless it’s commercially unavailable. The organic seed industry was almost non-existent when the federal organic standards went into effect in 2002. As State of Organic Seed, 2016 shows, the organic seed supply isn’t keeping up with broader organic industry growth, as most organic farmers still rely on conventional (non-organic) seed for at least part of their operations.

The good news is that we’re seeing progress in increasing the availability, quality, and integrity of organic seed available.
As important are the many benefits organic seed provides — benefits that go well beyond helping organic farmers meet a regulatory requirement.

**More Choice for Farmers in a Changing Climate**

Plants bred under organic conditions have the potential to be better adapted to these production systems. Organic farming challenges can be quite different from conventional systems, where synthetic chemicals and nutrient sources are commonly used to control pests, diseases, and plant nutrition. Seed provides the genetic tools to confront these day-to-day challenges in the field, and breeding plants in the environment of their intended use benefits this process.

Furthermore, adaptation is key to achieving resilience in our food and agricultural system. Adapting seed to changing climates, resource availability, and environmental conditions is one way to mitigate risks for farmers and the food supply they serve. This resiliency is longer lasting when more organic farmers have the skills to further adapt and improve plant genetics through seed saving and on-farm breeding.

Seed therefore represents profound potential for improving our food and agricultural systems. The plant genetics contained within a seed can determine if chemical controls will be necessary for dealing with production challenges (we can adapt seed to naturally resist disease). Genetics can also determine the security of our food supply (we can adapt seed to warmer and dryer conditions), how input-dependent crops are (we can breed for water use efficiency); and the quality of our food (we can breed for improved nutritional content).

**Healthy People and Planet**

Organic seed also benefits our environment. Agriculture brings the interconnectedness of natural systems and human activity into sharp relief. The way we farm has a huge impact on our environment and human health. Most US agriculture relies intensively on synthetic pesticides that are almost
entirely produced from crude petroleum or natural gas products, and that have harmful impacts on human health and the environment.

Conventional seed is typically produced in chemical-intensive systems. Not many farmers, let alone consumers, think about their “seed footprint” – that there are negative byproducts to consider even before a seed is planted. Crops grown for direct consumption, such as vegetables, are typically harvested before they go to seed. Crops grown for seed remain in the ground longer to complete their reproductive cycle. This extended growth means there are more opportunities for pests and diseases to damage seed crops. Pesticide regulations often allow higher applications of chemicals on non-edible crops, including crops produced for seed. Therefore, when farmers (and gardeners!) choose organic seed they are choosing to not contribute to this upstream pollution caused by conventional seed production.

A Solution to Corporate Control

Organic seed reduces organic agriculture’s reliance on a seed industry based on proprietary control and chemical-intensive farms. Organic seed systems – when viewed as an alternative to the dominant seed system – help address bigger problems in agriculture.

Expanding organic seed systems can also increase economic opportunities for farmers who successfully produce organic seed on their farm. The economic benefits include selling organic seed commercially, becoming more seed self-sufficient and reducing input costs, and reducing financial risks by having seed that’s better adapted to their farm. Farmer involvement decentralizes how organic seed is bred, produced, and distributed, and expands the diversity of seed grown and available.

A Thriving Organic Community

The expansion of organic seed systems has been coupled by a growing diversity of stakeholders involved in their development. For example, more chefs, retailers, and food companies are involved in variety testing and
evaluations, identifying organic seed and food market gaps, and even in organic plant breeding. This diversity of decision makers fosters a participatory and decentralized nature to organic seed systems that results in varieties with aesthetic and culinary qualities desired by consumers while also addressing the agronomic challenges of organic farmers.

**Organic seed systems – when viewed as an alternative to the dominant seed system – help address bigger problems in agriculture. Join the nation in advancing organic seed as a solution to these problems to ensure a healthier food and farming future.**

**References**


Diagnosis and management of seed borne diseases of cole crops

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Cabbage, cauliflower, kale, brussels sprout, broccoli and knol-khol are the important cole crops. Among these cole crops, cauliflower, cabbage broccoli are the principal vegetable crops and the total area under these crop in the world is 3674985 ha with the production of 93484.256 thousand tonnes. China and India have the largest areas, covering more than 50 per cent of the total acreage. In India, these crops are being grown in an area of 836000 ha with the production of 17642 thousand tonnes (NHB,2015). In Himachal Pradesh, among cole crops cabbage, cauliflower and broccoli have also attained a special significance as off-season crop for the plains during summer months and its quality seed production in mid-hills with an area & production of 8200 ha and 255.24 thousand tonnes, respectively.

During cultivation, these crops are severely affected by various seed borne diseases which are causing substantial yield reduction. The seed borne diseases are caused by variety of organisms including fungal bacterial and vi* pathogens. The fungi affects the seed quality and the direct impact of fungi on seed is considerable. Many fungi are serious pathogens of seed primordia and maturing seed which reduces yield of seed both quantitatively and qualitatively. Bacteria are commonly carried on seed, potentially any bacterial pathogen may probably be seed transmitted. As the methods of management vary with the nature and cause of individual disease, therefore accurate diagnosis is essential to prevent waste of time and material inputs. Besides, the information on nature of disease occurring at various stages during the cycle of a crop is also necessary for developing integrated management schedule for
a given geographical area. This write up describes the seed borne diseases affecting cole crops and their integrated management.

**Sclerotinia rot**

The symptoms of the disease start appearing with the earthing up of plants. The infection starts from the lower most leaf petiole touching the ground. The infected leaves lose their turgor during day time and droop down to the ground, but regain turgidity during night or early morning. The yellowing starts from tips of the older leaves downwards which shed, prematurely. In most of the cases, mid-rib and petioles at a point touching the soil, show small, discrete to large irregular dark brown to black necrotic lesions. The lesions are covered with fluffy growth of extrametrical fungus under cool and humid weather. Rotting from petioles advances to the stalk where dark brown to black spots are produced which girdling whole of the stem at ground level. The stalk rot progresses towards the curd and occasionally whole of the pith portion up to the forks of curd branching get completely rotten. The pith and the curd also rot, giving way to large cavities lined inside with fluffy mycelium and numerous sclerotia of the causal fungus. Under cool humid conditions, the mycelium emerges out and can be seen sticking to affected portion of the plant. With the progress of the disease, curds are also affected and show brown to dark brown rotting which may start from any portion of the curd, but generally from the center. The affected tissue becomes soft and mushy bearing numerous sclerotia.

Inflorescence is also affected during the months of April-May in hilly areas. If there are plenty of rains during bolting and seed setting, the fungus progresses fast and engulfs whole of the branches and inflorescence where mycelium can be seen hanging out with sclerotia sticking to it. However, if the weather is dry, the mycelial growth is restricted only up to branches. affected branches become dry and bear shriveled seeds.
The disease is caused by *Sclerotinia sclerotiorum* (Lib.) de Bary. The fungus overwinters in the form of sclerotia in soil as well as in the diseased plant debris. In the presence of proper humidity and light conditions, sclerotia germinate by forming apothecia, which in turn form asci and ascospores. If the spores, upon escaping from the ascus, lodge on a susceptible host, a new infection may originate. Mycelium from sclerotia is also capable of infecting cauliflower. During cool and moist weather fluffy mycelium appears on the host surface and when food is exhausted, the mycelium coagulates and starts forming sclerotia. The fungus can infect the host at a temperature ranging from 0 to 25 °C with an optimum at 15 to 20 °C and high humidity (95-100%) also favours the disease development. Application of nitrogen aggravates the disease.

**Management:**

- Follow long crop rotations with paddy and maize.
- Remove infected leaves at weekly intervals.
- Soil amendment with oil cakes like sunflower and mustard and mulching with pine needles and sunflower inflorescence also reduces the disease incidence.
- Some antagonistic fungi like *Trichoderma harzianum*, *T. viride*, *Gliocladium virens* and *Coniothyrium minitans* have been found promising in managing this disease.
- These fungi either inhibit the development of new sclerotia or destroy the developed ones by colonizing them.
- In chemical control, sprays of fungicides like carbendazim (0.1%) or thiophenate methyl (0.1%) or mancozeb (0.25%) or combination of mancozeb (0.25%) and carbendazim (0.05%) effective in reducing the disease.
- Initiate sprays immediately after earthing up and repeat at fortnightly intervals.
Downy mildew

The disease is caused by *Peronospora parasitica* (Pers.) Fr. An obligate parasite. The disease is most serious in seed beds and appears as small leaf spots which first are yellow and later turn brown with bluish black markings. In moist weather, a white downy mold develops on the underside of the leaf spots. Damage to heads curds may occur under conditions of high humidity, warm days and cool nights followed by heavy dew. The causal fungus overwinters on seed, in crucifer weeds and in soil. Disease is promoted by cool weather and occurs at 8-14°C and 90-95 per cent relative humidity. Downy mildew can predispose plants to bacterial soft rot.

**Management:**

- Collect and destroy the infected plant debris and perennial weed hosts.
- Crop rotation with non cruciferous plants.
- Use disease free seeds. Heat treatment of seeds at 43 – 50°C for 20 minutes and treating them with Apron metalaxyl + mancozeb (0.3%) is also effective.
- Spray the crop with metalaxyl + mancozeb (0.25%) or mancozeb (0.25%) or copper oxychloride (0.3%) and repeat at 10 to 14 days interval.

Alternaria leaf spot

The disease is characterized by distinct spots with concentric rings on the lower leaves; the dark dusty fungus growth develops on these spots during moist periods. During storage spots enlarge. Soft rot bacteria may enter through dead leaf spots. The disease is caused by *Alternaria brassica* (Berk.) Sacc. and *A. brassicicola* (Sachow.) Wiltsh. The fungus overwinters in seed and in residue from diseased plants. Wet conditions promote disease development. Moderate temperature (21-27°C), high relative humidity (95-100 % at least for 18h) and splashing rains favour the disease development and spread.
Management:

- Collect and destroy the infected plant debris. Use disease free seeds and treat them with captan (0.3%).
- Spray the crop with mancozeb (0.25%) or copper oxychloride (0.3%) and repeat at 10 to 14 days interval.

BLACK ROT

Initial symptoms of the disease appear as chlorotic lesions along the margins of leaves which progress in the direction of midrib forming “V”-shaped lesions. The veins and veinlets in the chlorotic area turn black and with the passage of time, the blackening of veins advances to the stem and from there to other leaves and roots. The stem and stalk of infected leaves show blackening of vascular tissues. Due to the systemic infection, black spots appear on flower stalk and siliques.

The heads of cabbage and curds of cauliflower are also invaded and become discoloured. The roots of radish and turnip are also invaded from leaves which show discolouration and internal breakdown.

The disease is caused by *Xanthomonas campestris* pv. *campestris* (Pammel) Dowson. The pathogen survives in infected seeds, diseased plant debris and on cruciferous weeds. The optimum temperature for the disease development is about 26.5 to 30°C, minimum being 5°C and maximum 36°C. Heavy rains have been reported to be responsible for the fast spread of the pathogen and the disease through splashes.

Management:

- Follow crop rotation with non-cruciferous crops for at least two years.
- Use disease free seeds and treat them either with hot water (52°C) for 30 minutes followed by same duration dip in Streptocycline solution (100 ppm) or by dipping the seeds in Streptocycline (100 ppm) solution for 30 minutes to eradicate the pathogen.
• In disease prone areas, apply grass or pine needle mulch on the field floor.

• With the initiation of the disease, give fortnightly sprays of combination of Streptocycline (100 ppm) and copper oxychloride(0.3%).

References:


Diagnosis and management of seed borne diseases of solanaceous crops

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Solanaceous vegetable crops constitute a major group of vegetables which include potato, tomato, bell pepper and chillies and brinjal. These crops are generally grown during winter months (Oct.-April) in the plains of India while in the hills of Himachal Pradesh, Uttar Pradesh and Bangalore area of Karnataka, these are mostly grown during summer and rainy season, thereby ensuring the availability of fresh fruits round the year in the market. Prevalence of high humidity and warm temperature during the growing season of these crops not only favours the luxuriant growth of the crop but also favours the development of various fungal, bacterial and viral diseases. Under favourable environmental conditions, epiphytotics of certain diseases have often reduced the yields considerably in certain years.

The term seed borne is used to denote a disease whose causal pathogen is carried in, on or with the seed. The first report of a seed-borne pathogen constitutes of the fungus *Tilletia caries*, causing hill-bunt of wheat by a French botanist, Tillet in 1755. Since then more than 800 fungi, 100 bacteria, 80 viruses and about 10 nematodes have been found associated with seeds (Noble and Richardson, 1968; Phatak, 1974). Mechanism of seed transmission includes the passage of pathogen internally, externally or as an admixture with the seed. If the pathogen is located inside the seed, it is internally seed borne and if it is located on outer side of the seed, it is called externally seed borne. Structures of pathogen mixed with the seed in the form of pathogenic units are termed as admixture.
Seed borne diseases have caused heavy losses to almost all cultivated crops throughout the world in the past. The Irish famine of 1845 due to the tuber-borne fungus which caused late blight of potato is very well known. In 1942, one of the major factors which contributed to the Bengal famine was the failure of rice because of the seed borne brown spot disease. In recent years, seed borne diseases have caused substantial losses to solanaceous crops. Many seed borne pathogens become active as soon as the seed is sown. As a result, there may be seed decay and pre or post-emergence damping-off which in turn results in poor plant stands in the field. It is evident from several examples that seeds are the most efficient means of long distance dissemination or trans-boundary movement of pathogens in the history (Khetarpal et al., 2006). The quotation given by Kandan et al. (2015) “the responsibilities of the plant pathologists do not end with the harvest of satisfactory yields of plant products and that harvesting marks the termination of one phase of plant protection and the beginning of another” emphasizes that seeds and other plant propagating material is important in second phase of crop protection.

**Diagnosis of seed borne diseases**

Diagnosis of seed borne diseases is essential for a number of reasons. First, seed certification schemes require a measure of good quality seed as indicated by the absence of pathogens and also if disease is present, information about inoculum level can help to make accurate decisions regarding the appropriate use of seed treatments. Additionally, diagnosis of seed pathogens for quarantine purposes helps to avoid the spread of disease to new regions (Maddox, 1998). To prevent the spread of diseases that may have a devastating impact on agricultural production, scientists have identified important seed borne pathogens for each country and the appropriate phyto-sanitary methods have been introduced (Richardson, 1996). To make appropriate use of seed treatment, it is important to understand the development of seed borne diseases including the amount of seed borne inoculum, extent of inoculum transmission from seed to seedling,
rate of disease increase in the crop and the amount of reestablishment of seed borne inoculum (Paveley et al., 1997).

Most seed borne pathogens cannot be detected by naked eye examination and contaminate the seed by invisible spores or presence of mycelial infection. Many traditional and modern methods are available for detection of pathogens in different crops and new ones continue to be developed. The main criteria are that the test must be specific, sensitive, accurate, reproducible, rapid, easy to perform and cost effective. Economics dictate that the cost of the test must be appropriate for the importance of the crop and the ability of the producers to pay. The seed health method selected for the detection of a seed borne pathogen depends on the type of pathogen and the association between the pathogen and the seed (Maude, 1996; Neergaard, 1977). Current seed health testing is based on standardized methods described by International seed testing association (ISTA) working sheets. The size of the sample to be analysed in a seed health test is determined by the epidemiological pattern of a specific pathogen. In general, the majority of the standard ISTA methods are performed with a working sample of between 200 and 1000 seeds selected randomly from a seed sample.

Conventional diagnostic methods include agar plate tests, seedling bioassay and microscopic observation. More recent nucleic acid based assays have an advantage in that they are highly specific, sensitive and rapid with potential to being automated, leading to high throughput (Reeves, 1995). New molecular diagnostic technologies offer the potential for automated high throughput screening with sensitive and specific detection of pathogens, often with detection of more than one pathogen in a single test by multiplex PCR and/or the use of fluorescent probes or primers (Taylor et al., 2007). Sensitivity can be such that infection can be detected long before visual symptoms appear.
### i) Conventional diagnostic methods

<table>
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<tr>
<th>S.No.</th>
<th>Method</th>
<th>Description</th>
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</table>
| 1.    | Direct visual examination      | • The most basic examination method.  
• Examination is performed relying on the macroscopic structure of the pathogen or typical symptoms exhibited.  
• e.g., Sclerotia of *Rhizoctonia* or *Macrophomina* clinging to surface on potato.  
• Black or brown spots caused by *Colletotrichum capsici* in chilli. |
| 2.    | Sediment suspension examination | • Inspection of a seed wash suspension using a microscope allows the detection of superficial pathogen structures located on the seed coat. |
| 3.    | Staining methods               | • Normally used to detect obligate parasites                                                                                                                                               |
| 4.    | Growing-out test               | • Planting seeds in field plots or in boxes normally filled with sterile sand.  
• Seedlings are examined for symptoms produced after a period  
• Can be used to detect seed borne fungi and bacteria |
| 5.    | Blotter test                   | • Most commonly used method and is reliable, cheap and easy to perform  
• Seeds are normally incubated on two or more damp blotting papers placed inside a plastic container or in petri dishes. |
| 6.    | Agar plate method              | • Highly recommended and widely used method                                                                                                                                               |
• Seeds are surface sterilized and distributed under aseptic conditions in petri dishes usually containing PDA or other specific media and then plates are incubated for 7 to 8 days.

7. Selective or semi-selective media

- Used for detection of bacteria.
- Bacteria are extracted and cultured using selective media.
- *Clavibacter michiganensis* subsp. *michiganensis* in tomato seeds has been detected using semi selective media.

8. Immunological seed health techniques

- Most widely used is DAS-ELISA.
- Based on a binding reaction between an antigen and specific antibody.
- Commonly used for identifying bacterial and viral infections that is not possible to detect by microscopic analysis.
- Used for detection and identification of seed-borne *Ralstonia solanacearum* in tomato by using specific monoclonal antibodies.

### ii) Molecular methods

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Method</th>
<th>Description</th>
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</table>
| 1.    | Conventional PCR  | DNA sequence information of the pathogen of interest is required.  
Screening for RAPD DNA PCR products or ITS regions of the ribosomal genes using universal primers can be done. |
### Sequences of ITS1 or ITS2 regions can often show variation even between very closely related species.

#### 2. Real-time PCR
- Direct detection of PCR amplicons using either a double stranded DNA binding fluorescent dye (e.g., SYBR Green I) or a specific fluorescent probe (e.g., Light cycler hybridization probes, Taqman probes, Molecular beacons etc.).
- *Verticillium* sp. in tomato seeds have been detected by the quantitative real-time PCR.

#### 3. Real-time PCR using specific fluorescent probes
- SYBR Green I is a nonspecific dye for detection of product amplification, hence nonspecific products such as primer-dimers will also be detected.
- Fluorescent probes are designed to hybridize with the amplified sequence and therefore directly detect the product of the specific primers used for amplification.
- Taq man probe are dual labelled fluorogenic probes with a reporter dye at 5’end and a quencher at the 3’end.

#### 4. Bio-PCR
- Method used for improving sensitivity of detection from bacterial pathogens.
- Infected seed is washed and liquor from this wash is plated onto selective medium. Colonies are washed and an aliquot is removed for PCR analysis.
• Used for detection of *Clavibacter michiganensis* ssp. *Sepedonicus* in potato tubers.

5. DNA chips

• DNA biochips consist of either high density probes on plate based substrates or integrated biochip devices that include DNA arrays and integrated circuit (IC microchip sensors for detection of a signal.
• Samples of DNA in the form of spots are printed on the slide using an arrayer which consists of high speed robotic arm fitted with pins which can precisely position the DNA.

### Management of seed borne diseases of solanaceous crops

Some of the important seed borne fungal, bacterial and viral disease problems of solanaceous crops are described below along with management practices.

<table>
<thead>
<tr>
<th>Disease/Causal Organism</th>
<th>Symptoms</th>
<th>Management</th>
</tr>
</thead>
</table>
| Damping off (Species of *Pythium*, *Phytophthora*, *Fusarium* and *Rhizoctonia solani*) | i) **Pre-emergence damping-off** - failure of seedling emergence from the soil either due to seed rots or killing of young seedlings.  
ii) **Post-emergence damping-off** - Toppling over of infected | • Change the nursery site every year.  
• Either solarize the soil with transparent polyethylene (25µm) sheet for 45 days during summer months or treat the soil with Formalin (5%) at least 21 days |
| Late blight (Phytophthora infestans) | On leaves, pale, green, irregular spots appear on the tips and margins which in moist weather enlarge rapidly, turn necrotic and dark brown or black. On lower surface of the infected leaves, a white downy growth of the fungus appears around the dead areas which are more prevalent in moist climate. On fruits, dark and greasy spots are formed which gradually cover the entire fruit surface. White growth of the fungus may also be appear on the lower surface of the infected leaves. | before sowing or apply bioagents like *Trichoderma harzianum*/*T. viride* (40g/m²).  
• Treat the seed with captan or thiram (0.3%).  
• After seedling emergence from the soil, drench the bed with the mixture of mancozeb (0.25%) and carbendazim (0.1%) and repeat at 10 days interval.  
• Give light but frequent irrigations.  

| Follow crop rotation and avoid solanaceous crops like potato in rotation.  
| Improve drainage of the field and keep field free from weeds  
| Diseased fruits should be collected regularly and destroyed.  
| Spray the crop with mancozeb (0.25%) as a protective spray followed by metalaxyl + mancozeb (0.25%) at a critical stage of disease appearance followed by mancozeb sprays at 7-10 days interval.  

seedlings at any time after their emergence from the soil.
<table>
<thead>
<tr>
<th>Disease</th>
<th>Description</th>
<th>Prevention Measures</th>
</tr>
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</table>
| Alternaria leaf spot (Alternaria solani, A. alternate, A.a. f.sp. lycopersici) | A. solani- dark brown spots with concentric rings develop on the leaves which give target board effect.  
A. alternata- spots are small, circular, scattered, dark brown. Older spots are surrounded by yellow halo. The affected leaves dry prematurely.  
A.a. f.sp. lycopersici- spots are small, angular, scattered and light brown in colour. Spots are not surrounded by yellow halo. The symptoms also appear on stems and branches as light to dark brown spots. Dark spots may also appear on mature fruit. Pathogens survive on infected plant parts and seed. | • Destruction of infected plant debris.  
• Follow crop rotation for at least 2 years.  
• Field should be weed free.  
• Procure seed from healthy fruits.  
• Treat the seed with captan (0.3%).  
• Remove foliage up to a height of 15-20 cm to avoid moist and stagnant air conditions.  
• Spray the crop with copper oxychloride (0.3%) or mancozeb (0.25%) at 10-14 days interval. |
| Bacterial spot (Xanthomonas vesicatoria) | On leaves and stems, the spots are water soaked which are darker in colour.                                                                                                                                   | • Follow rotation of fields to avoid carryover of the bacterium and                  |
and not surrounded by halo. Later blightening of foliage takes place that gives a scorched appearance. Fruit spots appear as brownish black elevated scab like areas with eathered or irregular margins which later become sunken and appear grey and bleached.

| Bacterial canker (Clavibacter michiganensis subsp. michiganensis) | Lower leaves show wilting symptoms. On stem, brown streaks and canker develop and small brown, scabby lesions surrounded by white halo appear on fruits. | destruction of infected fruits and plant debris. |
| | | • Use disease free seed. |
| | | • Dip the seed in Streptocycline (100 ppm) solution for 30 minutes. |
| | | • Spray the crop with Streptocycline (100 ppm) immediately with initiation of the disease followed by sprays of copper oxychloride (0.3%) at 7-10 days interval. |
| | | • Collect and destroy all the infected plant debris. |
| | | • Follow crop rotation and tomato should not be grown in infested field for at least 3 years. |
| | | • Use disease free seed. |
| | | • Treat the seed by dipping in the Streptocycline (100 ppm) solution for one hour. |
| | | • Remove diseased plants and destroy them. |
| Tomato mosaic (Tomato mosaic virus) | Infected tomatoes develop light and dark green leaf mottling and sometimes distortion of young leaves. The lamina of leaves is much reduced (fern leaf) | Treatment of freshly harvested seed with dilute hydrochloric acid activates virus contaminating seed coats. |
and yield is greatly reduced. • Virus on seed coats can also be eliminated by dry heating seed at 70°C for 2-4 days. • The use of virus free seed and application of strict hygiene can often reduce and sometimes prevent infection.

| Tomato spotted wilt  | Plants show bronzing, curling, necrotic streaks and spots on the leaves. Dark-brown streaks also appear on leaf petioles, stems and growing tips. The plants are small and stunted. The ripe fruit shows paler red or yellow areas on the skin. Sometimes affected plants are killed by severe necrosis. | • Seedling beds should be isolated from ornamental plants and susceptible crops and the surrounding areas kept free from weeds. • Fine mesh netting may possibly be useful to exclude thrips. • Infected plants should be rogued and destroyed immediately. |

II. Potato

| Late blight (Phytophthora infestans) | On leaves, water soaked lesions develop at the tips and margins which enlarge to form brown to purplish black, necrotic lesions. Whitish downy fungal growth is visible on the underside of the affected leaves during | • Use healthy seed tubers. Cull piles near cold stores should be destroyed. • Restrict irrigation during cloudy days. Use resistant varieties like Kufri Giriraj, Kufri Jyoti, Kufri Giridhar, Kufri Himalini. |
morning. Brown elongated lesions appear on stem and petioles which may girdle it. The entire crop in the field may be killed in one or two weeks and field gives blighted appearance. Brown areas appear on the tuber which extend deep into the internal tissue.

### Black scurf

*(Rhizoctonia solani)*

**Stem canker** - growing tips of sprouts show browning. Sunken, brown necrotic spots are also observed on the sprouts. Severely affected sprouts are killed.

**Black scurf** - presence of black crust on tubers due to the formation of sclerotia. These are normally on the skin and not damage tuber inside. Black scurf phase is more common than stem canker in India.

- Spray the crop with mancozeb/chlorothalonil/propineb (0.25%) and repeat at weekly interval as a protective spray. This should be followed by metalaxyl + mancozeb or cymozanil + mancozeb (0.25%) at a critical stage of disease appearance.

- Healthy and disease free tubers should be planted.
- Two to four years crop rotation with cereals, Brassicas and legumes should be adopted.
- The increase in organic matter content of the soil help in reducing the population of the fungus. The normal unsprouted tubers should be dipped in carbendazim (0.1%) or Monceren (0.25%) for 10 minutes. The seed after treatment should be dried under shade by spreading on the floor of the cold store.
| Common scab  
(Streptomyces scabies) | On the skin of tubers raised rough and corky pustules and deep pits surrounded by hard corky tissues are produced. | • Green manuring and cultivation of certain legumes before planting potato is useful in managing the disease.  
• Dip seed potato in mercurial fungicides such as agallol or Emisan (0.25%) for 10 minutes. |
|--------------------------|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Viral diseases  
(Potato virus X,  
Potato virus Y,  
Potato leaf roll virus) | *Potexvirus-* interveinal mild mosaic symptoms with light and dark green patches, mottling with stunting and often crinkling of leaves.  
*Potyvirus-* induces severe or rugose mosaic. Veinal necrosis may also occur and plants remain stunted. Severe mosaic causes rugosity, bunching or twisting of leaves.  
*Luteovirus-* there is rolling of upper leaves. Infected leaves remain upright and turn pale yellow in colour. Rolled leaves are leathery, stiff and brittle. | • Use virus free certified seed from a reliable source. Rogue out infected plants immediately.  
• Spray insecticides like Rogor or metasystox @250 ml/acre or apply 5 kg of Thimet 10g/acre at first earthing up. |
### III. Bell Pepper and Chillies

<table>
<thead>
<tr>
<th>Disease</th>
<th>Description</th>
<th>Control Measures</th>
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<tbody>
<tr>
<td><strong>Damping off</strong></td>
<td>Same as in tomato</td>
<td>Same as in tomato</td>
</tr>
<tr>
<td>(Species of <em>Pythium</em>, <em>Phytophthora</em>, <em>Fusarium</em> and <em>Rhizoctonia</em>)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **Leaf blight and fruit rot**                | Symptoms appear as water soaked bleached spots on any portion of the leaf resulting in premature leaf fall. Small water soaked spots also appear on the fruits and the flesh under the skin become soft and usually there is a distinct line of demarcation between the invaded tissue and healthy. Whitish grey mould appears on the rotten fruits under humid conditions. Completely rotten fruits may fall down on the ground. | • Collect and destroy the infected leaves and fruits regularly.  
• Drainage of the field should be proper.  
• Apply pine needles on the field floor before the onset of monsoon rains.  
• Spray the crop with the onset of monsoon rains with metalaxyl + mancozeb (0.25%) followed by sprays of either mancozeb (0.25%) or copper oxychloride (0.3%) or Bordeaux mixture (4:4:50) at 7-10 days intervals. |
| **Cercospora leaf spot**                     | On leaves, symptoms appear as circular spots with brown borders and light coloured, faded or greyish central par. | • Collect and burn the infected plant debris.  
• Follow crop rotation.  
• Maintain proper drainage of the field. |
<p>| <em>(Cercospora capsici)</em>                       |                                                                            |                                                                                  |</p>
<table>
<thead>
<tr>
<th>Disease</th>
<th>Description</th>
<th>Control Measures</th>
</tr>
</thead>
</table>
| Anthracnose (Colletotrichum capsici) | Branches show die-back symptoms and become straw coloured. Fruits turning red are most susceptible to this disease. Fruits have dark sunken spots along with pink areas of fungal fructifications. | - Collect and burn the infected plant debris.  
- Procure seed from healthy fruits.  
- Treat the seed with captan (0.3%).  
- Spray the crop with carbendazim (0.1%) or thiophanate methyl (0.1%) or combination of mancozeb (0.25%) and carbendazim (0.1%) or copper oxychloride (0.3%) and repeat at 10-14 days interval. |
| Bacterial leaf spot (Xanthomonas vesicatoria) | On leaves, initially the lesions are water soaked, circular or irregular that becomes necrotic with brown centres and thin chlorotic borders. These lesions are generally | - Collect and destroy infected plant debris.  
- Follow crop rotation and avoid tomato in rotation.  
- Use healthy seed and treat the seed by dipping in Streptocycline (100 ppm) |
sunken on the top surface of the leaf and slightly raised on the bottom. Such leaves turn yellow and fall down prematurely. Fruit lesions are raised with a cracked, roughened wart like appearance.

| Pepper mild mottle (Pepper mild mottle virus) | The virus induces small malformed mottled fruits (which sometimes have sunken necrotic spots), mild leaf mottling and stunting of plants. Symptoms are often more severe in plants infected early. | followed by sprays of copper oxychloride (0.3%) and repeat at 7-10 days interval. |
| • The virus can be substantially eliminated from seed coats by soaking seeds in 4.2% sodium hypochlorite for 15 min or in 10% trisodium phosphate for 30 min or by dry heating seed for 72 h at 70°C. |
| • Infected plants should be detected and removed as soon as possible. |

### IV. Brinjal

Damping off (Species of *Pythium*, *Phytophthora*, *Fusarium* and *Rhizoctonia*)  
Same as in tomato  
Same as in tomato
**Phomopsis blight and fruit rot** *(Phomopsis vexans)*

Circular grey spots with light coloured centres appear on the leaves. Affected leaves turn yellow and fall down prematurely. Pale sunken spots eachin later enlarge and cover the entire surface appear on fruit. A large number of dot like pycnidia also develop on the spots.

- Collection and burning of old plants as soon as the crop is over.
- Use disease free seed and treat the seed with carbendazim (0.2%)
- Spray the crop with mancozeb (0.25%) or carbendazim (0.1% or copper oxychloride (0.3%) and repeat at 10-14 days interval.

**References:**


Perspectives in quality seed production of Garlic in India

K C Sharma
CSKHPKV, KVK, Bajaura-175 125 (HP)

Garlic (*Allium sativum* L.) is the second most widely cultivated *Alliums* after onion and has long been recognized all over the world as valuable spice for food and a popular remedy for various ailments and physiological disorders. It belongs to the family *Alliaceae* and has originated in the Central Asia and Southern Europe. Garlic is rich in carbohydrates, protein, phosphorus, potassium, sulphur, iodine, fiber and silicon in addition to vitamins. Diallyl disulphide is said to possess the true garlic odour. Its pungent flavour makes it used mainly, as a spice seasoning and flavouring the foodstuff involving green tops and bulbs. Its medicinal value is also well recognized for the treatment of hypertension, worms, germs, bacterial and fungal diseases, diabetes, cancer, ulcer, rheumatism etc. Dehydrated garlic extracts are fast replacing fresh bulbs for industrial and home usage in the production of drugs, insecticides and explosives.

Globally, it occupies an area of 14.65 lakh ha with a production of 248.37 lakh tonnes with the productivity of 16.94 t ha\(^{-1}\) (FAO, 2015). Although, India is the second largest producer of garlic in the world, covering an area of about 2.81 lakh ha with a production of about 16.17 lakh tonnes but its productivity is quite low (5.76 t/ha) as against the world average of 16.94 t/ha (Anonymous, 2016). Important states producing garlic on commercial scale in India are Gujarat, Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, Madhya Pradesh, Orissa, Uttar Pradesh and Haryana. Himachal Pradesh, a hill state in northern India under western Himalayas has witnessed a sharp increase in garlic producing area during last decade, especially in Kullu and Mandi districts of the state. Presently, Himachal Pradesh occupies an area of 4570 ha with a production of 2050 MT (Anonymous, 2017). The bulbs produced in the state are also qualitatively better than the other garlic growing states in the country. Although, the
climatic conditions are favourable for garlic cultivation in Himachal Pradesh, however its average productivity (4.48 t ha\(^{-1}\)) is low compared to 5.76 and 16.94 t ha\(^{-1}\) in national and world level, respectively. Unawareness of the farmers about improved technology like high yielding varieties, integrated nutrient management and proper plant protection measures are the main reasons for its low productivity in India.

India is projected to have a population of 1.7 billion by 2050, and there is no possibility of increase in cultivable land. To cater to the requirement of this ever increasing population and keeping per capita consumption at the present rate of 4.0 g/person/day and 87.5% population consumes garlic (above 5 years age group) and export requirement increases to 3.0 lakh tonnes, processing 2.5 lakh tonnes and need bulbs 1.50 lakh tonnes and losses in storage 4.50 lakh tonnes(15%), then total requirement during 2050 will be around 30.0 lakh tonnes. To achieve this target average productivity per hectare needs to be increased to 10 tonnes/ha compared with the existing productivity of around 5.76 tonnes/ha and storage losses need to be reduced to some extent.

**Quality seed production technology:**

The production and productivity of garlic in India is very low as compared to many other countries. Unawareness of the farmers about improved technology viz. high yielding varieties, congenial climate and soil, agro techniques, insect pest damaging the crop and their management though main reasons, inadequate market supply is also for limiting the production indirectly. Garlic cloves refers to as garlic seed but seed produces after sexual reproduction is actually a true seed. It is considered to be completely sterile plant and is, therefore, commercially propagated only by cloves (Dhull, 2015).

**Climate**

It is a cool season crop. Higher yields are obtained under in a mild climate. It can tolerate frost up to some extent. During maturity of the bulbs, long days and dry weather are beneficial while short days and cool temperature favour vegetative growth. As soon as bulbing commences leaf
initiation ceases. Because of this reason, garlic should be planted early to promote vegetative growth under short days and cool weather.

**Soil**

Garlic can be grown on variety of soils but thrives better on fertile, well-drained loamy soils. The bulbs get discolored in badly drained soils and pulling the bulbs from hard soils caused spitted and bruised loosing its storage life. pH should be in the range of 6-7.

**Varieties:**

**Agrifound White (G-41):** Bulbs are compact, silvery white with creamy flesh bigger elongated cloves with 20-25 in number and diameter 3.5 to 4.5 cm. Recommended for Maharashtra, and Madhya Pradesh.

**Yamuna Safed (G-1):** Bulbs are compact, silvery white skin with creamy flesh, diameter 4.0-4.5 cm. Sickle shaped cloves with 25-30 in number. Recommend to cultivation in all over the country.

**Yamuna Safed-2 (G-50):** Bulbs are compact, attractive white creamy flesh and average diameter is 3.5-4.0 cm. Number of cloves 35-40. Recommended for cultivation in Northern India.

**Yamuna Safed-3 (G-282):** Bulbs are creamy white and bigger sized about 4.5-6 cm in diameter. Number of cloves/bulb is 15-16. Recommended for Madhya Pradesh, Maharashtra, Haryana, Gujarat, Punjab, Rajasthan, Uttar Pradesh and Chhattisgarh.
**Yamuna Safed-4 (G-323):** Bulbs are silvery white and average diameter is 3.5- 4.0 cm. Number of cloves 20-25/bulb. Recommended for North and central India.

**Yamuna Safed-5 (G-189):** Bulbs are creamy white and bigger sized 4.5-5 cm in diameter. Number of cloves/bulb is 22-30. Suitable for processing purpose and recommended for growing in Sikkim, Meghalaya, Manipur, Nagaland, Mizoram, Tripura, Arunachal Pradesh, Andaman and Nicobar Island, Punjab, Tarai region of Uttar Pradesh, Uttarakhand, Bihar, Jharkhand, Gujarat, Rajasthan, Haryana and Delhi.

**Agrifound Parvati (G-313):** Bulbs are bigger size 5.0-6.5 cm in diameter, creamy white colour with pinkish tinge, 10-16 cloves/bulb. Recommended for Himalayan hills of Himachal Pradesh, Uttarakhand, Jammu Kashmir and high altitude of North eastern states like Sikkim etc.

**Agrifound Parvati-2 (G-408):** Bulbs are bigger size 5.0-6.0 cm in diameter, creamy white colour, 12-14 cloves/bulb. Suitable for growing in Himalayan hills of Himachal, Uttarakhand, Jammu Kashmir and high altitude of North eastern state like Sikkim etc.

**GHC-1:** This is the most popular variety of garlic in Kullu and Mandi districts of HP. It is high yielding, fragrance, bigger size cloves and easy for peeling. Average yield is 200-225 q/ha.
Crop production System Management: The planting of garlic cloves of 8-10 mm size at a spacing of 10-12.5 cm x 7.5. cm in the month of October is recommended for obtaining higher bulb yield, however, for quality bulb production planting at 15.0 cm x 10.0 cm spacing is recommended (Lawande et al. 1993). The planting of garlic is generally recommended from 15th Oct. to 15th Nov. however, planting from 15th Oct. to 30th Oct. is recommended for Karnal conditions of Haryana and 25th Oct. to 5th Nov. under Nashik condition of Maharashtra.

Besides Nitrogen-Phosphorus-Potash (NPK) (100:50:50 or 125:75:60 Kg/ha), the use of Sulphur @ 30-50 Kg/ha and Zinc sulphate @ 20 Kg./ha are recommended for enhancement in yield and quality. Wange et al. (1998) reported that application of Azotobacter + N @100 kg per hectare; Azotobacter + Azospirillum + N @ 50 or 75 kg per hectare and Azospirillum + N @ 50 kg per hectare increased significantly the growth and yield characters of garlic compared to the nitrogen alone. Similarly studied that the maximum plant height (59.67 cm) and number of leaves per plant (8.96) were recorded with the application of 100:40:60 NPK kg/ha + Azotobacter + Phosphorus Solubilizing Bacteria (Bhandhari et al. 2012). Sharma et al. (2013) also reported the maximum values of yield and yield attributes like, average bulb weight (37.62 g), number of cloves/bulb (11.08) and bulb yield (181.08q/ha) in garlic bulb when the plots were supplemented with recommended NPK fertilizer compared to untreated control. They further observed that the yield (177.08 q/ha) obtained with the application of 75 % NPK was statistically significant over 50 %NPK (155.00 q/ha) and control (90.83 q/ha).

The use of specialty fertilizers (water soluble fertilizers) as NPK -19:19:19 @ 1 % at 30,45 and 60 DAP followed by NPK -13:0:45 @ 1 % at 75, 90 and 105 DAP increase the yield and enhance the storability substantially. The fertigation in 10 splits are recommended for higher bulb yield. For garlic grown on Avid system, the integrated nutrient management is recommended with saving of 50 % chemical fertilizers (NPK @ 50:25:25 Kg./ha + Sulphur @ 25 Kg./ha + Zinc @ 10 Kg./ha + Azospirillum or Azotabactor @ 10 Kg./ha
Phosphate solubilizing bacteria @ 10 Kg/ha) to 70 % chemical fertilizers (NPK @ 30:15:15 Kg./ha + Suphur @ 15 Kg./ha + Zinc @ 6 Kg./ha + foliar spray of Polyfeed @ 1 % at 15, 30 and 45 DAP followed by Multi-K @ 1 % at 60, 75 and 90 DAP) without any significant reduction in yield with improvement in soil health and environmental soundness in comparison to standard check (NPK @ 100:50:50 Kg./ha + S @ 50 Kg./ha + Zn @ 20 Kg/ha). The farm application of GA3 @ 25 ppm at 45 & 60 DAP have been recommended to enhance the yield of garlic and improve the quality under Nashik condition of Maharashtra and Karnal conditions of Haryana (Anonymous, 2015). Use of Pendimethalin @ 3.5 l/ha + one handweeding or Oxyfluorfen @ 0.25 Kg a.i/ha + one handweeding are recommended for effective control of weeds in garlic. The irrigation at 1.5 CPE (Cumulative Pan Evaporation) is recommended for higher yield of quality garlic bulbs. Drip irrigation is recommended in garlic grown on raised bed to get higher bulb yield.

**Plant Heath Management:**

**Foliar diseases:** Foliar spray of mancozeb (Dithane M-45) @ 0.25% or Ziram (Dithane Z-78) @ 0.3 % with sticker Triton @ 0.06% at fortnightly intervals after appearance of disease recommended to control the purple blotch (*Alternaria porri*) and stemphylium blight (*Stemphylium vesicarium*) of garlic.

15th October planting of garlic cloves in Nashik (Maharashtra) was found suitable for reducing the prevalence of diseases and thrips in garlic varieties us Yamuna safed, Yamuna safed-2 and Yamuna safed-3 and 15th September for Agrifound white during rabi season. 15th September planting of garlic clove in Karnal (Haryana) was found suitable for reducing the diseases and insect pest in garlic varieties us Yamuna safed, Yamuna safed-2, Yamuna safed-3 and 15th October for Agrifound white during rabi season

**Management of thrips:** Sprays of deltamethrin 2.8% EC @ 0.095% at 15 days interval or fipronil 5% SC @ 0.1% at 10 days interval or profenofos 50% EC @
0.1% or spinosad 45% SC @ 0.1% is recommended for reducing thrips population and increasing yield.

**Post Harvest Technology:** Harvesting of garlic at 75 – 100% neck fall stage, windrow curing till complete drying of tops and neck cutting leaving 2.5cm neck above bulb and storage in nylon-netted bags are recommended to reduce post harvest losses in garlic. The cloves treated with Potassium orthophosphate solution @1% for 15 minutes before planting are recommended to minimize the storage loss in garlic. The garlic variety Yamuna sated-3 planting on 5th Nov. is recommended for level losses at Nashik (for 6 months) as well as Karnal (for 9 months). Artificial curing of garlic bulb variety Agrifound Parvati grown in Kullu valley in curing chamber with full load at 35°C and velocity of airflow at 3.2 m/s. for 14 hours is also recommended for adoption in view of lower storage losses during storage. The garlic genotype G-189 is recommended for processing purpose in view of having desired dehydration qualities

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Seed Genetic Purity- Assessment Using Molecular Markers
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The seed is the basic and critical input for enhancing agricultural production and productivity. The seeds sold by seeds companies and grown by farmers are commonly “certified seeds”. The certification of seeds is for quality control. The certified seeds have improved traits like better yield, pest resistance, drought tolerance, herbicide tolerance etc.

Genetic purity of seeds refers to the percentage of contamination by seeds or genetic material of other varieties or species. Genetic purity test is essential as impurity is caused during processing due to pollen shedders and physical admixtures.

To detect off-types, Grow out test (GOT) is practiced by researchers for genetic purity. It is time-consuming (takes one full growing season for completion), land intensive, tedious and highly vulnerable to human and environmental error. Crop varieties and hybrids identification is essential for their intellectual property right (IPR) protection, prevention of unauthorised commercial use and misuse of the brand name. A set of qualitative and quantitative characters known as descriptors are currently used for varietal identification in Distinctiveness Uniformity and Stability (DUS) testing. However, quantitative characters interact with the environment and are misleading process for varietal identification. The continued release of new cultivars, particularly F_1 hybrid seeds, by public and private breeders in the last 20 years pressed the development of faster and more reliable new technologies for seed genetic purity determination.

There are three major types of markers: morphological markers (also called "classical" or "visible"markers) which are phenotypic traits, biochemical
markers, which are called isozymes, including allelic variants of enzymes and DNA markers (or molecular markers), which reveal sites of variation in DNA.

**Morphological markers** are basically the indicators of phenotype such as seed colour, seed shape, seed size, seed length, etc. They generally represent genetic polymorphisms which are easily identified and manipulated. **Biochemical /protein markers** are based on isozymes. “Isoenzymes” or “isozymes” are the alternative forms or structural variants of an enzyme that have different molecular weights and electrophoretic mobility but have the same catalytic activity or function. Seeds, seedlings or mature leaves etc. of a crop plant have a specific mixture of proteins, which are crop and variety specific (genotype-specific). Electrophoresis separates the mixture of proteins extracted from seeds, seedlings or mature leaves into distinct bands. Each variety (or genotype) has a specific “banding pattern” and on the basis of it admixtures of other varieties, differing in "banding pattern" could be detected. Protein banding patterns of analysed samples are compared with the standard banding patterns of a particular variety. This method is being increasingly used for determining the genetic purity of seed samples. The major disadvantages of morphological and biochemical markers are that they may be limited in number and are influenced by environmental factors or the developmental stage of the plant. Besides these limitations, morphological and biochemical markers have been extremely useful to plant breeders.

**Molecular marker**- ideal molecular marker should have following characteristics i) highly polymorphic ii) Co-dominant, should be able to discriminate between heterozygous states in diploid organisms iii) frequent occurrence in genome iv) detect multiple independent and reliable loci v) provide adequate resolution of genetic differences vi) selective neutral behaviours – DNA sequences of any organisms are neutral to environmental conditions or management practices and this permits to confer the variations only to a genetic origin vii) easy acess and fast assay, it must be simple quick and in expensive viii) high reproducibility to guarantee robust results among different laboratories and equipments ix) require small amounts of tissues and DNA sample x) link to distinct phenotypes xi) require no prior information about genome of an organism
**DNA Markers** are defined as a fragment of DNA that is associated with a certain location within the genome. They arise from different classes of DNA mutations such as substitution mutations (point mutations), rearrangements (insertions or deletions) or errors in replication of tandemly repeated DNA. Basically, DNA markers are divided into two main categories: PCR-based molecular markers and Hybridization-based molecular markers. **Restriction Fragment Length Polymorphism (RFLP)** is a hybridization-based molecular marker. Though it is a co-dominant marker with high reproducibility, it has few limitations like the process is time consuming, expensive, requires large amount of DNA and involves the use of radioactively labelled probes. These disadvantages can be overcome by using PCR-based markers - i) **Random Amplified Polymorphic DNAs (RAPD)** - anonymous stretches of DNA is amplified using arbitrary primers, it is a fast and easy method for detecting polymorphisms but it is a dominant marker along with reproducibility problems. **Amplified Fragment Length Polymorphism (AFLP)** is technically demanding, stable and a very reliable method which uses relatively small amount of DNA, it does not require sequence information or probe collection and has a very high multiplex ratio with relative reproducibility. Its limitations include dominant nature, requirement of high quality DNA for complete restriction enzyme digestion, high cost and experience of sequencing gels. **Simple Sequence Repeat (SSRs)** is a simple, easy and preferable marker system because of co-dominant nature, vast abundance and uniform distribution throughout the genome. Their limitations are high cost investment in oligonucleotide synthesis and require initial identification and necessary prior sequence information. **Sequence Characterized Amplified Regions (SCARs)** are mono locus, less sensitive to reaction conditions, and they can be potentially converted into codominant markers, easy to use and has high reproducibility. Prior sequence information (i.e., sequencing the polymorphic fragments) is required for designing the primers contiguous the polymorphic region. **Sequence Tagged Sites (STS)** unlike PCR with arbitrary primers, sequence-tagged sites (STS) are primers that are based on some degree of sequence knowledge. These unique, sequence-specific primers detect variation in allelic, genomic DNA. STS have a particular advantage over
RAPDs in that they are co-dominant, that is, they can distinguish between homozygote and heterozygote. They also tend to be more reproducible, because they use longer primer sequences. However, they have the disadvantage of requiring some pre-existing knowledge of the DNA sequence of the region, even if only for a small amount. The investment in effort and cost needed to develop the specific primer pairs for each locus is their primary drawback. **Single Nucleotide Polymorphism (SNPs)** is co-dominant markers, often linked to genes and present in the simplest/ultimate form for polymorphism, and thus they have become very attractive and potential genetic markers in genetic study and breeding. Moreover, SNPs can be very easily automated and quickly detected, with a high efficiency for detection of polymorphism. Therefore, it can be expected that SNPs will be increasingly used for various purposes, particularly as whole DNA sequences become available for more and more species (e.g., rice, soybean, maize, etc.). However, high costs for start-up or marker development, high-quality DNA required and high technical/equipment demands limit, to some extent, the application of SNPs in some laboratories and practical breeding programs. **Microsatellites (SSRs, STMS or SSRPs)** are also called simple sequence repeats (SSRs) and, occasionally, sequence-tagged microsatellite sites (STMS) or simple sequence repeat polymorphisms (SSRPs). They are by far the most widely used type of STS. SSRs are short tandem repeats, their length being 1 to 10 bp, most typically, 2-3 bp. SSRs are highly variable and evenly distributed throughout the genome. This type of repeated DNA is common in eukaryotes, their number of repeated units varying widely among organisms to as high as 50 copies of the repeated unit. These polymorphisms are identified by constructing PCR primers for the DNA flanking the microsatellite region. The flanking regions tend to be conserved within the species, although sometimes they may also be conserved in higher taxonomic levels. **Single Strand Conformation Polymorphism (SSCP)** Single-strand conformational polymorphism (SSCP) analysis is a simple and sensitive technique for mutation detection and genotyping. The principle of SSCP analysis is based on the fact that single-stranded DNA has a defined conformation. Altered conformation due to a single base change in the sequence can cause single-
stranded DNA to migrate differently under non-denaturing electrophoresis conditions. Therefore wild-type and mutant DNA samples display different band patterns. SSCP analysis involves the following four steps: 1) polymerase chain reaction (PCR) amplification of DNA sequence of interest; 2) denaturation of double-stranded PCR products 3) cooling of the denatured DNA (single-stranded) to maximize self-annealing 4) detection of mobility difference of the single-stranded DNAs by electrophoresis under non-denaturing conditions. Several methods have been developed to visualize the SSCP mobility shifts. These include the incorporation of radioisotope labelling, silver staining, fluorescent dye-labelled PCR primers, and more recently, capillary-based electrophoresis. Silver staining is simple, rapid, and cost-effective, and can be routinely performed in clinical laboratories.

**Single polymorphic amplification test (SPLAT)** – If sequence tagged site (STS) does not reveal polymorphism it is usually converted into SPLAT. Individual STS products from different genotypes are sequenced any differences revealed can be sequence from nuclear ribosomal DNA. They can be exploited in production of internal primers. Single amplified sequences are dominant markers.

**Variable Number of Tandem Repeats (VNTRs)** is a location in a genome where a short nucleotide sequence is organized as a **tandem repeat**. These can be found on many chromosomes, and often show variations in length (number of repeats) among individuals.

**RNA-Based Molecular Markers (RBMS)** – Markers derived from transcribed / expressed regions of genomes. Since they are based on expressed portion of genome, it could be also affected by phenological plant stage and environmental conditions. The generated fragments can be easily associated with phenotypic traits (QTLs Genetic mapping studies of qualitative traits loci). Among PCR based markers are – iSNAP inter small RNA polymorphism – based on endogenous non-coding small RNAs consisting of 20-24 nucleotides, highly reproducible and useful in genome mapping and genotyping. Other markers cDNA-SSCP, cDNA-AFLP, cDNA—RFLP and RAP-PCR – these are used for differential RNA studies using selective amplification of cDNA.
Molecular markers have facilitated in resolving complications of conventional GOT and DUS testing. Molecular markers methods are being adopted by the researchers for fingerprinting cultivars, assessment of genetic purity and varietal identification in seed technology and breeding programmes. In genetic purity assessment, molecular markers detect the degree of contamination due to selfing and out-crossing in a hybrid seed lot, segregation of genotypes in DUS testing and trait confirmation in transgenic. For varietal identification it is desirous to obtain a specific/unique pattern for each variety. Such patterning provides protection to varieties in DUS test and characterization of Essentially Derived Varieties (EDVs).

**Retrotransposon-based molecular markers** - Retrotransposons are a class (Class I) of transposable elements (TE) and constitute a major portion of the genome in plants with large genomes. They are important for chromatin modifications and epigenetic reprogramming. Retrotransposons are also an ideal target for developing molecular marker techniques because of their amplification mechanism and sequence characteristics. There are different types of transposon based marker techniques. Some of them are; Inter Retrotransposon Amplified Polymorphism (IRAP), Retrotransposon Microsatellite Amplified Polymorphism (REMAP), inter Primer Binding Site amplification (ipBS), Sequence Specific Amplification Polymorphism (S-SAP), Retrotransposon Based Insertion Polymorphism (RBIP), Inter Sine Amplified Polymorphism (ISAP), RAPD- Retrotransposon Amplified Polymorphism (RRAP), Inverse Sequence Tagged Repeats (ISTR), Inter-MITE Polymorphism (IMP) and Transposable display (TD). These methods are the most widely used for different breeding strategies like; the determination of candidate genes, genetic variability, linkage, genome mapping, the DNA fingerprinting, phylogenetics, systematics, conservation, molecular ecology, somaclonal variation studies, transgenic research, developmental biology, and mutagenesis.

Therefore, it is concluded that genetic purity analysis using molecular markers may be used as a potential tool for resolving the problems arise in seed certification program owing to genetic impurity as well as the rapid
determination of genetic purity of hybrids with the deployment of molecular makers as compared to GOT. The use of precise molecular marker would definitely replace GOT in the days to come, which is obviously very tedious, time consuming and highly vulnerable to manual mistakes that normally occur during production, processing and marketing.

**Keywords:** DNA Markers; Distinctiveness Uniformity and Stability (DUS) testing; GOT (Grow Out Test); Morphological markers; RNA- Based Molecular Markers (RBMS); Retrotransposon-based molecular markers; Seed purity

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Genetic Mechanisms for Hybrid Seed Production in Vegetable Crops

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Introduction:
Heterosis/hybrid vigour, whereby, \( F_1 \) falls outside the range of parents with respect to some character(s). This advantage in vegetables was first reported in cucumber in 1916 by Hayes and Jones, and thereafter it has been exploited in other vegetables like tomato, bell pepper, hot pepper, brinjal, cucumber, muskmelon, watermelon, bottle gourd, pumpkin, onion, carrot, cabbage, cauliflower etc.

Heterosis is generally manifested in the following ways.

- High yield in terms of large size, weight or number of fruits.
- Uniformity in shape, size, color and maturity.
- Early maturity
- More number of roots, bulbs, heads, curd knobs and sprouts per units area.
- Resistance to biotic and abiotic factors.

Bases of heterosis:
Genetic, physiological and biochemical causes were assigned earlier for the manifestation of heterosis. In contrast, heterosis has been established as genetic phenomenon, which may involve:

i) Dominance \( i.e \) accumulation of favourable dominant genes distributed among parents.

ii) Overdominance \( i.e \) favourable interactions between two alleles at the same locus.

iii) Epistasis \( i.e \) complementary interaction of additive, dominance or recessive genes at different loci.

Once the dispersion of genes among the parents has been established, the heterosis breeding approach can be applied where over-dominance or over-
interaction is observed. However, in self-pollinated crops where dispersion of genes with partial to complete dominance, epistasis, coupled with over-dominance at some loci is observed, improvement of parental lines and then development of F₁ hybrid should be the basic approach. In case of cross-pollinated crops, if such dispersion arises, development of improved lines through inter population improvement and then developing the F₁ hybrid, should be the need based approach.

**Mechanisms for hybrid seed production:**

Once the hybrid is developed, commercial seed production becomes the mandate. Seed production is easier in those crops where monoecious, dioecious, self- incompatible and male sterile conditions are present. Various techniques can be used for hybrid seed development.

i) Both hand emasculation + hand pollination: Okra, tomato, eggplant, hot and sweet pepper, owing to hermaphrodite nature of the flower.

ii) Removal of staminate flowers+ hand pollination: Cucurbits (squashes, bitter and bottle gourd).

iii) No emasculation + hand pollination : Cucurbits owing to monoecious nature of blooming.

iv) Hand emasculation + wind pollination: Dioecious vegetables like spinach and asparagus.

v) Hand emasculation + insect pollination: Tomato where emasculation can be done with ease and stigma receptivity is observed for longer duration of the day.

vi) Self-emasculating mechanisms+ free insect pollination:

- Using self-incompatibility *e.g.* turnip, radish, cabbage, Brussels, broccoli, cauliflower and chinese cabbage.
- Using male sterility *e.g.* GMS in muskmelon, tomato, hot and sweet peppers and CMS in onion, cabbage, carrot, hot pepper and cauliflower.
- Using gynoecism *e.g.* cucumber.
- Using gametocide like GA₄/GA₇(onion), maleic hydrazide (tomato, capsicum and onion) sodium 2,3-dichloroisobutyrate (tomato).
Various Mechanisms for Hybrid Seed Production

Genetic Male Sterility:
The male sterility gene usually is recessive and the male sterility may be due to pollen abortion, failure of anther dehiscence, anther abortion, pistillody of the anthers or several other possible causes. Through a combination of crossing, selfing and collecting seed set on sterile plants, a population can be created which segregates in 1:1 ratio for Msms.

Msms individuals as given below:

Now, onwards the seed set on msms will always segregate into 1 fertile: 1 sterile. This stock seed will be used as the female parent in hybrid seed production. However, 50% male fertile plants will have to be rogued from the seed production rows prior to pollen shedding.

Cytoplasmic Genetic Male Sterility:
The cytoplasmic factor S interacts with recessive nuclear gene ms and produces a male sterile line of the genotype Smsms which is male sterile and is known as ‘A’ line in the hybrid seed production programme. The genotype with normal cytoplasm is known as Nmsms and is male fertile. This is referred to as ‘B’ line and is used as a maintainer for the male sterile line, Smsms (A line). After repeated backcrossing, the male sterile ‘A’ line and the maintainer ‘B’ lines become almost isogenic. To produce hybrid seed the ‘A’ line is inter-planted with the pollinator or ‘C’ line of the genotype NMsms.

These steps are demonstrated as follows:
The CMS system can easily be used to produce seed of single, double or 3-way hybrids as given in Fig. proposed by Riggs (1988)

The discovery of cytoplasmic genetic male sterility in onion by Jones and Clarke has been instrumental in application of this system in hybrid seed production on large scale in several crops, particularly the 4 crops, namely, onions, pear millet, sunflower and grain sorghum, and now rice.

**Self-Incompatibility:**
The term 'self-incompatibility' is defined as inability of a plant to set seed when self-pollinated, even though it can form normal zygotes when cross-pollinated and its pollen can fertilize other plants. The genetic control of SI may be gametophytic or sporophytic.

The gametophytic incompatibility is controlled by pollen grain, whereas in the sporophytic system the reaction is between the exine of the pollen grain, which is sporophytic in origin and the papillae of the stigma. This incompatibility is determined by the diploid nucleus of the sporophyte.
In other words, the behaviour of each pollen grain is determined by the diploid genotype. As a result, patterns of inter-allelic interaction ranging from independence to complete dominance may occur in both pollen and style. All kinds of brassicas have a sporophytic SI system being strongest in kale and weakest in summer cauliflower. The S-allele system is complex with about 50 alleles at a single locus.

It is known that glycoproteins have an important role in causing self-incompatibility. Increased rate of synthesis of these S-locus specific glycoproteins coincides with the onset of the incompatibility reaction. Therefore, while developing parental inbred lines this reaction is overcome by pollinating the flowers in the bud stage during selfing. The commercial F1 hybrids are produced by inter-planting 2 self-incompatible but cross-compatible inbred lines. The inbred lines are maintained through bud-pollination.

**A simple system is shown below:**

Thompson (1964) recommended production of ‘triple-cross’ hybrid kale, a hybrid type which can be produced only with the sporophytic SI. The triple-cross is a hybrid between 2 three-way crosses, that is (ABxC)x(DExF).

With this type of cross there is a minimum of bud-pollination (needed to maintain inbred lines), and the simple cross, three-way cross and triple-cross can also be made without emasculation if proper self-incompatibility alleles are present in the 6 inbred lines. If kale has gametophytic system of incompatibility, the triple-cross could have been impossible because some plants in each three-way cross could be cross compatible.
In cole crops (Brassica oleracea L), hybrid seed production makes use of the sporophytic incompatibility mechanism. Due to the great number of alleles, cabbage populations, generally, consist of plants that are heterozygous at the incompatibility locus. With bud pollinations, inbred lines may be developed from such a population.

If inbred lines with the constitution $S_1 S_1$ and $S_2 S_2$ which have been tested for specific combining ability, are produced by bud-selfing and grown next to one another, seeds only with the allelic combination $S_1 S_2$ will be formed. This is due to the fact that the $S_1$ pollen cannot fertilize any egg cells of the $S_1 S_1$ plants, nor can $S_2$ pollen fertilize any egg cells of the $S_2 S_2$ plants. To prevent occurrence of pseudo-fertility and pollination of parent lines by selfing during hybrid seed production, it is necessary to develop inbred lines with strong dominant alleles.

If the seed production after a single cross is too low and therefore, uneconomical, double crosses can also be produced according to the following scheme:

\[
S_1 S_1 \times S_2 S_2 \quad S_3 S_3 \times S_4 S_4 \\
\downarrow \quad \downarrow \\
S_1 S_2 \quad S_3 S_4 \\
\downarrow \quad \downarrow \\
S_1 S_3 \quad S_1 S_4 \quad S_2 S_3 \quad S_2 S_4
\]

As a result of the pseudo-fertility, e.g. due to high temperatures or late flowers, pollination within parental lines leading to the development of selfed or sibbed seeds, must always be taken into account. Depending upon the cole crop species, the plant material, environmental conditions, and modifying genes, their proportion may amount to as high as 40%.

**Manipulation of Sex Expression:**

Production of hybrids in certain crops like cucurbits is possible through manipulation of sex expression. Cucumber plants are typically monoecious producing male and female flowers on the same plant. Now gynoecious lines are available. These lines produce only female flowers and can be easily used as female parent to produce $F_1$ seed of cucumber on large scale.
Multiplication of such lines is made possible by induction of male flowers through spraying of gibberellic acid i.e., GA 4/7 (2000 ppm) or Ag NO₃ on seeding leaves. On the other hand, monoecious lines of squash can be rendered female by applying ethephon to suppress male flower production. Two applications of ethephon @ 600 ppm at the 2-and 4-leaf stage result in complete male flower suppression during the fruiting stage. Ethephon is being used on commercial scale for production of hybrid seeds in squash.

**Chemical Hybridizing Agents (CHAs):**

The CHAs are defined as the chemicals which cause pollen abortion and render the treated plants male sterile without affecting ovule fertility. These chemicals are also called as gametocides. To be really useful in F₁ hybrid seed production, CHAs should have no mutagenic effect, be easy and economical to apply, have wider applications and have no harmful side effects.

Although CHAs have relatively larger application in major cereal crops, their use in vegetables is yet to be commercialized. Positive responses have been achieved with GA₃ and GA 4/7 in lettuce and onion, with maleic hydrazide in tomato and onion, and with sodium 2, 3-dichloroisobutyrate in tomato.

**Biotechnological Approaches in Hybrid Seed Production:**

The conventional F₁ hybrid seed production systems have depended on hand emasculation, genetic, cytoplasmic genetic male sterility and self-incompatibility, etc. In most cases these systems have some disadvantages, involving cost, efficacy, ease of use, reliability and effect of environmental factors leading to breakdown of the systems.

The production of cell-toxic ribonuclease enzyme in the tapetal cells (which nourish cells that develop into male gametes), thereby causing male sterility. For technical reasons, mother gene, bar conferring resistance to herbicide glufosinate was hooked to the barnase cytotoxic gene.

This gene cassette helps in retaining only male sterile plants from mixed progenies in commercial hybrid seed production plots. For commercial crop production, the F₁ hybrids have to bear normal bisexual flowers. To restore male fertility in the F₁ hybrids, they used barstar gene from the same bacterium, *B. amyloliquefaciens*. The product of barstar forms a complex with barnase enzyme and nullifies the toxic effect of Rnase.
Incorporating *barstar* in the male parent which can be used to pollinate *barnase* carrying male sterile, but female fertile plants provided a perfect system for commercial hybrid seed production. This system has been patented by M/s Plant Genetic Systems (PGS) Ltd., Belgium.

In 1994, Proagro Seed Company Ltd. (PSCL) made a joint venture company with Plant Genetic Systems, Belgium to develop transgenic plants in mustard (*Brassica juncea*) and in vegetables. The technology of Plant Genetic Systems known as Seed-link technology was already tested in *B. napus* in Canada. Proagro Seed Company has converted *B. juncea* lines with the help of transgenes, barnase, barstar and bar, and stabilized the hybridisation system in mustard to produce hybrid seed on commercial scale. The limited field study trials for environmental and food safety as per the requirements of Department of Biotechnology (DBT) were conducted in India but commercial release did not materialize.
Basic Principles of Quality Seed Production in Vegetable Crops

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Seed production is an exacting task. During seed production strict attention must be given to maintenance of genetic purity and other qualities of seed in order to exploit the full dividends sought to be obtained by introduction of new superior crop plant varieties.

Quality seed: A quality is one which is genetically pure, physically pure, physiologically active and is healthy as per prescribed seed certification standards. To maintain the quality of seed basic principles may be grouped into genetic and agronomic principles.

Genetic principles:

Genetic purity of a variety can deteriorate due to several factors during production cycles. The important factors responsible for genetic deterioration of varieties as listed by Kadam (1942) are:

- Developmental variations
- Mechanical mixture
- Mutations
- Nature crossing
- Minor genetic variations
- Selective influence of diseases
- The technique of plant breeder

- Developmental variations: When the seed crops are grown in difficult environment, under different soil and fertility conditions, or different climatic conditions, or under different photoperiods, or at different
elevations for several consecutive generations, the developmental variations may arise sometimes as differential growth responses. To minimize the opportunity for such shifts to occur in varieties, it is advisable to grow them in their areas of adaptation and normal growing seasons.

- **Mechanical Mixture:** Mechanical mixture may take place at the time of sowing, if more than one variety is sown with same drill or through different varieties grown in adjacent field. Two varieties growing alongside each other in the same field are often mixed at the time of harvesting and threshing operation. Threshing equipments (i.e. threshing machine) is often contaminated with seeds of other varieties. The gunny bags, seed bines are also quite responsible for mechanical mixture of varieties. To avoid mechanical mixture, it is necessary to rogue the seed fields and care should be taken at the time of harvesting, threshing and handling.

- **Mutations:** Though chances of mutations are very rare \((10^{-6})\) but if noticed in a seed crop, the plants should be rouged out as soon as visible. e.g. ‘rabbit ear’ in peas.

- **Natural Crossing:** In sexually propagated crops, natural crossing is most important source of varietal deterioration. The deterioration in varieties due to natural crossing may occur due to natural crossing with undesirable type, natural crossing with diseases plants or natural crossing with off-type of plants. According to Bateman (1947) genetic contamination in seed fields due to natural crossing depends upon factors like the breeding system of species, isolation distance, varietal mass and pollinating agents. As the isolation between varieties is increased the contamination decreases. Isolation of seed crop is the primary factor in the seed production of crop plants of cross pollinated by wind or insects and their activities, humidity and temperature at the time of anthesis etc.

- **Minor genetic variations:** Minor variations exist in phenotypically uniform and homogeneous varieties at the time of their release which
are eliminated in later production cycles by the selective influence of environment. Multi-location yield trials before release of the variety in self-fertilized crops (Hann, 1953) and due care during production of nucleus and breeder’s seed of cross-fertilized crops will be helpful in minimizing such variations.

- **Selective Influences of Diseases:** New crop varieties often become susceptible to new races of diseases often caused by parasite. Some vegetative propagated stocks deteriorate fast if infected by viral, fungal and bacterial diseases. Therefore, it is very important to produce diseases free-seeds /stocks.

- **Techniques of the plant breeder:** Some irregularities at the time of development of a variety may lead to the deterioration of such variety, if the material is not properly assessed. Further, premature release of a variety still segregating for resistance to insect-pests and diseases may also result in its deterioration. Hence, careful handling and assessment of the material during development of a variety is necessary.

**Agronomic principles**

**Selection of agro-climatic region:** A crop variety to be grown for seed production in an area must be adapted to the photoperiod and temperature conditions prevailing in that area.

**Selection of seed plot and land preparation:** The plot selected for seed crop must be free from volunteer plants, weed plants and have good soil texture and fertility. The soil of the seed plot should be comparatively free from soil borne diseases and insects pests. Good land preparation helps in improved germination, good stand establishment and destruction of potential weeds. It also aids in water management and uniform irrigation.

**Isolation of seed crops:** The seed crop must be isolated from other nearby fields of the same crops and other contaminating crops as per requirement of the certification standards. Contamination can be avoided through different methods:
a) **Space isolation**: By providing minimum specified distance from the sources of genetic contamination so that foreign pollens are unable to reach in viable state.

b) **Time isolation**: By adjusting the time of sowing i.e. keeping a gap of 15-20 days between sowing of varieties /cross-compatible crops.

c) **Barrier isolation**: Isolation can be achieved by physical barriers such as barrier crop/ polythene sheet of optimum height around the seed plot, polyhouse/ polytunnels/ net houses and mountains which reduce the movement of pollen.

d) **Discarding border rows**: Foreign pollens mainly pollinate the plants present on the outer periphery of the seed plot. Therefore, contamination can be reduced by discarding the produce of 5-6 lines on the outer periphery.

**Selection of variety**: The variety for seed production must be a higher yielder, should possess disease resistance, earliness, grain quality, and adapted to the agro-climatic conditions of the region.

**Seed sowing/ planting**: Seed should be obtained from an authentic source and should be sown after suitable treatment depending upon the seed. Preferably seed crops should be sown at their normal planting time following some adjustments, if necessary. To facilitate rouging operations and inspection of seed crops, slightly lower seed rates than usual for raising commercial crops are desirable. The most efficient and ideal method of sowing is by mechanical drilling as it ensures sowing at uniform and proper depth resulting in good plant stand.

**Rouging**: Adequate and timely rouging is extremely important in seed production. Rouging in most of the field crops may be done at vegetative/ pre-flowering stage, flowering stage and maturity stage as per need of the seed crops. Rouging should be done in the morning or evening. Dull, excessively bright and windy days should be avoided for doing rouging operations. The back of the person doing rouging should be towards the sun.
Supplementary pollination: Provision of honey bees hives in close proximity to the seed fields of crops largely cross pollinated by the insects ensure good seed set thereby greatly increase the seed yield.

Weed control: Effective weed control is the basic requirement in producing good quality seed. Weeds may cause contamination of the seed crop besides reduction in yield due competition between crop and weed plants for light, space, moisture and nutrients. Wild cucumber (*Cucumis hardwii*) and wild watermelon (*Citrullus colocynthis*) are the objectionable weeds in cucumber and water melon, respectively.

Disease and insect control: Successful disease and insect control is another important factor in raising healthy seed crops. Apart from reduction in yield, the quality of seeds from diseased and insect damaged plants is invariably poor. Black rot (*Xanthomonas campestris pv. Campestris*), black leg (*Leptosphaeria maculans*) and soft rot (*Erwinia carotovora*) are designated diseases in cole crops.

Nutrition: In the nutrition of seed crops, nitrogen, phosphorus, potassium, and several other elements play an important role for proper development of plants and seed. It is, therefore, advisable to know and identify the nutritional requirements of seed crops and apply adequate fertilizers.

Irrigation: Irrigation can be important at planting of seed crops on dry soils to ensure uniform germination and adequate crop stands. Excessive moisture or prolonged drought adversely affect germination and frequently results in poor crop stands. Dry regions are more suitable for quality, disease free seed production and hence, assured source of irrigation is a must.

Harvesting and storage of seed: It is of great importance to harvest a seed crop at the time that will allow both the maximum yield and the best quality seed. In order to preserve seed viability and vigour, it is necessary to dry seeds to safe moisture content levels. The best method of storing seed for short periods is in sacks or bags in ordinary buildings or godowns.
References:

Advances in Production Technology of Root Vegetables

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Root vegetables are an important group of cool season vegetable crops. They are main crops of a winter diet. The most commonly grown root crops in India are carrot (Daucus carota L.), radish (Raphanus sativus L.), turnip (Brassica rapa L.) and beet root (Beta vulgaris L.). Radish and turnip belong to family Brassicaceae, carrot to Umbelliferae and beet root to Chenopodiaceae. Although, these crops belong to different families but they require similar cultural practices for their cultivation. Due to their short growing period and high productivity, root crops fit well in sequential, inter and relay cropping system, which enable maximum use of available land. In India, root and tuber crops are grown in an area of 2.18 million hectares with annual production of 44.66 million t (Anonymous, 2010). Uttar Pradesh, Assam, Karnataka, Andhra Pradesh, Punjab, Haryana, West Bengal, Bihar and Himachal Pradesh are the major root vegetable growing states in India.

Off-season Production

The off-season vegetables are grown in the areas where the climatic conditions are moderate for both normal as well as for off-seasons. The hill regions of the country offer most congenial climatic conditions for off-season vegetable production during summer months. The main season vegetables of these hilly regions become off-season in the plains as result growers fetch lucrative returns from their produce. Off-season vegetables produced in the hills have a special significance because of specific flavour, aroma, freshness, prolonged self-life and keeping quality. These being environment specific are primarily confined to hilly areas of the country. Root vegetables such as radish, carrot, turnip and beet root are grown by the farmers in summer
(March-May) on hilly or semi-hilly areas where climatic conditions are favorable for a particular vegetable. The off-season root vegetables so produced are being supplied to the plains where they get the remunerative prices, resulting in the improvement of the social status of the hill farmers.

Root crops are generally storage organs enlarge to store energy in the form of carbohydrates. Root vegetable like carrots are highly efficient in producing the highest amount of nutrients and health promoting substances per unit area. Carrot is a rich source of high carotene content which is reported to be anti carcinogenic in nature, whereas radish leaves are rich in minerals and vitamins (A and C), which has cooling effect and prevents the constipation. Beetroot is a rich source of potent antioxidants and nutrients, which is important for cardiovascular health. After the sugarcane, it is the second most important crop for the preparation of sugar. Root crops thrive well in cool season and yield excellent quality of produce. However, a number of varieties of carrot, radish, turnip and beet root have been developed, which are adapted to comparatively warm season and produce crop of fairly good quality.

**Improved cultivars**

There are two distinct groups of radish, carrot and turnip i.e., European or temperate and Asiatic or tropical type. European radishes are quick growing, having short duration (25-30 days), produce roots of good quality, less pungent and are smaller in size, whereas Asiatic varieties are slow growing, having long duration (45-55 days), more pungent and produce roots of large size. European types of carrots are biennial in nature and they require chilling temperature for bolting and seed production. They are low yielding and do not produce seeds in plains. While, Asiatic types are annual in nature and their seeds can be produced in the plains and yields more as compare to European carrots. European types of turnips are biennial in nature, sweeter and more palatable than the Asiatic types, whereas Asiatic types are annual in nature, more pungent and possess tolerance against heat. Several improved cultivars of important root crops recommended for cultivation in different regions of the country are as follows:
<table>
<thead>
<tr>
<th>Crop</th>
<th>Asiatic cultivars</th>
<th>European cultivars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrot</td>
<td>Pusa Kesar, Pusa Meghali, No. 29, Sel. 21 and Sel 233, Pusa</td>
<td>Chantenay, Early Nantes,</td>
</tr>
<tr>
<td></td>
<td>Rudhira, Pusa Ashita and Pusa vrishti</td>
<td>Imperator, Pusa Yamdagini,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Solan Rachana, Zeno and Pusa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nayan Jyoti (F1)</td>
</tr>
<tr>
<td>Radish</td>
<td>Arka Nishant, Jaunpuri Giant, Nadauni, Punjab Safed, Pusa</td>
<td>Chinese Pink, Japanese White,</td>
</tr>
<tr>
<td></td>
<td>Chetki, Pusa Desi, Pusa Himani and Pusa Reshmi</td>
<td>Rapid Red White Tipped, Scarlet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Globe, Scarlet Long, Pusa Himani</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and White Icicle</td>
</tr>
<tr>
<td>Turnip</td>
<td>Pusa Kanchan, Punjab Safed, Pusa Sweti and Punjab Safed-4</td>
<td>Purple Top White Globe, Pusa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chandrima, Snow Ball, Golden</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ball, 4, Early Milan Top Red and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pusa Swarnima</td>
</tr>
<tr>
<td>Beet root</td>
<td>---------------</td>
<td>Crimson Globe and Detroit Dark</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Red, wonder and Crosby Egyptian</td>
</tr>
</tbody>
</table>

Selection of cultivar should be done according to location, situation, need, market demand, insect-pest, diseases and length of growing period.

**Improved Production Techniques**

A sunny site with deep, well drained, friable soil having good tilth is ideal for root vegetable production. Soil may range from organic muck soils to sandy loams. A compaction layer of shallow plough pan or heavy soils hampers the root growth resulting into mis-shapen roots. Root crops can tolerate wide range of pH from 5.5-7.0. All the root crops are cool season vegetable crops. However, Asiatic varieties of root crops can also tolerate higher temperature. The temperature range of 10-15°C is optimum for proper growth and development of roots, texture and flavour in all roots crops. In hot weather, growth and colour development of roots is affected by higher temperature resulting in the tough and pungent roots before reaching the edible maturity. Beside this, long photoperiod and warm temperature favour early bolting even prior to proper development of roots.
All root vegetables are sown directly in the field. Appropriately, 10-12 kg (radish), 8-10 kg (carrot), 4 kg (turnip) and 7-8 kg (beet root) seeds are required for sowing in one hectare of area. Seeds are usually sown at a spacing of 30-45 cm (radish, turnip and beet root) or 25-30 cm (carrot) on ridges. Shallow furrows of 2 cm depth are prepared on the ridges using a stick. The seeds are thinly sown in the shallow furrows and covered with a mixture of soil and well rotten manure. After sowing the ridges are kept moist till the germination is completed. The seed of beet root is **multigerm** which produces 3-4 seedlings per seed ball, hence thinning is an important operation. To avoid the competition among seedlings remove the seedlings leaving the single robust plant per seed ball. The thinning should be done when seedling attain 3-4 leaves. The seedlings are thinned to a distance of 6-8 cm for proper growth and development of the crop. Also remove the weak, diseased and insect affected plants to maintain proper distance between the plants with in the rows.

Root crops can also be seeded precisely with mechanical seeders that prevent the need for subsequent thinning. Precision seeding requires specialized planters and uniformly sized seeds. Pelleted seeds having uniform size are sown with the help of mechanical planters like gravity-feed cone seeder, belt driven seeder and vacuum seeder. Plantings are often irrigated until germination to prevent the soil from crusting and to cause uneven stand.

Time of sowing of any crop depends upon the type of the variety and location. In north India, radish can be grown throughout the year, but the main season is from August to January. European varieties can be sown from September to March, whereas in South India main growing season is from April to June and October-December. In the hills, radish is grown from March to October. For carrots, August to November is the optimum time of sowing of Asiatic group, while for European types is October to November. Tropical type varieties of turnip are sown from the end of July to September and temperate types from September to December in north Indian plains, whereas July to September is the optimum time for growing the turnip in the hills. In northern plains, beet root is sown during September to November, whereas in southern
plains its sowing is extended from July to November. In hills the seed is sown from March to July.

Weeds pose a very serious problem in the early stages as growth of seedlings is very slow and they cannot compete with the weeds. Generally, one to two shallow weedings at early stages of crop growth keep the field free from weeds. Moreover, pre-emergence application of Fluchloralin (0.5-1.0 kg/ha) or Pendimethalin (1.0 kg/ha) is also effective to control the weeds in the field of root crops. Soil should be hoed time to time to allow proper aeration. Beside this, organic mulches also help in keeping soil weed free and lower down the soil temperature.

Manure and fertilizer application is also an important step which decides the productivity potential and quality produce of any crop. Fertilizer program should be based on a soil test. Random soil samples should be collected from the entire field and nutritional status of the field should be checked out before planting any crop. Due to climatic conditions, differing cultural practices, varying soil conditions and other situations, the crop’s response to the fertility program may vary from region to region. In general for healthy crop stand in root vegetables, 20-25 tonnes of FYM per hectare along with 80-100 kg nitrogen, 40-60 kg phosphorus and 80-100 kg potassium per hectare should be incorporated into the soil. However, requirement of NPK will depend upon soil fertility and crop variety. Temperate varieties require less fertilizer as compared to Asiatic types. One half of the quantity of nitrogen should be applied as basal dose and remaining half should be top dressed 35-40 days after sowing. The FYM to be applied must be fully decomposed because fresh or partially decomposed manure may cause deformation of roots like forking, branching, rough skin and numerous adventitious roots.

Moisture stress can reduce the crop yields. Plants that wilt intermittently may produce smaller yields, while those which wilt frequently will often die due to irreversible cell damage. Most of root crops require irrigation prior to germination to prevent a crust from forming on the soil which impedes germination. After germination, irrigation is only necessary
during drought or on typically dry soils such as sands. Both drip and overhead sprinkler irrigation systems are effective. Radish require adequate soil moisture to prevent them from developing an overly pungent taste. Carrot yield is higher with an even water supply, which can prevent cracking caused by wet weather immediately following dry weather.

**Harvesting and post harvest technology**

Harvest the root crops when they are sweet and sizable but not too large or fully matured. Harvesting should be done all at once with the help of a tractor pulled digger or by hand after loosening the soil with the help of a fork. Bunched crops like radish, carrot, turnip and beet root are pulled by hand after they are dug by machine. Harvested roots are washed clean in a rotating barrel type of washer or with a strong spray of water of soaked in water. After washing, allow roots to dry on screen tables and pack them into waxed cardboard boxes. It is very important to maintain the high humidity to prevent the shriveling.

The Asiatic/Tropical types of carrots attain marketable stage of maturity when these are 2.5-4.0 cm in diameter at the upper end. Generally, Asiatic types give higher yield (25-30 tonnes/ha) than the European types (10-15 tonnes/ha). Fresh carrots cannot be stored for more than 3-4 days under ordinary storage conditions. However, long-term storage can be achieved in cold stores, without appreciable change in quality attributes. The optimum temperature for minimizing decay is 0-1°C. But, carrots can be stored for 6 months at a temperature of 0-4.5°C with 93-98 % relative humidity.

Radish can be harvested when its roots are still tender. They are pulled out vertically with least breakage. The edible maturity period varies from 25-60 days depending upon the type of the cultivar. Early maturing European varieties mature in 25-30 days, while Asiatic types take around 45-60 days. The delayed harvesting results in pithiness and bitterness hence unfit for marketing and consumption. The average yield of Indian cultivars is 150-200 q/ha, whereas European cultivars produce about 50-70 q/ha. The harvested roots along with tops are properly washed, graded and tied in bundles. About
3-6 roots are tied in a bunch depending upon the size of roots. These bundles are loose packed in baskets and transported to the market. Harvested roots can be stored for 3-4 days at room temperature without impairing its quality. However, it can be stored up to 2 months in cold storage at 0°C with 90% relative humidity.

The fully developed roots of turnip are uprooted on attaining the marketable size. Normally the roots are harvested when they are 5-10 cm in diameter, depending upon the variety. The roots become tough and fibrous if harvesting is delayed. On an average it yields 200-400 q/ha. Harvested roots along with green tops are properly washed to remove the adhered soil. These are sent to the market in baskets either along with green tops or after cutting them off near the surface of the crown. The roots can be stored safely for 2-3 days under cool and moist conditions. However, it can be stored for 2-4 months at 0°C with 90-95% relative humidity.

Beet root is harvested 50-60 days after planting, when the roots are still round and tender. It can be stored for 10-14 days under cool and moist conditions, but storage life can be extended to 6 months if it is kept at a temperature of 0°C with 95% relative humidity.

Male-Sterility

Welch and Grimball (1947) reported the first male sterile plant in 1945-46. Now morphologically there are 3 types of male sterility available:

- **Wax coated and Swollen Anthers**: These anthers do not produce any fertile pollen.
- **Brown coloured Anthers**: These anthers are shriveled and brown without any viable pollen.
- **Anthers replaced by petals**: These anthers are petaloid. This type of sterility is more stable.

**Characteristics of Male Sterile Lines**

- The male sterile plants are less vigorous than the male fertile plants.
• The cell differentiation of male sterile lines also differs. It may be either earlier or later than normal lines resulting in petaloid or brown anther type sterilities respectively.
• Male sterile lines produce off white to green coloured flowers, while fertile ones produce white flowers.
• Male sterile lines start anthesis much later than fertile lines.
• Nectar produced in the male sterile lines is often poor in quality as well as in quantity.
• Male fertile lines generally produce perfume like aroma while most of male sterile lines produce indistinct carrot like or no aroma in the flowers.
• Male sterile flowers are less visited by the honey bees.

A. Genic Male Sterility

Hausche and Gabelman (1963) reported that male sterility is conditioned by two nuclear genes. The plants carrying ms\textsubscript{5} ms\textsubscript{5} or ms\textsubscript{4} in heterozygous condition (MS\textsubscript{4} ms\textsubscript{4}) or homozygous condition (MS\textsubscript{4} MS\textsubscript{4}) result in male sterility.

B. Gene Cytoplasmic Male Sterility

Jones (1950) and Lamprech (1951) reported that the male sterility is due to interaction between dominant nuclear gene and cytoplasm. It is not clearly that how many genes are involved, but according to Timin \textit{et al}. (1981), the brown anther male sterility is conditioned by dominant and recessive genes (MS\textsubscript{1} MS\textsubscript{1} MS\textsubscript{2} MS\textsubscript{2}) in (s) cytoplasm, while the petaloid type is conditioned by three dominant genes (MS\textsubscript{3} MS\textsubscript{3} MS\textsubscript{4} MS\textsubscript{4} MS\textsubscript{5} MS\textsubscript{5}) in (s) sterile cytoplasm.

Hybrid Seed Production:

Hybrid seed production using male sterility needs location of male fertile plants (maintainer) which in successive generations will yield all male sterile progenies. Such plants should be homozygous dominant for one or more MS loci, should be free from epistasis.
In the heterosis breeding programme 3 lines are used, namely the male sterile line (A), male fertile sister line (B), and the pollinator line (C) which is male fertile and has a good combining ability with the male sterile line. By the use of suitable cytoplasm and one or more gene it has proven possible to facilitate production and maintenance of hybrids. But there are some difficulties

- Firstly seed behavior is not uniform.
- During seed set seeds of a higher order umbel start growth and ripen later than those of a lower order umbel resulting in low seed germineability and slow seedling growth.
- Large scale maintenance of hybrids has not been very successful because of loss of vigour of inbred components or instability in sterile/maintainer line.
- Narrow genetic base of modern carrots.
- Two CMS systems suffer from instability of male sterility under specific conditions viz., high temperature, dry conditions and long days.
- The development of male sterile line and maintain lines is a very laborious work due to dominant state of male sterility.

High degree of homozygosity in the male sterile and maintainner lines is recommended but lines with low inbreeding depression reduces the probability of finding good parents for hybrid varieties. To overcome this problem the development of three way hybrids have been recommended (Stein and Nothangel, 1995).

Three way hybrids viz. Spartan Classic, Spartan Premium, Spartan Winter have been developed. All the three hybrids are early maturing, smooth rooted, moderately resistant to *Cercospora carotae* and rusty root (*Pythium* spp.)

The male sterile and pollinator lines are grown in alternate rows of 4:1 or 8:2 and the F1 hybrid seed is harvested from female line only. Rouging of off types and pollen bearers in female line is very important. Flowering of male
and female parents should have synchronization for flowering. Five to six bee colonies/ha is beneficial in pollination.

The F₁ hybrids are early in maturity and have uniformity in root shape, size and colour resulting in higher number of marketable roots and higher yield than the open pollinated variety. In carrot 3 way or single cross hybrid are made using male sterile line as one of the parent. Hybrids can also be developed with high carotene content as breeding lines in USA are available now having very high carotene of 5000 ppm. Hybrids in carrot are not popular due to problems in the utilization of male sterile lines and production of hybrid seed.

**Radish (Raphanus sativus L.)**

Major breeding objectives are:

- Early maturity and high root yield.
- Non-pithy blunt ended cylindrical roots.
- High pungency and nutrients.
- Slow and late bolting with less foliage.
- Tolerance to heat, drought and wet situations, and cold hardiness, etc.
- Resistance to Alternaria blight, white rust, radish mosaic virus and aphids.

The production of F₁ hybrid seed in radish by hand emasculation and pollination is easy as compared to carrot as the flower buds are bigger, easy to emasculate and single pollination yields more number of seeds. However, the male sterility can be used for commercial hybrid seed production. In general, the system of breeding remains the same as followed in other brassicas.

**Use of Male Sterility and Self-incompatibility in Hybrid Seed Production**

**Male Sterility**

Ogura (1968) reported gene- cytoplasmic male sterility in radish which is due to interaction between recessive nuclear gene ms ms and sterile (s)
cytoplasm. later it has been reported that there are two pairs of ms genes in
the nucleus (Kalloo & Bergh, 1993) hence the genotype of the male sterile line
(A) could be s ms₁ ms₂ ms₂, maintainer line (B) Nms₁ ms₁ ms₂ ms₂; pollen
parental line (C) NMS₁ MS₁ MS₂ MS₂. Ogura (1968) described first sterile
cytoplasm in a Japanese population of radish. On the bases of flower
morphology, radish CMS is classified into three types.

- Degenerative corolla
- Shriveled stamen
- Abortive pollen

Ogura cytoplasm has been found widely distributed among the wild
Japanese radish plants and most of the early European radish population.
Male sterility in line 64A has been found to be associated with tapetum
abortion and serious vacillation of cytoplasm of tapetum cells which resulted
in hypertrophy (Su et al. 1995).

The successful transfer of Ogura CMS to three cultivars of radish
(Japanese White, Pusa Chetki and Pusa Desi) has been reported by Sodhi, et al. (1993). These three cultivars producing flowers with pollenless anthers are
now available as male sterile lines for hybrid seed production in radish.
Hawaldar et al. (1997) crossed Ogura radish, a cytoplasmically genetic male
sterile line with four local and three Japanese cultivars to identify maintainer
lines. Out of seven F₁ families, one or involving a local cv. Ayushi produced
100% male sterile (MS) progeny. The hybrid seed production is done by using
A and C lines in 1:1 ratio.

**Self -Incompatibility:**

Radish is normally self-incompatible and insect pollinated. The
incompatibility system is of saprophytic in type in which the papillae on the
stigma surface form the barrier to pollen tube penetration.

Hawaldar and Mian (1997) investigated the self incompatibility
mechanism through seed set analysis and pollen tube growth behaviour.
Moderately strong self-incompatibility was observed in Red Kalpin and Kuni
White.
Monakhos and Barasheva (1999) crossed 8 self incompatible lines in a full diallel and the results indicated that trait was controlled by several dominant genes with lines differing greatly in dominance and additive effects as well as cytoplasmic effect.

The parental lines may be developed by the same procedure as adopted in *Brassicas*, however there is no much progress in developing self incompatible lines in radish. Single, double and triple cross hybrids can be made. For the production of hybrid seed 1:1 ratio of two parental strains is advocated. Excess of nitrogen causes poor pod set in radish. Spraying of 30 ppm boric acid or 0.2% multiplex at flowering is useful for seed setting. Radish is less preferred by bees in comparison to cabbage, turnip, carrot etc. necessitates keeping bee hives in the seed crop. For maintenance purpose, the self incompatibility can be overcome by bud pollination or by CO$_2$ at relatively high concentration of 3-5% for 2 hours in the evening on other day to their opening by their own pollen. It has been observed that the seed is better when the buds are pollinated only a day prior to opening when there is at least 30 % flowering on the plant than bud pollinating only a day prior to opening just at the commencement of flowering.

**Turnip (Brassica rapa L.)**

The main breeding objectives are:

- Earliness in attending marketable size.
- High yield.
- Stump rooted varieties with thin tap root and non-branching habit.
- Slow bolting and no pithiness.
- Resistance to club root, powdery mildew, turnip mosaic virus, while rust, cabbage root fly and turnip root fly.

All the systems of hand emasculation and pollination, use of incompatibility and production of hybrid seed are similar to that of radish and other brassicas. Heterosis has not been exploited commercially though reported for yielded and dry matter content and other characters in turnip. Synthetic cultivars developed by using inbred lines of good combining ability have out yielded the best commercial cultivars in Holland.
Recurrent selection in progeny of crosses involving cultivars such as PTWG, Raab Salad and Shogoin Turnip has resulted in considerable progress towards developing cold tolerant and aphid resistance turnips.

**Beet root (Beta vulgaris L.)**

The main breeding objectives are:

- Breeding high yielding varieties having dark red, uniformly colored roots with absence of any internal white rings.
- Uniform shape and size of roots, and slow bolting habit.
- Developing varieties of spherical, flattened spherical, cylindrical or conical root shapes depending upon regional preferences.

**Methods of seed production**

The seed production is taken in the hills for European types and in the plains for Asiatic types. European types require high chilling of 4-7°C for a period of about 4-6 weeks. The mild summer and low rainfall of hills especially during flowering and seed setting stages are beneficial. The 'root of seed' and 'seed to seed' methods can be used seed production preferable 'root to seed'. In root to seed method, fully matured roots (before pith development) are harvested, true to the type roots are selected and after giving proper root and shoot cuts are transplanted in a well prepared field. The selection and rouging are done on the basis of foliage characters, root shape, size, color, flesh color, pithiness, and pungency and bolting behavior. Small, deformed, diseased and other undesirable roots are discarded. Hairy forked roots and early or late bolters are also removed. The sowing time should be so adjusted that the roots become available and their stecklings could be set in before chilling months. In heavy snowfall areas where chilling period is long, the roots after uprooting are stored in trenches before the onset of winters and replanting is done in the month of March- April. In such case stecklings are prepared just before planting. The seed is ready for harvesting from July- August in the hills and from May to June in the plains depending upon the weather, crop and cultivar.
Future Strategies

To encourage the high-tech root vegetable production, attention should be given equally to production/productivity factors, quality of produce and to availability of quality seeds and planting material. Shaping up the growth will require highly skilled manpower at the middle and lower levels, necessitating training and development. Organic cultivation seems to offer a viable alternative for the problem of pesticide residue in vegetables. Increasing quality consciousness among farmers and processors and enhancing skills in the areas of grading and standardization, will be crucial for global trade in the WTO regime. In order to survive in International markets, synchronization between market trends and production system is necessary. Integrated management of nutrients and water has the potential to improve productivity and residue operation costs. This couple with soil health and integrated management of insects, pests and diseases would pay an important role in reducing the use of pesticides. Creation of a well dispersed infrastructure and efficient storage and transport system will be crucial factor in harvesting the full potential of horticulture sector. The introduction of these technologies has paved the way for taking up more sophisticated intervention like precision farming, which has the potential to increase the productivity by manifolds with judicious management of natural resources including time.

References:


Recent Techniques in Seed Production of Cole Crops

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Vegetable seed production is thought to be a layman’s job but it is not so simple. To produce vegetable seeds on scientific basis one has to acquaint himself with various fundamental principles of seed production. The culture of many of the vegetables for home or market does not involve the production of the inflorescence, fruit or seed. A vegetable producer’s job is finished when the edible portion of the plant has reached the desired maturity and is ready for harvest. The seed grower, in contrast has to carry many crops on through further stages of growth. This often necessitates a familiarity with methods and techniques not generally known by many gardeners. With some vegetables, seed production is relatively simple; with others it is more difficult and involves more elaborate techniques with increased risk of crop loss; with a few not only considerable skill is required to grow a satisfactory market vegetable in the first place but a great deal more skill is demanded to carry the crop on through the final but essential stage of flowering and seed development. Good seed is the basic requirement of all growers. Thus seed producer stands in a position of great responsibility, and to fill his obligation satisfactorily he needs to understand thoroughly many factors which enter into production and processing of good seed.

Cole group of vegetables has originated from a common parent, the wild cabbage or ‘cole wart’ (Brassica oleracea var sylvestris). The cole crops have spread all over Europe from Mediterranean region which is supposed to be the center of origin and are among the most widely grown vegetables in the temperate zones and possibly occupy the largest area in India in winter, except potato and onion.

Among the cole groups grown in India, cauliflower and cabbage are the two most important while knol-khol sprouting broccoli and Brussels sprouts,
though grown in certain areas, are yet to be as popular as the other two. There is substantial increase in the area of cabbage and cauliflower during the last decade in India and are grown almost round the year either in the hills or plains. At present the level of yield is low in India, as compared to other developed countries of the world. One of the main reason for dismal performance is the lack of quality seed. Therefore, it became imperative to make available sufficient quantity of quality seed to the farmers. This is only feasible when seeds of improved varieties are produced by adopting advanced production techniques to meet the inflated demand.

**Cabbage (Brassica oleracea var. capitata)**

Cabbage is the second most popular vegetable of the cole group. Both early and late cultivars are grown in India for seed production. Golden Acre, Pusa Mukta, Pride of India and Copenhagen Market are early cultivars whereas Pusa Drum Head and September are late types. The sowing time of cabbage is adjusted in such a way that it should form heads before the onset of winter or snowfall for proper inspection, roguing and transplanting depending upon the method of seed production. Planting of late types by mid August and early types by mid September is done in Kullu and Kashmir Valley. In Kalpa, planting of both types is done in July and heads are ready for storage in November. The central stalk develops into flowering shoots and if head is removed axillary buds form the flowering shoots.

**Cauliflower (Brassica oleracea var. botrytis)**

In India, cauliflower is the most popular among the winter vegetables. The initial introductions were Cornish types from England followed by the European types. The Indian cauliflower or the tropical types are a result of inter crossing among these types. Two separate groups of cauliflower are commonly grown in India, Indian or tropical types and the annual temperate types known as Erfurt or Snowball types. The major difference between these two groups is their adaptability to different temperatures.
The temperature requirement for curd initiation and development in different maturity groups is 20-27°C in September/October (Group I), 16-20°C for November (Group II), 12-16°C for December (Group III) and 10-16°C for late cauliflower (Group IV). Seeds of tropical cauliflower can only be produced in the plains of north India and snowball type in the hilly regions only.

**Varities**

Various varieties of cauliflower developed and released in different maturity groups are:

- **Group I** (Sept.- Oct. maturity): Pusa Early Synthetic, Early Kunwari
- **Group II** (November maturity): Pusa Deepali, Pusa Katki, Pant Gobhi-2, Improved Janapese
- **Group III** (December maturity): Pant Subhra, Pusa Himjyoti

**Climate**

Cabbage, late cauliflower, knol-khol, kale and brussels sprouts require temperate climate for successful seed production, while seeds of early and mid season varieties of cauliflower and broccoli can be produced in tropical conditions. Cool climate having moderate to heavy rain fall well distributed through out the season in which vegetative development takes place properly are most favourable for raising these vegetables. The main feature of the temperate climate is low temperature (4-7°C) for at least 40-60 days. This is favourable for breaking dormancy of biennial vegetables. Cole group of vegetables except early cauliflower and broccoli are biennial. The other feature of such climate is mild summer and low and well distributed rainfall especially during flowering. Some tropical varieties of cabbage are being developed which require only 10-13°C temperature for two months. At present seed production of cabbage, late cauliflower, knol-khol, brussels sprouts and broccoli is done only in the states of Himachal Pradesh, J & K, U.P. and Nilgiri hills in the South.
Soil

Cole crops can be grown almost in all types of soils with sufficient water supply. However, light soils are suited for early crop varieties while in heavier soils late varieties thrive better. On heavy soils plants grown slowly and keeping quality of head/curd/knob is increased. The optimum pH requirement of these vegetables varies from 6.0-6.5. Plants grown in saline soils are more prone to diseases.

Methods of Seed Production

Three methods of seed production are practiced for cole crops depending upon their merits and demerits:

1. Head to Seed Method

   This method is mainly used for seed production of cabbage and knol khol. However, it is rarely used for brussels sprout. The selected true to type fully mature plants (heads/knobs) are uprooted and then transplanted at other locations after removing the outer leaves. This method is usually employed for the production of nucleus seed. In Kinnaur and Lahaul Spiti regions of Himachal Pradesh, the mature plants (heads/knobs) are stored in trenches before the onset of snow and replanted in late spring. A single layer of heads along with roots is placed in 75 cm deep, 3 m long and 11 m wide trenches in the soil. The roots are covered with soil up to depth of 5-7.5 cm. These are covered with wooden planks and about 15 cm layer of soil is spread over them. Small holes are kept on both ends of the trenches for proper ventilation.

2. Seed to Seed Method

   In this method the seed crop is raised on the same location where it was originally transplanted to get heads/curds/knobs or sprouts. Any of the following three techniques can be used depending upon the crop and their suitability:
(A) **In situ**

The plants are allowed to over winter in their original position. The partially buried plants can withstand temperature of 5-12°C especially in cabbage, knol-khol and brussels sprout. The rouging of off type plants is done thrice to retain the true to type plants both during vegetative and reproductive stages of growth. The operations like cross cutting of heads in cabbage and scooping of curds in cauliflower facilitate bolting. Generally, this method is used to produce foundation and certified seed.

(B) **Stump method**

The fully mature heads of cabbage are cut just below the base leaving the outer leaves intact with stem. The heads of selected true to type plants are cut. The stumps left *in situ* develop flowering shoots and ancillary buds during spring. These stumps can also be replanted where it is necessary.

(C) **Stump with core method**

The cabbage heads are chopped off on all sides with perpendicular cuts in such a way that central core is not disturbed. The stump go through flowering shoots in spring which are not decumbent. Therefore, it is an improvement over stump method.

### 3. Late Planting

Cabbage seedlings when transplanted late in autumn from seed stalks in spring without head formation provided the stem of the seedling planted is thicker than the pencil diameter. The method can be followed in early types. The stock seed used for this method should be of high quality.

**Agrotechniques**

**Nursery Management**

Seedlings are first raised in nursery beds before transplanting in the field for raising healthy and disease free seedlings. Proper seed treatment and nursery management are necessary. Soil of nursery bed should be well prepared and
free from disease organisms. The seived well rotten Farm Yard Manure @ 2-3 kg/m² must be added in the seed beds. If necessary manure NPK may be added @ 30-50 g/m². The use of excessive N should be avoided to check the formation of lanky seedlings. Generally, beds are kept 15 cm high from ground level to provide proper drainage. These are 1 m wide and 5-10 m in length. Seed should be treated with fungicides like Thiram/Captan/Brassicol/Diflotan @ 3 g per kg of seed before sowing. The optimum spacing between rows in the nursery bed is 2.5 cm. Seeds should be sown at a depth of 1.5- 2.5 cm to raise seedlings for one hectare, 50-70 m² of area is sufficient. After sowing seed is properly covered with a thin layer of fine soil. Proper moisture level is necessary for rapid germination of seed and optimum growth of the seedlings. Nursery beds are covered with grass after sprinkling water.

Seed beds are sterilized by drenching with 1:50 Formalin solution at least 10-15 days before sowing. Nursery beds are covered with alkathene sheets for 3-5 days and then kept open for 7-10 days before sowing of seed. This is done to avoid the toxic effect of formalin on young germinating seeds. Seeds can be treated with hot water at 50°C for 30 minutes and then dried in the shade before sowing in nursery. Sowing is done in July-August for raising seed crop in the temperate regions and November December in tropical conditions. About 300-600 g seed is sufficient to raise seedlings for planting one hectare.

**Isolation**

The cole crops are highly cross pollinated and percentage of cross pollination varies from crop to crop. The botanical varieties of *Brassica oleracea* group i.e. cabbage, cauliflower, broccoli, knol-khol, brussels sprouts, kale, collard and other wild allies freely cross with each other. Hence, proper isolation among these crops is needed to keep purity of seeds. Similarly growing of different cultivars of each crop also requires proper isolation. An isolation distance of 3000 m for breeder seed and 1600 m for certified seed production is recommended.
Preparation of Land

Land should be thoroughly prepared by ploughing 3-4 times to raise a healthy seed crop. Soil should be made loose and friable. The stubbles of previous crop should be collected and burnt. Farm yard manure or compost should be properly mixed with soil. The beds of suitable size (3m x 3m) should be prepared before planting the crop.

Transplanting

Generally 4-6 weeks old seedlings are ready for transplanting depending upon the variety, temperature and fertility of the soil. Seedlings are transplanted in the field 60x45 cm apart, however, a spacing of 60x60 cm is commonly used for cole crops.

Manures and Fertilizers

Among cole crops cabbage is a heavy feeder hence require additional manures as well as fertilizers depending upon the fertility of soil. Generally, 20-25 tons/ha of farm yard manure is supplied during land preparation. Application of 250 kg nitrogen, 125 kg phosphorus and 100 kg of potash per hectare are the optimum and economical doses for getting good seed yield in cabbage variety Golden Acre. Application of 250 kg/ha of nitrogen. 150-200 kg/ha of phosphorus and 80-100 kg/ha of potash are the optimum doses for raising good seed crop of cauliflower. Soil application of Agromin 20-25 kg/ha helps in preventing physical disorders like whiptail and browning. Application of 10-15 kg/ha of Sodium molybdate and borax also controls these disorders. The whole dose of farm yard manure, half of nitrogen, complete doses of phosphorus and potash should be added during preparation of land. Half of the nitrogen is given in three equal split doses after 30-70 and 140 days of transplanting. Last dose should be given just before bolting to obtain maximum growth of lateral branches for increasing seed yield.
Irrigation

Crop is immediately irrigated after transplanting. Thereafter the number of irrigations depends upon weather conditions and moisture regime of the soil. Generally, 3-5 irrigations are given at an interval of 7-10 days.

Inter culture

Inter culture operations of hoeing and weeding should be done regularly to check weeds soon after establishment of the crop in the field. At least three hoeing and weedings are necessary for effective weed control. Pre transplant application of Stomp 750 ml/ha and one hoeing of Basalin 1 litre/ha and one hoeing are quite effective to check weeds. Application of Fluchloralin 1 kg/ha one day before transplanting is also very effective. Mulching with paddy husk is also useful in control of weeds in cole crops.

Roguing and Inspection

A thorough rouging of off type plants should be done immediately after curd/head/knob/sprout formation. The true to type plants having genetic purity of the variety are retained and rests are pulled out. Second rouging is done at the time of bolting. Curds of cauliflower which bolt in the centre are removed. Similarly, plants with deformed inflorescence are pulled out.

The field inspections are carried out at least four times. First inspection is done to remove off types, diseased and blind plants during early vegetative phase. The morphological qualities of head/curd/knob/sprouts are checked during second inspection. Third inspection should be made critically for horticultural characters including maturity. Fourth inspection is done at the time of flowering.

Harvesting and Threshing

The maturity of cole group of vegetables differs between varieties of each crop as well as from region to region. Crop is generally harvested when 60-70% of pods turn yellow or light brown in colour as the whole crop do not
mature at one time. Therefore, harvesting is done in two to three lots. Stem or branches are cut from base with sickles at the time of maturity. The harvested crop is kept for curing in heaps for 7-10 days. These heaps are frequently stirred to facilitate proper aeration and prevent premature germination during this process. After complete curing it is dried in thin layers in the sun.

Threshing is done with bullock driven rollers or beating with sticks after proper drying. Seeds are separated manually with bamboo sifters or with machine. These seeds are graded manually or mini petkus machine is used for this purpose. Seeds are then thoroughly dried in the sun to bring moisture level to 6-8% for their longer storage life. Average seed yield of cole group of vegetables varies from 200-700 kg/ha.

Certification

Isolation

The cole crops are highly cross pollinated and percentage of cross pollination varies from crop to crop. The botanical varieties of *Brassica oleracea* group i.e. cabbage, cauliflower, knol-khol, brussels sprouts, kale, collard and other wild allies freely cross with each other. Hence, proper isolation among these crops is needed to keep purity of seeds. Similarly growing of different cultivars of each crop also requires proper isolation. An isolation distance of 3000 m for breeder seed and 1600 m for certified seed production is recommended.

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phase. The morphological qualities of head/curd/knob/sprouts are checked during second inspection. Third inspection should be made critically for horticultural characters including maturity. Fourth inspection is done at the time of flowering.

**Crop and seed standards**

Besides isolation and rouging, a seed crop must have the prescribed field standards (Table 1) regarding true-to-type plants, diseased plants, plants of other crops and freedom from objectionable weeds. In well spaced crops like cabbage, knol khol and Brussels sprouts, the plants of other crops and objectionable weeds can be removed easily and there is no question of their presence in the seed crop. However, seed standards and maximum permissible limits of off-type and disease (seed borne) affected plants have been fixed separately for foundation and certified seed crops (Table 2).

**Table 1. Specific standards prescribed for certification at field stage for cole crops**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Min. No. of Inspections</th>
<th>Isolation distance (m)</th>
<th>Off-type plants</th>
<th>Plants affected by Phyllody</th>
<th>Plants affected by seed borne diseases (Black leg, Black rot &amp; Soft rot)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FS</td>
<td>CS</td>
<td>FS</td>
<td>CS</td>
<td>FS</td>
<td>CS</td>
</tr>
<tr>
<td>Cabbage</td>
<td>3</td>
<td>1600</td>
<td>0.10</td>
<td>0.20</td>
<td>0.50</td>
<td>1.0</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>3</td>
<td>1600</td>
<td>0.10</td>
<td>0.20</td>
<td>0.50</td>
<td>1.0</td>
</tr>
<tr>
<td>Knol-khol</td>
<td>3</td>
<td>1600</td>
<td>0.10</td>
<td>0.20</td>
<td>0.50</td>
<td>1.0</td>
</tr>
<tr>
<td>Brussels Sprouts</td>
<td>3</td>
<td>1600</td>
<td>0.10</td>
<td>0.20</td>
<td>0.50</td>
<td>1.0</td>
</tr>
<tr>
<td>Sprouting broccoli</td>
<td>3</td>
<td>1600</td>
<td>0.10</td>
<td>0.20</td>
<td>0.50</td>
<td>1.0</td>
</tr>
</tbody>
</table>
### Table 2. Seed standards for foundation and certified seed classes of cole crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Pure seed (% min.)</th>
<th>Inert matter (% max.)</th>
<th>Other crop seeds (max. No./kg)</th>
<th>Total weed seeds (max. No./kg)</th>
<th>Germination (% min.)</th>
<th>Moisture for ordinary container % max.)</th>
<th>Moisture for vapour proof container % max.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FS</td>
<td>CS</td>
<td>FS</td>
<td>CS</td>
<td>FS</td>
<td>CS</td>
<td>FS</td>
</tr>
<tr>
<td>Cabbage</td>
<td>98</td>
<td>98</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>70</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>98</td>
<td>98</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>65</td>
</tr>
<tr>
<td>Knol-khol</td>
<td>98</td>
<td>98</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>70</td>
</tr>
<tr>
<td>Brussels sprouts</td>
<td>98</td>
<td>98</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>70</td>
</tr>
<tr>
<td>Sprouting broccoli</td>
<td>98</td>
<td>98</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>65</td>
</tr>
</tbody>
</table>

FS= Foundation seed, CS= Certified seed

### Hybrid seed production

Hybrid seed production suffers from limitations of high cost. Cole crops are naturally cross-pollinated due to the mechanisms of self incompatibility and stigma is normally pollinated by bees and blow flies. When a male sterile or self incompatible plant is used as a female parent, the emasculation procedure can be omitted and the cost of production of hybrid seed can be decreased substantially.
1. **Male Sterility**

This is one of the mechanisms of cross-pollination and used for economical hybrid seed production. Male sterility results due to the absence or non function of the pollen grains in the plants.

**Genic male sterility**

In cole crops, male sterility is controlled by a single recessive gene msms which is mutated from the fertile gene Ms (Nieuwhof, 1968). Male sterile plants are female fertile but their flowers and anthers are slightly smaller than those of male fertile ones. Vanders Meer (1985) had presented data from crosses involving several cauliflower varieties where male sterility could be interpreted as being caused by duplicate dominant genes with cumulative effect. Lieur Yumei et al. (1997) reported that male sterility in broccoli is controlled by 2 genes but how these two genes interact remained to be further studied. Ruffio et al. (1993) reported a monogenic dominant form of male sterility which can be used for hybrid production in autumn and winter cauliflower.

**Cytoplasmic male Sterility**

Cytoplasmic male sterility has not apparently been found in cauliflower, but it has been introduced from several sources. Pearson (1981) crossed *Brassica oleracea* with *Brassica nigra* and derived male sterile material. This character was bred into broccoli and later into cauliflower (Dickson, 1975). Hoser-Krause and Antosik (1987) introduced this male sterility into cauliflower.

Both genic and cytoplasmic male sterility have been associated with physiological problems. Some forms of genic male sterility are temperature sensitive resulting in possible self-pollination contaminating F₁ seed production (Nieuwhof, 1968). With the Pearson (1981) type of cytoplasmic male sterility, absence of functional nectaries prevents the commercial production of F₁ hybrid seed using normal insect pollinators (Pelletier et al.,
1983) Low temperature has been found to induce chlorosis in the early stages of cytoplasmic male sterile plants which was expressed in the field grown F₁ plants as a loss of vigour (Dickson, 1975). The Ogura source has also been associated with low seed set and poor curd quality in F₁ cauliflower (Hicer Krause, 1989). Jourdan et al. (1985) reported a cauliflower line carrying Ogura cytoplasmic male sterility factor which exhibited high regeneration capacity from cultural mesophyll cell. This was useful as first step in the possible production of cytoplasmic mutants, transgenic, recombinants without the temperature sensitivity associated with male sterility and the problem is reported to have been overcome by the production of non-chlorotic male sterile plants from artificial hybrids (cybrids) following protoplast fusion between sterile and normal genotypes.

2. Self-incompatibility

It is the inability of a functional pollen grain to fertilize the same flower or other flowers of the same plant. The sporophytic self-incompatibility system operating in cole crops is used in making single, double and triple cross hybrids for commercial seed production. Production of hybrid seed involves:

1. Development of homozygous self-incompatible lines by inbreeding and their maintenance

2. Testing of combining ability

3. Production of F₁ hybrid seed commercially.

For producing hybrids utilizing self-incompatibility (SI) the degree of SI alleles and their dominance is of utmost importance. In case strong dominant alleles are not present in the inbred parents, the chances of hybrid seed production will be weak and therefore, such strong alleles should be introduced in the parents. Other problems associated with the use of self-incompatibility for hybrid seed production are:

1. Continuous inbreeding in many brassica crops may lead to complete loss of inbred lines. It will, therefore, be desirable if tissue culture techniques for propagation of inbred lines are followed.
2. Some inbred lines have unstable SI alleles which are largely controlled by environmental conditions, especially temperature and humidity.

3. The restriction of pollination within parental lines by bees also hampers cross-pollination because bees do not always visit the plants at random resulting in less cross-pollination.
Advances in seed production in Indian and snowball cauliflower

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Cauliflower (Brassica oleracea L. var. botrytis L.) is one of the important vegetables belonging to the family Brassicaceae. The word cauliflower is derived from two Latin words i.e. caulis and floris which means stem or stalk and flower, respectively. It is mainly grown for its “Curd” which is prefloral fleshy apical meristem, which invariably precedes floral initiation. The curd of cauliflower has been described as pre-floral structure that possesses characteristics of both a vegetative and reproductive apex. Morphologically, it is an early stage of inflorescence development, since its formation takes place before floral initiation. The inflorescence is a raceme, and flowering starts from the bottom to the top of the inflorescence. During the development of the reproductive structures, the inflorescence begins to elongate from the outer flowers of the curd and can be as large as 60 to 75 cm.

Commercial production:

FAO reports that in 2005, China and India were the top producers of cauliflower and broccoli. About half of all cauliflower is raised in China and one fourth in India. Other major producers of cauliflower in the world are France, Italy, United Kingdom, USA, Spain, Poland, Germany and Pakistan. In India, it is grown over an area of 238.2 thousand hectares and contributes to 4.4 % of the total vegetable production in India. The major cauliflower growing states are Bihar, Uttar Pradesh, Orissa, West Bengal, Assam, Haryana and Maharastra. India is second largest producer of cauliflower with the production of 4.5 mt. With the development of tropical types in cauliflower in addition to temperate types, it has now become possible to grow this
vegetable almost throughout the year particularly in northern and central parts of India.

**Importance and uses:**

Cauliflower is low in fat, high in dietary fiber, folate, water and vitamin C, possessing a very high nutritional density. As a member of the brassica family, cauliflower shares with broccoli and cabbage several phytochemicals which are beneficial to human health, including sulforaphane, an anti-cancer compound released when cauliflower is chopped or chewed. In addition, the compound indole-3-carbinol, which appears to work as an anti-estrogen, appears to slow or prevent the growth of tumors of the breast and prostate. Cauliflower also contains other glucosinolates besides sulforaphane, substances which may improve the liver's ability to detoxify carcinogenic substances. A high intake of cauliflower has been found to reduce the risk of aggressive prostate cancer. Cauliflower curd extract is used as a traditional medicine in treatment of scurvy; as a blood purifier and as an antacid (Liebstein, 1927). Its seeds also have contraceptive properties (El-Dean, 1972).

Cauliflower can be roasted, boiled, fried, steamed or eaten raw. When cooking, the outer leaves and thick stalks are removed, leaving only the florets. The leaves are also edible, but are most often discarded. As cooked vegetable, it can be used either singly or mixed with potato, carrot and peas. In raw form, it is also mixed with green salad or its pieces are dipped in sauces. It is also used for pickling. Pieces of cauliflower (buttons) can be fried with besan to prepare *Pakoras*. Grated cauliflower is used to prepare stuffed *paranthas*.

**Climatic Requirements:**

**Vegetative Phase:** It is cultivated worldwide in different climatic conditions, ranging from temperate to tropics during most of cropping seasons and is available round the year in the market. It is more exacting in its climatic requirements than most other crops in this family. It grows best in a comparatively cool temperature with a moist atmosphere. Two distinct types
of cauliflower, early Indian or tropical and late snowball or temperate summer are grown in India. On the basis of maturity and temperature requirement it is divided into four groups. The temperature requirement for curd initiation and development in different maturity group is 20-27°C in September/October (Group I), 16-20 °C for November (group II), 12-16 °C for December (group III) and 10-16 C° for late cauliflower (Group IV).

Sensitivity to vernalization varies according to plant size. Larger plants are more sensitive than smaller plants and require a shorter period of low temperature exposure. The early varieties, however, require high temperature and longer day lengths. The plant is extremely sensitive to unfavorable conditions, such as unusually hot weather, drought or too low temperature, which often result in the formation of premature heads or curds. These "baby" cauliflower heads are called "buttons". It is also susceptible to cold injury after the curds have appeared. Excessive rains or snowfall, after curd formation, results in curd rotting.

Reproductive Phase: In India, the seed production of early and mid-season varieties can be done in the plains. However, the seeds of late varieties can only be produced in temperate regions of the country. Lately, Himachal Pradesh has emerged as the major producer of quality cauliflower seed of late varieties. Periods of low temperature are not essential, but cool conditions are required. Therefore, these conditions must be given due consideration in selecting suitable areas for seed production. In spring, moderate temperatures of 20°C promote bolting followed by flowering. During seed maturation and at harvest, higher temperatures of 25-30°C and the absence of rainfall promote high seed quality. The high temperature and relative humidity along with frequent and considerable rainfall during the period of seed development, and heavy rainfall just prior to harvesting reduced seed viability, vigour, cell membrane integrity, protein and oil contents. The harsh weather conditions had also caused lodging of plants and shattering of siliques.
Varieties:

Cauliflower is a thermo sensitive crop. Varieties differ in their temperature requirement for curd formation and development. They have been classified into different maturity groups according to their temperature requirement. The sowing and transplanting time have to be adjusted so that the varieties are ready for harvest at specified period in the north Indian plains (Table 1).

Table 1: Maturity groups in Cauliflower

<table>
<thead>
<tr>
<th>Maturity</th>
<th>Sowing Time</th>
<th>Transplanting Time</th>
<th>Temperature for curd development</th>
<th>Varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>September maturity</td>
<td>Mid-May</td>
<td>July beginning</td>
<td>22 °C - 27 °C</td>
</tr>
<tr>
<td></td>
<td>(mid Sep.-mid Oct.)</td>
<td>May end-mid-June</td>
<td>Mid July</td>
<td>20 °C - 25 °C</td>
</tr>
<tr>
<td></td>
<td>October maturity</td>
<td></td>
<td></td>
<td>Early kunwari*, Pusa Early Synthetic, Pusa Meghna, Pusa Kartik Shankar, Pusa Deepali, Pant Gobhi 2, Pant Gobhi-3, Pusa Katki</td>
</tr>
<tr>
<td>Mid early</td>
<td>November maturity</td>
<td>July end</td>
<td>Septembe r beginning</td>
<td>16 °C - 20 °C</td>
</tr>
<tr>
<td></td>
<td>(mid Nov.-mid Dec.)</td>
<td></td>
<td></td>
<td>Pusa Sharad, Improved Japanese, Pusa Hybrid-2, Pant Gobhi-4,</td>
</tr>
<tr>
<td>Mid late</td>
<td>December maturity</td>
<td>August end</td>
<td>Septembe r end</td>
<td>12 °C - 16 °C</td>
</tr>
<tr>
<td></td>
<td>(mid Dec.-mid Jan.)</td>
<td></td>
<td></td>
<td>Pusa Synthetic, Pusa Himjyoti, Pusa Shubhra, Pusa Paushija (DC-76), Pusa Moti (DC-5)</td>
</tr>
<tr>
<td>Late</td>
<td>Snowball</td>
<td>Sept. end-mid Oct.</td>
<td>Oct. end – mid Nov.</td>
<td>10 °C - 16 °C</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pusa Snowball-1, Pusa Snowball-2, Pusa Snowball K-1, Pusa Snowball K-25</td>
</tr>
</tbody>
</table>
Early Varieties:

**Early Kunwari:** Early variety suitable for growing in Punjab, Haryana, Himachal Pradesh and Delhi. Ready to harvest from mid September to mid October. Curds are semi-spherical, loose and yellowish in colour.

**Pusa Early Synthetic:** Plants erect with bluish green leaves, curd small to medium in size, flat, creamy white and compact. Average yield is 11.7 t/ha.

**Pant Gobhi 3:** A synthetic variety combining inbred lines. Plants with long stem, semi-erect leaves and hemispherical creamy white, medium compact non ricey curds. Yield 12 t/ha. Curds are ready for harvest in September.

**Pusa Meghna:** Belongs to early maturity group, suitable for growing under hot and humid climate. Curds compact, creamish white and medium in size, weighing about 350-400g.

**Pusa Kartik Sankar:** It is hybrid of Indian cauliflower which belongs to early maturity group. It is resistant to downey mildew and can tolerate high temperature and high rainfall during its vegetative growth. Curds are medium sized, semi dome shaped, compact, retentive white with fine texture, weighing about 475g. It is free from bracts and riceyness.

**Pusa Deepali:** Plants medium tall, erect, bluish green and waxy leaves, curds compact, retentive white and medium in size with an average yield 10-12 t/ha.

**Pant Gobhi 2:** Recommended for cultivation in northern plains of the country. Curds are medium compact and yellowish. Yield potential is 10t/ha. Available in October in the plains.

Mid-early varieties:

**Improve Japanese:** An introduction from Israel. Plants erect, leaves bluish green; curds compact and creamish-white. Average yield is 16-18 t/ha.
**Pusa Hybrid 2:** First f1 hybrid released by a public sector organization. Plants semi-erect with bluish green upright leaves, resistant to downey mildew. Curds are creamy white, very compact, with an average yield of about 23 t/ha.

**Pusa Sharad:** Foliage bluish-green, leaf with narrow apex and prominent mid rib. Semi-dome shaped white and very compact curds. Average yield 24 t/ha.

**Pant Gobhi 4:** A variety released for November maturity. It has medium long stem, semi-erect leaves; hemispherical creamy white, medium compact, non ricey curds. Average yield is 14 t/ha.

**Mid late varieties:**

**Pusa synthetic:** a synthetic variety, plants erect, frame narrow to medium, curds creamy white to white and compact. The yield potential is 27 t/ha.

**Pant shubhra:** Released for cultivation in Bengal Assam basin and Sutlej Ganga Alluvial plains. Curds compact, slightly conical, retentive, creamish-white in colour, non ricey and non leafy. The yield potential is 25 t/ha.

**Pusa Himjyoti:** Erect bluish-green leaves and waxy coating; curds retentive white, self blanched, solid and 500-600g in weight. This is the only variety which can be grown from april-July in the hills. Also suitable for growing in December maturity group in north Indian plains.

**Pusa Moti (DC-5):** High yielding variety of mid late maturity group (December-January) and is recommended for growing in north Indian plains and hills. This variety produces attractive compact white curds compact, full of flavour, suitable for use as cooked vegetable or in combination with other vegetables and for pickling. Tolerant to major pest and diseases and can even tolerant to low frosting temperature. Average curd yield is about 30-33 t/ha.

**Pusa Paushija (DC-76):** High yielding variety for mid late maturity group i.e. maturing during 2nd fortnight of December to first fortnight of January. It has distinguished bluish green, narrow conical leaf top. Curds are compact, retentive white in colour weighing about 900 g with average curd yield of 31-
41 t/ha. This variety is highly fertilizer responsive and gives stable performance under wider environmental conditions.

**Late Varieties:**

**Pusa Snowball 1:** A late variety suitable for cool season. Leaves are straight and inner leaves cover the curd. Curds are compact, medium and snow white in colour. Ready for harvest in January-February in north Indian plains and during March-April in the hills. Yield potential is about 22-25 t/ha.

**Pusa Snowball K 1:** Among the snowball types grown in the country, it has best quality curds which are snow white and retain it even if harvesting is delayed. The leaves are puckered, serrated and light green in colour. It is late in maturity by about a week than Snowll 1. It is tolerant to black rot disease. Average yield is 25-30 t/ha.

**Varieties on the basis Colour:**

**Orange cauliflower:** Orange cauliflower (B. oleracea L. var. botrytis) contains 25 times the level of Vitamin A of white varieties. This trait came from a natural mutant found in a cauliflower field in Canada. Cultivars include 'Cheddar' and 'Orange Bouquet'.

**Green cauliflower:** Green cauliflower is sometimes called broccoflower. It is available both with the normal curd shape and a variant spiky curd called "Romanesco broccoli". Both types have been commercially available in the US and Europe since the early 1990s. Romanesco's head is an example of a fractal image in nature, repeating itself in self-similarity at varying scales. Green curded varieties include 'Alverda', 'Green Goddess' and 'Vorda'. Romanesco varieties include 'Minaret', and 'Veronica'.

**Purple cauliflower:** Purple cauliflower also exists. The purple color is caused by the presence of the antioxidant group anthocyanin, which can also be found in red cabbage and red wine. Varieties include 'Graffiti' and 'Purple Cape'. In Great Britain and southern Italy, a broccoli with tiny flower buds is
sold as a vegetable under the name "purple cauliflower." It is not the same as standard cauliflower with a purple curd.

**Soil Requirements:** Cauliflower is grown on many different types of soil, but does best in a rich, well drained soil with a high moisture-holding capacity. High humus content in the soil will provide better aeration and water penetration. If a soil is low in organic matter, stable or green manures can be supplied. Cauliflower grows best on a neutral or slightly acid soil (pH 6.0 to 6.5).

**Cropping System:**

In order to maximize returns from a particular area of land, Spinach can be grown as an intercrop in cauliflower field. Randhawa (1990) has suggested following vegetable crop rotations

- Cauliflower – Tomato – okra

- Eggplant – Cauliflower – Bottle gourd

With the development of newer and early maturing cauliflower cultivars which are transplanted in the rainy season and harvested by Oct- Nov, rabi vegetables can be grown easily after harvest.

**Nursery raising:**

Cauliflower is propagated through seed. Role of healthy nursery is very important to raise a good crop. Cauliflower seeds germinate optimally between 27 and 29°C. The time of sowing in the nursery will depend largely upon the cultivar and temperature requirement for curd formation. The nursery of group I needs special care because the temperature is not congenial that time. Low cost polytunnels can be utilized to raise nursery of group I. Covering nursery bed with ‘Sirkis’ will protect young seedling from hot and dry wind during day time. To maintain sufficient moisture channels may be filled with water every evening. The nursery of group and group II raised during rainy season, needs protection from heavy downpour. It can be overcome by raising
seedlings in plastic tunnels. The nursery of group III and group IV comparatively easy to raise because of the favorable climatic conditions during that period.

**Nursery Bed Preparation:**

Raised nursery beds of size 3 x 0.6 m and 10-15 cm in height are prepared. The width of beds of nursery should not be more than 60 cm, so that water can easily percolate upto the middle portion from the border channels, made in between the beds. An about 70 cm distance is kept between two beds to carry out intercultural operations such as watering, weeding, etc. The surface of beds should be smooth and well leveled. Well-decomposed FYM @ 8-10 kg/m² is added at the time of bed preparation. Raised beds are necessary to avoid problem of water logging in heavy soils.

**Soil Preparation:** The nursery beds should be thoroughly prepared by the addition of well rotten farm yard manure or compost @ of 10 Kg/m². The soil should be fumigated to control weeds and soil borne diseases and insects. Alternatively, the nursery beds should be treated with 0.3 percent solution of captan or thiram (5 litres/ m²) and seed can be sown immediately after the treatment in the workable soil.

**Seed Treatment:** Before sowing the seeds should be treated with captan or thiram (3g/Kg) or Bavistin (2g/Kg) to get rid of fungal disease. However, to control seed borne disease like black rot, hot water treatment of 50 °C for 30 minutes is only remedy. About 450-700gm seed for early type and 300-500g for mid types is sufficient to raise crop in one hectare. The seed are sown in furrows, 7-8 cm apart and the depth of furrow should be 1.5-2.0 cm. After sowing cover the seed with mulching material like dry “Kans” grass before watering. In the initial stage the watering is done by watering-can and after ward through channels. The grass cover should be removed as soon as the seedling starts emerging. The drenching of nursery between the furrows with captan or thiram (0.25%) will help in preventing the post emergence damping off.
If there is considerable overcrowding in the plant bed, thin the plants to an in-row spacing of 1 inch. Over-crowding can be avoided by not over seeding.

**Land Preparation:**

Soil should be prepared well and brought to a fine tilth before transplanting. The manure and fertilizers should be added as a basal dose while preparing the field. Drainage is a problem for early and mid early crop in North India and sometimes in mid season crop when the monsoon prolongs, beds should be prepared after the last ploughing and following fertilizers application as basal dose. The beds should be so prepared that the excessive water drains out rapidly without causing soil erosion.

**Transplanting:**

The seedlings are ready for transplanting in 3-6 weeks. In early maturity, 5-6 weeks old seedlings and in mid season 3-4 weeks old seedlings give optimum yields. The seedlings of early group I (a) and I (b) are transplanted in early July and August respectively. The mid season cultivars are transplanted in September-October. Snowball types are transplanted in September-October. Snowball types are transplanted in the beginning of October in Kashmir, Kullu and Saproon valley of Himachal Pradesh. As a result, the seeds are planted in greenhouses during the summer. At the 3 to 4 real (true) leaf stage, seedlings are transplanted in early autumn to obtain the high- to mid temperatures necessary for rapid vegetative growth. This allows the plants to be large enough in the winter to ensure successful vernalization.

**Spacing:** The transplanting distance varies according to variety and time of planting. Generally, closure spacing is kept for early and mid season crop and wider spacing for late maturing cultivars. Transplanting of September group is recommended on ridges at a spacing of 60X30 cm. For midseason and late varieties, a planting distance of 60X40 cm is ideal. Mishra et al. (1970) recommended 30X60 cm spacing as best for Snowball 16. Hari Om et al. (1985) recommended 60X45 cm as the best spacing for Pusa Synthetic and Snowball 16. Trials at Bhubneshwar and Kalianpur under all India Co
ordinated project revealed that a spacing of 0X60 cm was the best for Snowball Cauliflower. IARI, New Delhi has recommended plant to plant spacing of 36-40 cm for early and 45 cm for other crops and 60 cm between the rows.

**Fertilizer** — Cauliflower requires heavy manuring as it removes large quantities of major nutrients from the soil. Nieuwhof (1969) reported that absorption rate of nutrient by cauliflower per hectare is 143-134 kg N, 22-37 Kg P, 128-209 kg k, 55-91 Kg Ca and 7-12 kg Mg. Most of the recommendation made by research workers is based on cultivars like snowball. Very little information is available on the fertilizer and manure requirements of the early crops. Since the early crop is grown under unfavorable conditions of monsoon season, cloudy days and high temperatures, they often fail to give satisfactory yields. In Tropical areas, a dose of 60-150 Kg N, 50-80 kg P, 60-120 Kg K along with 40-70 tones of FYM/ha is recommended. In northern and central India, application of 150 kg N and 60 kg P is recommended. Half of N and whole of P and K should be applied as a basal dose and the rest of n in 2-3 split doses. Weekly spraying of 1-2 % urea 20 days after transplanting is advised for good growth. Trials conducted at Bhuveshwar, showed that the maximum curd yield (178.03 q/ha) and C:B ratio 1:2.11 of cauliflower was obtained with three foliar sprays of NPK (19:19:19) in addition to the recommended doses of NPK. Further, 5 foliar sprays of water soluble fertilizers having a combinations of NPK-19:19:19 at 10 days interval after 40 DAP, resulted in maximum yield (342q/ha) in cauliflower cv. Snowball-16. Cauliflower requires high magnesium levels and shows deficiency symptoms readily when soils are too acid or the element is in short supply. In sandy loams of the Coastal Plain, magnesium at the rate of 100 lb of MgO² per acre may be beneficial.

A cauliflower crop often shows boron and molybdenum deficiency symptoms when grown either on an alkaline or highly acidic soil, or two sprays with 0.3 per cent borax applied on the seedlings may correct the boron deficiency. Molybdenum deficiency symptoms occur in highly acidic soils and can be corrected by liming, or application of about 1 to 1.5 kg per hectare of sodium molybdate. At Faizabad, the maximum C: B ratio 1:3.15 and better
yield of cauliflower cv. Pusa snowball K-1 was obtained with foliar application of boron @ 100ppm + molybdenum @ 50 ppm.

Biofertilizers also significantly improved cauliflower yields. At IIVR, Varanasi application, application of Azospirillum + 75 % N and full full P and K in cauliflower cv. Snowball-16 gave maximum yield (260.7q/ha) along with C:B ratio (1:2.54). At Hyderabad, the maximum yield (347.8q/ha) along with C:B ratio (1:2.96) were obtained in late cauliflower with application of VAM @ 15 Kg/ha + recommended dose of NPK. However at Hissar, the highest yield (347.8q/ha) and C:B ratio (1:5.53) were obtained with the application of PSB + 75 % of P and the recommended dose of nitrogen and potassium in late cauliflower.

**Use of Growth regulators:**

Treatment of cauliflower seedlings with NAA (10 ppm) as starter solution has been found effective in respect of plant stand in the field and vegetative growth. Application of GA$_4$ + GA$_7$ at the rate of 80mg/l of water shortened the period from transplanting to harvest. The quality of the curd was not affected by this treatment (Booij, 1990). Dipping of cauliflower seedling roots at transplanting in IBA (1 mg/l) + starter solution of ammonium sulphate and superphosphate (1:2) also induces earliness and increase curd yield. Synergistic effect of mineral nutrition and growth regulators has been noticed for plant growth and curd yield of cauliflower. Combined spraying of GA (100mg/l), NAA (120 mg/l) and Mo (2g/l) enhances the total yield. Similar increase in yield may obtained by spraying of GA (50 mg/l) and urea (1g/l). Spraying of 150 ppm ethrel at the time of emergence of flowering stalks increase seed yield.

**Aftercare:** Cauliflower is a highly sensitive crop and any check in its growth at any stage results in buttoning. Crust formation after first irrigation is more common in heavy soils, hindering water and penetration to the roots thereby affecting adversely its growth. During the rainy season, when the crop is raised on ridges, adequate earthing up is essential so that the roots are not exposed. Application of N along with the earthing up is more useful. Hoeing
and weeding operation should not be deep to avoid injury to the shallow root system. The weed problem is very serious in this crop because of wider spacing, frequent irrigation and high fertility. The curd yield of cauliflower can be reduced to the tune of 36-69% if weeds are not controlled. The crop needs four weeks of weed free period after transplanting to prevent yield losses. Preplanting application of stomp (Pendimethlin) or Basalin (Fluchloralin) @ 2.0-3.0 kg/ha helps in weed control. Application of weedicides supplemented with one or two hand weedings is enough to keep the crop weed free.

**Irrigation:** It is necessary to maintain proper soil moisture level to harvest good yield of cauliflower. First irrigation is given just after transplanting of seedlings. The number and frequency of irrigation depends upon weather, soil type and variety. However, optimum water supply is must both during growth and curd formation stages. For early and mid season groups, irrigation depends upon intensity of monsoon. As ridge planting is recommended in both the groups, irrigation is given in furrows. However, 5-8 irrigations are generally required for cauliflower crop. Heavy irrigation results in water stagnation which is very harmful to group. Singh (1978) observed that the yield and curd quality were best with single or double row planting method in drip irrigation system. However, furrow system of irrigation is more commonly used. In a study, it was found that 0.25 bar soil moisture regime was the best for getting maximum yield, while in another study in early snowball cultivar 0.45 bar soil moisture regime was found to be the best. It was also observed that P and K uptake of plants is reduced and n uptake increased with increasing salinity in irrigation.

**Mulching:** Clear plastic covering in cauliflower resulted in faster growth and advanced the harvest up to 10 days. Singh and mishra (1975) reported highest returns by mulching with mango leaves. Ten-centimeter-thick mulching with paddy husk has been found to be beneficial in increasing growth and yield of cauliflower. Forty percent increase in yield has been reported in cauliflower using black polythene film which retained moisture, prevented deterioration of soil structure and reduced the differences between maximum and minimum temperatures. Mulching and long intervals of
irrigation were found to be as effective as short intervals of irrigation and ‘no mulch’ treatment (Patel and Jyotishi, 1969).

**Blanching** – Blanching is a method to protect the curds from attaining yellow colour after their direct exposure to sunlight. Exposure to sunlight dis-colors the cauliflower curd and can produce off-flavors. This is quite common in early and mid season varieties having spreading and open plant types. While curds are still small, the inner leaves protect them from sunlight. In most varieties, as the curds develop, they force the inner leaves apart and expose the small curd to the sunlight. Thus, cauliflower must be blanched - that is, the outer leaves are tied to protect the curd. When the curd is 2 to 3 inches in diameter the large outer leaves should be "tied." The leaves can be tied with rubber bands, tape or twine. Be sure your rubber bands are thick enough. Since the curds develop at different rates, the field needs to be checked every 2 to 3 days and plants tied where the curd is beginning to show. Use a different color band at each tying. If several curds of one color tie are ready, then all tied with that color can be cut. Time from tying to harvest varies from 4 to 5 days during warm weather to 14 to 21 days during cool periods. Most of the late types commonly known as snowball type have self-blanched habit.

**Harvesting of curds:** Mature heads which are fully developed, compact, clear white in color and about 6 inches in size should be cut. If harvested late, the curds start loosening because of flower stalk emergence. They may become leafy, ricey, or fuzzy. Heads are cut with a large knife (a Russell knife improves labor efficiency) leaving one or more sets of leaves attached to protect the curds.

The large leaves are then trimmed away leaving only sufficient jacket leaves to protect the curd from brusing and other mechanical injury in transport. More leaves are kept when cauliflower curds are transported in crates.

**Hybrid seed production in cauliflower:** The seed production of annual Indian cauliflower is possible in north Indian plains whereas annual European cauliflower (Snowball and Erfurt types) is done in saproon valley
and Kullu valley of Himachal Pradesh. Though the later types do not require any chilling for transformation to reproductive phase but mild temperature for seed setting which is not available in north Indian plains after their curd formation. Winter cauliflower requires chilling temperature for both curd and seed stalk development. In recent years, a number of hybrid varieties have been developed in cauliflower by public and private concerns. In cauliflower, F1 hybrids have been found advantageous for earliness, high early and total yield, better curd quality with respect to compactness and color, uniform maturity, resistance to insects, pest, diseases and unfavorable weather conditions. In India, F1 hybrids in cauliflower currently share only 3% of the total seed requirement for cauliflower, and the rest, 97% of the seeds for the crop, are open pollinated. However, the acreage under F1 hybrids is increasing every year. Therefore, there is a tremendous potential for the development of hybrids in cauliflower. The main hindrance to the popularization of F1 hybrids is non-availability and cost of hybrid seed.

**Pollination Control mechanism:** There are two naturally occurring mechanism for ensuring cross-pollination in a hermaphrodite species like cauliflower i.e. male sterility and self incompatibility. The use of both these systems is very useful in commercial hybrid seed production (Singh, 2000). In another study it was found that both SI and CMS lines are suitable for hybrid breeding of cauliflower. With regards seed production, self-incompatibility appears to be more effective than cytoplasmic male sterility. On the contrary, CMS system provides much more reliable sterility than self-incompatibility.

**Self incompatibility:** Self-incompatibility in plants is a mechanism preventing the seed set by self pollination, and is probably most important way in which out crossing is enforced. Other factors that may cause selfed plants not to set seed may be embryo abortion, but self incompatibility is prezygotic and prevents embryo formation. Homomorphic sporophytic self incompatibility associated with trinucleate pollen and inhibition of pollen germination at stigma surface (Bateman, 1955). Self-incompatibility in the Brassicaceae is controlled by the single multiallelic S-locus which contains at
least two genes expressed in the stigma, the *SLG* (*S*-locus glycoprotein) and *SRK* (*S*-locus receptor kinase) genes.

Higher level of self incompatibility is present in biennial winter and autumn types and low in summer types (snowball, alpha and erfurt) (Watts 1963). Annual Indian cauliflower and biennial winter cauliflower have stronger self-incompatible mechanism. A detailed investigation of self incompatibility in Indian cauliflower revealed that inbred lines of maturity group I have strongest self incompatibility followed by maturity group II, whereas, group III showed weak self incompatibility (Sharma et al., 2001. The studies have resulted in development of 7 SI lines namely aa (327), aa (395), xx (EPK), cc-12, cc-13, cc-14, cc-15 in early and 6 SI lines CC(12C), VV(351), dd (PAU), bb(PKUG), 443-5 and 443-7 in mid maturity group. Snowball types have very low level of self incompatibility and a line 87 (162587) has been isolated at Katrain recently.

Being a natural method, self-incompatibility has no side effects as associated with cytoplasmic or chemically induced male sterility. Although the possibility of using self incompatibility to produce hybrids have been suggested over 60 years ago, it was not until 1950 that they first appeared in Japan, and 1954 before they were produced in the USA. However, in recent years, use of self incompatible lines has become a standard practice for the production of commercial hybrid seed in several brassica vegetable crops. Two hybrids viz., Pusa hybrid-2 and Pusa kartik Shankar (DCH-541) have been developed using SI. The former is the first indigenous hybrid developed by public sector and belongs to mid maturity group and latter to early maturity group.

**Breakdown of Incompatibility:**

CO₂ gas treatment is widely used by breeders to produce large quantity of self pollinated seeds of incompatible parents.

The best results in reproduction of SI lines derived from the cultivar Montano were achieved by spraying with 3% NaCl solution in the evening and using
bumblebees as pollinators. In another study it was found that CO₂ concentrations of 4 to 6% applied for 8, 16 or 24 h at 100% RH proved to be the most effective treatment for blocking the SI response in cauliflower.

One of the most important aspects of self incompatibility is that in this mechanism, pollen and nectar production are unaltered. This may not matter much with wind pollinated plants, but with insect pollination, it is very important. Some insects, especially honeybees are highly discriminatory when foraging amongst flowers.

**Male sterility:**

Male sterility in cole crops are mainly recessive character. A single recessive ms gene mutated from male fertile Ms gene has been reported in cauliflower by Nieuwhof (1961), Borchers (1966) and Ahluwalia et al. (1977) and was designated as ms-4 and ms-C. vander Meer (1985) reported, male sterility under the control of duplicate dominant genes with cumulative effect. Dominant male sterility has been described in cauliflower (Ruffo-Chable, 1997). This has some possible practical value in hybrid seed production programs, because of inadequate and unreliable nature of self incompatibility systems in some of cauliflowers. This sterility can be responsive to temperature and humidity.

**Cytoplasmic Male Sterility (CMS)**

Cytoplasmic male sterility is not apparently found in cauliflower or other cole crops but has been introduced from several other sources. CMS has been reported in an identified cultivar of Japanese radish by Ogura (1968) and was introduced to Brassica oleracea genome by repeated back cross with broccoli (Bannerot et al., 1974 and Mc collum, 1981). Later Dickson (1975) and Hoser- Krauze (1987) transferred it from broccoli to cauliflower. The Ogura type cytoplasmic male sterility was transferred into heat tolerant Indian cauliflower from Kale and broccoli through repeated back crosses, Four lines, MS-91, MS-51, MS-11 and MS-110 from Kale and five lines, MS-01, MS-04, MS-05, mS-09 and MS-10 from broccoli were developed, which
are now being used in hetrosis .......... ?? . Cytoplasmic male sterility is the best alternative to overcome the practical problems faced in using self-incompatibility and or genic male sterility to produce hybrid seed. The ogura cytoplasm was commonly used to develop CMS lines

Both genic as well as cytoplasmic male sterility have been associated with physiological problems. Some forms of genetic male sterility are temperature sensitive and result in self pollination when used for F1 seed Production (Nieuwhof (1968). In, Pearson (1972) types of cytoplasmic male sterility nectories are not developed making them unsuitable for commercial hybrid seed production (Pelletier et al., 1983). Both the Ogura and Mc collum types of CMS plants or their hybrids when grown at low temperature less than 12°C show chlorosis and loss of vigour at their early stage of growth (Dickson, 1985; Hoser Krauze, 1989). High regeneration from cultured mesophyll cells of a cauliflower line having Ogura system was reported by Jourdan et al. (1985). This was a useful step in the possible production of cytoplasmic mutants, transgenic or recombinant superior male sterile genotypes. By genetic engineering, it has become possible to develop female parents having barnase genes, which inhibits the activity of pollen producing tapetum cells and make them male sterile. The introduction of Barstar gene in the male parent, which restore fertility in hybrid seed by inactivating the functioning of barsnase genes responsible for disruption of pollen development in female parents (Reynaerts et al., 1993).

Production of hybrids in cauliflower involves:

- Selection of Parents
- Development of self-incompatible inbred lines
- Testing of combining ability
- Field evaluation of the F1 hybrids along with parents and check varieties
- Production of F1 hybrid seed commercial.
Isolation distance: Cauliflower is mainly cross-pollinated. In cauliflower, the cross pollination varies from type to type. In European summer cauliflower (Snowball or Erfurt types), the self pollination may be as high as 70 per cent (Nieuwhof, 1963), while in winter cauliflower and in early Indian cauliflower, the cross-pollination is quite high due to its self incompatibility nature. But this relationship may not always be true. Pollination is mainly done by honeybees. The botanical varieties of Brassica oleracea group i.e. cabbage, cauliflower; knol-khol, Brussels sprouts, Kale, collard and other wild allies freely cross with each other. Hence, proper isolation among these crops is needed to keep purity of seeds. Similarly growing of different cultivars also require proper isolation. The seed fields must be separated from fields of other varieties, fields of the same variety not conforming to varietals purity requirements of certification, and from all kinds of cole crops, at least by 3000 m for breeder seed, 1600 m for foundation seed class, and by 1000 m for certified seed class.

Method of Seed Production: There are two methods of seed production:

- In situ method (seed to seed method)
- Transplanting method (head to seed method)

For seed production, seed to seed method is recommended since the head to seed method in India has not been very successful. In seed to seed method (in situ method) the crop is allowed to over-winter and produce seed in the original position, where they are first planted in the seedlings stage.

Cultural Practices for in Situ method

Main season and late varieties (seed production in hills)

Time of sowing and transplanting: In the hills, the sowing time of cauliflower should be so adjusted that the plants put up the maximum leafy growth by the fifteenth of December, when the temperature goes down and the plants become almost dormant. The last week of August is the optimum sowing time for the crop. The seed is sown in a nursery. Transplanting of seedlings should be completed by the end of September. The mean
temperature of 6.5 to 11 C during February to March is very conducive to curd formation which is completed by the first fortnight of March.

Early sowing in June to July result in curd formation during October to November. The curds, being very susceptible to cold injury, rot during winter and hence fail to flower the following summer. If sown late, the crop starts curd formation late in the spring and consequently flowering is delayed. It starts when the temperature is high and humidity is low, with the results that pollination and setting of seed is not normal.

1. **Method of Sowing in nursery**: Seeds may be sown on raised nursery beds (15 to 20 cm high from the ground), in rows 5 cm apart. Cover the seeds with fine leaf mould and water with a sprinkler. Twenty-five nursery beds of 2 to 2.5 m long and 1 to 1.25 m wide will raise enough seedlings to plant one hectare. A spray of four to five handfuls of ammonium sulphate or C.A.N. dissolved in 30 to 35 litres of water at 10 to 15 days after germination will be helpful in producing healthy and vigorous seedlings. Wash out the fertiliser immediately by spraying simple water. Thin sowing should be done to avoid “damping-off” disease.

2. **Source of seed**: Obtain breeder’s /foundation seed from source approved by a seed certification agency.

3. **Seed rate**: Main season and late varieties – 375 to 400 grammes per hectare.

4. **Preparation of land for transplanting**: the field should be prepared to fine tilth by deep ploughing, three to four harrowing followed by levelling.

5. **Fertilisation**: the cauliflower seed crop required heavy manuring as it removes large quantities of major nutrients from the soil. For best results apply 50 to 60 tonnes of farmyard manure at the time of land preparation. Normally 25 to 30 tonnes of farmyard manure is applied per hectare due to limited availability of farmyard manure in hills. Apply 200 to 300 kg superphosphate and 100 kg potassium sulphate sufficiently before transplanting, or calcium ammonium nitrate, during
Advances in Quality Seed Production of Vegetable Crops

Growing period (one application during October to November, another in February to March is essential). Still higher doses of nitrogen may be applied it seemed necessary.

6. Transplanting: Transplant the seedlings when 12 to 15 cm long, preferably at evening time, and irrigate immediately afterwards.

7. Spacing: Row to row 60 to 90 cm, plant to plant 45 to 60 cm.

8. Irrigation: Irrigate the field according to the soil requirements and climatic conditions. A crop after transplanting may need irrigation twice a week and later once a week. At later stages, irrigation may be given if there is a long gap between rains. Adequate moisture supply during flowering and seed maturation are necessary to obtain high yields.

9. Interculture: Frequent shallow cultivation should be given to the soil to kill weeds and provide soil mulch. Earthing-up of plants four to five weeks after transplanting is highly desirable.


**Roguing:** In cauliflower at least four roguing should be done for production of quality seed.

**Vegetative stage:** First roguing is done at vegetative stage to remove off types, weak, diseased and blind plants.

**Curd initiation stage (transition stage):** At curd initiation very early or late curding, extra vigorous and diseased plants are removed. Also remove all small plants which are likely to form buttons and the plants showing the symptoms of whiptail.

**Curd maturity stage (75% curd formation):** At curd maturity stage, plants having small, unblanched, shallow depth, flat upper surface, ricey, fuzzy, creamy, yellowish and pinkish, bracteate curds are rogued out. Also remove the plants affected with sclerotinia, black leg, Rhizoctonia, soft rot, grey mould and black rots. Plants showing chimeral leaves and very early or late curd formation are also rogued out. Subsequent roguing for off-types, and
diseased plants affected by black-leg, black rot, leaf spot and phyllody should be done from time to time as required.

Bolting and pre flowering stage: Very early or late bolters, pinkish flower buds and stalks, diseased plants, curds throwing flowering stalks first from centre and creamy white flowering plants are rogued out.

**Harvesting:** Harvesting can be done when pods attains yellow colour. About 50-60 days are needed for pod maturity after fertilization. Harvesting can be problematic due to the uneven maturation of silique and their readiness to dehise. Hence, 2-3 harvesting are required. Harvest is done by hand. Seeds of early types are ready for harvesting in February- March and mid maturity in March-April months in north Indian Plains. The seeds of snowball types are ready for harvesting by June in India. Generally the early plants are harvested first, when about 60 to 70 percent of the pods turn brown and the rest of the crop changes to yellowish-brown. The entire plant is cut early in the morning to minimize shattering. After harvesting it is piled up for curing. After four to five days it is turned upside down and allowed to cure for another four to five days in the same way. It is then threshed with sticks and sifted with hand sifters. After thorough drying of seed in the sun (seven percent moisture content) it is cleaned and stored. The seed is properly graded using grading machine and a spiral separator is used to separate splits from whole seeds. Seed should not crush or split when rubbed between the hands.

**Seed Yield:** Average seed yield of Indian cauliflower varies from 500 to 600 kg/ha and snowball types from 300-500 kg/ha.
Haploid breeding and its role in vegetable hybrid seed production

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An individual/a cell that has the gametic chromosome complement of the species are called haploid. Haploids of diploid species are termed as monoploids since they have a single copy of one genome. In contrast, haploids of tetraploid species e.g. potato, have single copy of two genomes and are referred as dihaploids. In general haploids are much weaker than the normal plants. In most cases they are sterile and difficult to maintain, therefore, chromosome number of haploids is doubled to produce doubled haploids (DH), which have the normal somatic (2n) chromosome complement of the species and are fully fertile. They are produced from pollen or egg cells. Haploid cells occur naturally in the gametophytic phases of higher plants in their ovules and pollen. By manipulating the gametic cells, it is possible to produce embryos rather than mature pollen grains or ovules. By induced or spontaneous chromosome doubling, a completely homozygous doubled haploid plant can be produced. Conventional inbreeding procedures take six generations to achieve completely homozygous condition, whereas doubled haploidy reduces it to one step. Hence, it is of a great importance in plant breeding. The first report of the haploid plant was published by Blakeslee et al. (1922) in Datura stramonium. Subsequently, haploids were reported in many other species. Guha and Maheswari (1964) developed an anther culture technique for the production of haploids in the laboratory. Haploid production by wide crossing was reported in barley (Kasha and Kao, 1970) and tobacco
Doubled haploid methodologies have now been applied to over 250 species.

**Production of Haploids**

Doubled haploids can be produced *in vivo* or *in vitro*. Haploid embryos are produced *in vivo* by parthenogenesis, pseudogamy, or chromosome elimination after wide crossing. The haploid embryo is rescued, cultured, and chromosome-doubling produces doubled haploids. The *in vitro* methods include gynogenesis (ovary and flower culture) and androgenesis (anther and microspore culture). Androgenesis is the most preferred method for haploid production.

**Androgenesis:** Haploid plants may be obtained from pollen grains by placing anthers or isolated pollen grains on a suitable medium, this constitute anther culture and pollen culture, respectively. The development of haploid embryos/plantlets from pollen grains is termed as androgenesis. Haploid plantlets have been regenerated from pollen grains in potato, tomato, cole crops and other solanaceous vegetables. Pollen (microspore) culture is preferred over anther culture for production of haploids. The culture of microspore does not involve the risk of regeneration from somatic tissues and embryo yield from microspore culture is higher than anther culture. Anther culture is more laborious technique and require manual excision of anther and there is time lag before anther can be seen successful.

**Factors affecting Androgenesis:**

**Explant genotype:** Plant genotype plays a predominant role in determining the androgenic response, even the clones derived from the same variety varied in their response. Therefore, culture procedure should be optimized for each genotype. Genetics of androgenic response has been analyzed in *Brassica spp.* and potato

**Growth condition of donor plant**

The conditions under which donor plant are grown are an important consideration for successful haploid production. Temperature is very crucial
factor because sudden change in the temperature regime mainly after floral
differentiation could greatly diminish the embryogenic response as stress
alters the level of growth regulators, amino acids, carbohydrate or lipid in the
plant. In autumn-heading cauliflower the best results were obtained during
spring in a greenhouse where the temperature was maintained between 10
and 20°C. Overall winter and spring seemed more suitable than summer and
early autumn for culture establishment.

**Developmental stage of the pollen:** The optimal bud development stage in
cauliflower depended on the genotype: for the hybrid 702, the greatest
number of embryos for 100 plated anthers was obtained at the uninucleate
pollen stage of the microspores; for V23.2 and 703, the optimal stage of the
buds corresponded to the first mitotic division (Yang et al., 1992). In most of
the cole crops the buds for microspore culture should contain microspore at
mid to late uninucleate stage. In mid uninucleate stage microspores are round
and developed a thick exine with the nucleus in the center. At late uninucleate
stage, the nucleus migrates to the cell wall and exine become more yellow. In
certain species, bud sizes can be correlated the developmental stage of the
pollen. For e.g. anthers of cabbage ‘Hawake’, Swede ‘Gry’ and Chinese cabbage
‘Kasumi’ contains microspore at the late uninucleate stage when the buds are
6.5-7.0 mm, 4.5-5.5 mm and 2.5-3.0 mm in length, respectively.

**Pretreatments:** Pretreatment of the donor plants, floral organs, or anthers
with growth regulators or environmental stress can influence embryogenesis.
Abiotic stresses play an important role in androgenic induction. Low and high
temperature shocks are applied as pretreatment or at early stage of induction
in most protocols. Exposure of excised flower buds to a low temperature for
some time, e.g., 3-5°C for 2 days or at 7-8 °C for 12 days, prior to removal of
anthers for culture may markedly enhance the recovery of haploid plants.
Cold treatment of detached anthers is less effective than that of detached
flowers. Low temperature kills weak or non viable anthers and microspores;
it also arrests many of pollen grains in the first mitosis and blocks starch
accumulation. Microspore and tapetal developments then become
asynchronous, influencing the switch from gametophytic to sporophytic
Embryogenesis from eggplant anthers required essentially high temperature treatment combined with 2,4-D and kinetin (Matsubara et al., 1992). In addition treatments like centrifugation, irradiation with X-ray and gamma rays and reduced atmospheric pressure are reported to promote androgenesis.

**Media Composition:** The composition of culture media is an important factor influencing embryogenesis. For most species, a complete tissue culture medium is required. MS, LS (Linsmaer and skoog) and some other tissue culture media are generally used. Media with dilute salt solutions, e.g. white’s and Heller’s media are ordinarily supplemented with coconut milk. The most often modified components are the source of organic nitrogen, carbohydrates and growth regulators. Sucrose plays a key role in induction of embryogenesis, while other medium constituents are needed for post induction development of embryo. High sucrose level may play an osmoregulatory role during induction, but it is not necessary or even detrimental during embryo development. For cole crops, the basal media used for washing is B5 (Gamborg et al., 1968) and for culturing, NLN (Lichter, 1982). For microspore culture of Brassica species, sucrose concentration of culture medium is generally higher than the other species. This is usually 13% or 17 % with media change to 10% or 13% sucrose. In anther cultures of paprika and eggplants the inclusion of maltose in the induction medium improved the induction of microspore embryogenesis and raised the number of regenerant plants. Nitsch and Nitsch medium supplemented with glutamine, glutathione and serine is the most congenial for anther culture in Brassica. The use of ½ NLN-13 medium yielded greater number of embryos than the standard NLN-13 in broccoli. In general organic nitrogen levels should be raised in the induction medium. The use of media with pH around 6 and addition of activated charcoal seems to promote embryo yield in cabbage.

**Growth regulators:** In Solanaceous plants, pollen embryogenesis does not require any growth regulators, but low levels of auxins, cytokinins and even GA3 appears beneficial. The presence of an auxin may determine the mode of
subsequent development or androgenic cell mass. An increase in concentration of 2, 4-Dichlorophenoxyacetic acid (2, 4-D) from 0.1 to 0.3 mg/l also increased embryo yield in cauliflower. On the other hand, addition of a cytokinin (BAP) in the medium led to lower embryo production, and this negative effect increased when the hormone concentration in the medium increased (Yang et al., 1992). In brussels sprouts presence of silver nitrate proved to be beneficial. Increasing 2, 4-D could be beneficial in the absence of silver nitrate, but was sometimes detrimental in the presence of silver. Replacing agar with highly purified agarose was not particularly beneficial.

**Gynogenesis:** Culture of unfertilized ovaries to obtain haploid plants from egg cell or other haploid cells of the embryo sac is called as ovary culture and the process of haploid production is termed as gynogenesis. This method is used for plant species for which androgenesis is not effective to produce haploids. The first report of gynogenesis was by San Noem in 1976 in case of barley, but success has been obtained with sugarbeet, potato and onion. Haploid plants generally originate from egg cells in most species (*in vitro* parthenogenesis), but in some cases they may arise from synergids; *Allium tuberosum* and even antipodal cells. In most cases the optimum stage for ovary culture is the nearly mature embryo sac, but in case of rice ovaries at free nuclear embryo sac stage are most responsive. Generally culture of whole flower, ovary, and ovules attached to placenta respond better, but in gerbera and sunflower isolated ovules show better response. One of the most important factors influencing the efficiency of gynogenesis is donor plant genotype.

Gynogenesis frequency of different sugar beet varieties varied from 0 to 16%, of leek from 0 to 2% and in red beet reached 11%. Cold pretreatment (24-48 hr at 4°C in sunflower and 24 hr at 7°C in rice) of the inflorescence before ovary culture enhance gynogenesis. In *in vitro* flower-bud and ovary cultures of onion application of thidiazuron not only improved embryo induction but also increased the ratio of spontaneous doubled haploids. Pollination with irradiated pollen may have a promontory effect e.g. in case of potato, musk melon, onion and sugarbeet.
Ovary culture has mainly two limitations (i) it is successful only in few species. And (ii) the frequency of responding ovaries and the number of plantlets/ovary is quite low. Therefore, ovary culture is preferred over anther culture only where anther culture fails e.g. sugar beet and in cases of male sterile lines, ovary culture assumes significance.

**Haploids from interspecific crosses:** Double haploids in potato can be produced from tetraploid genotypes of *Solanum tuberosum* by pollination with the diploid potato sp. *Solanum phureja*. In about 0.55 of pollinated ovules, both male sperm cells of *S. Phureja* take part in the formation of functional endosperm which triggers the parthenogenetic development of unfertilized egg cells. Haploids can be identified with some markers. The best pollinator lines of *S. phureja* have been bred for a dominant purple spot marker thus seeds containing haploid embryos can be easily distinguished from hybrid *S. tuberosum* & *S. phureja* seed. Similarly low seed weight is associated with haploidy in cucumber.

**Irradiation:** Pollen irradiation represents a valuable method for inducing haploid plants especially when combined with embryo rescue. This method has been successfully adapted in France at INRA since 1987 in muskmelon, onion, cabbage, carrot, cucumber and watermelon are presented here. In the case of muskmelon it is now used routinely in breeding programmes. The conditions required vary from one species to another. For muskmelon, genotype and season influence the quantity of haploids.

**Diploidization of Haploids Plants** - Haploid plants obtained either from anther or ovule culture may grow normally under *in vitro* conditions up to the flowering stage but viable gametes are not formed due to the absence of one set of homologous chromosomes and, consequently, there is no seed set. The only mechanism for perpetuating the haploids is by duplicating the chromosome complement in order to obtain homozygous diploids. In pollen derived plants duplication of chromosomes may occur spontaneously in cultures but due to the small percentage of such double-haploids it is necessary to diploidize the haploids by chemical means. A simple procedure
designed to achieve diploidization involves immersion of very young haploids in a filter sterilized solution of colchicine (0.4%) for 2-4 days, followed by their transfer to the culture medium for further growth. In this procedure chromosome or gene instabilities are minimal compared to other methods of colchicines or chemical treatment.

**Applications of DHs in vegetable breeding**

**Cultivar development**

Traditional breeding methods are slow and take 10-15 years for cultivar development. Another disadvantage is inefficiency of selection in early generations because of heterozygosis. These two disadvantages can be overcome by DHs, and more elite crosses can be evaluated and selected within less time. Haploids are of great use for the production of homozygous plants. This has been amply demonstrated in potato where several monoploids are being used for the production homozygous lines which are used in breeding programs especially to develop resistant cultivars. This is especially important for inbred development in cole crops, where inbred development via bud pollination is cumbersome and time taking process. In these crops homozygous inbred lines can be produced in 1-2 years. Uniformity is a general requirement of cultivated line in most species, which can be easily obtained through DH production. There are various ways in which DHs can be used in cultivar production. The DH lines themselves can be released as cultivars; they may be used as parents in hybrid cultivar production or more indirectly in the creation of breeders lines and in germplasm conservation.

**Haploid Mutant Production:**

The use of haploid system for mutant induction and selection is one of the most important applications of haploid technologies. Haploid tissue can facilitate the generation of genetic variation and its identification.

Some of the benefits of applying DH systems for induction and selection of mutants are
- possibility to screen both recessive and dominant mutants in the first generation after mutagenic treatment.
- Immediate fixation of mutated genotypes, which saves time in production of pure mutant lines.
- Increased selection efficiency of desired mutants due to the gametic versus zygotic segregation ratios (1:1 vs. 3:1, respectively) and the lack of chimerism.
- Possibility of applying in vitro selection methods at the haploid or double haploid level.

**Mapping Quantitative Trait Loci**

Most of the economic traits are controlled by genes with small, but cumulative, effects. Although the potential of DH populations in quantitative genetics has been understood for some time, it was the advent of molecular marker maps that provided the impetus for their use in identifying loci controlling quantitative traits. As the quantitative trait loci (QTL) effects are small and highly influenced by the environmental factors, accurate phenotyping with replicated trials is needed. This is possible by doubled haploidy because of their true breeding nature and convenience of producing in large numbers. Using DH populations, 130 quantitative traits have been mapped in nine crop species. In total, 56 DH populations were used for QTL detection.

**Backcross breeding**

In backcross conversion, genes are introgressed from a donor cultivar or related species into a recipient elite line through repeated backcrossing. A problem in this procedure is being able to identify the lines carrying the trait of interest at each generation. The problem is particularly acute if the trait of interest is recessive, as it will be present only in a heterozygous condition after each backcross. The development of molecular markers provides an easier method of selection based on the genotype (marker) rather than the phenotype. Combined with doubled haploidy it becomes more effective. In marker assisted backcross conversion, a recipient parent is crossed with a
donor line and the hybrid (F₁) backcrossed to the recipient. The resulting generation (BC₁) is backcrossed and the process repeated until the desired genotypes are produced. The combination of doubled haploidy and molecular marker provides the short cut. In the back cross generation one itself a genotype with the character of interest can be selected and converted into homozygous doubled haploid genotype.

**Bulked segregant analysis (BSA)**

In bulked segregant analysis, a population is screened for a character of interest and the genotypes at the two extreme ends form two bulks. Then the two bulks were tested for the presence or absence of molecular markers. Since the bulks are supposed to contrast for alleles contributing positive and negative effects, any marker polymorphism between the two bulks indicates the linkage between the marker and character of interest. BSA is dependent on accurate phenotyping and the DH population has particular advantage in that they are true breeding and can be tested repeatedly. DH populations are commonly used in bulked segregant analysis, which is a popular method in marker assisted breeding.

**Genetic maps**

Genetic maps are very important to understand the structure and organization of genomes from which evolution patterns and syntenic relationships between species can be deduced. Genetic maps also provide a framework for the mapping of genes of interest and estimating the magnitude of their effects and aid our understanding of genotype/phenotype associations. DH populations have become standard resources in genetic mapping for species in which DHs are readily available. Doubled haploid populations are ideal for genetic mapping. It is possible to produce a genetic map within two years of the initial cross regardless of the species. Map construction is relatively easy using a DH population derived from a hybrid of two homozygous parents as the expected segregation ratio is simple, i.e. 1:1.
Genomics

Although QTL analysis has generated a vast amount of information on gene locations and the magnitude of effects on many traits, the identification of the genes involved has remained elusive. This is due to poor resolution of QTL analysis. The solution for this problem would be production of recombinant chromosome substitution line, or stepped aligned recombinant inbred lines. Here, backcrossing is carried out until a desired level of recombination has occurred and genetic markers are used to detect desired recombinant chromosome substitution lines in the target region, which can be fixed by doubled haploidy.

Genetic transformation:

These days, in genetic transformation studies, haploid microspores are being used as targeted in transforming a gene prior to chromosome diplodization process that allow a stable fixation of homozygosity of the integrated gene. Haploid plants can also be used for gene transformation followed by the chromosome diplodization process. Drought tolerant gene (HVA1) was successfully transformed in haploid bread wheat followed by chromosome doubling to fix the homozygosity of the integrated gene

Limitations of DHs:

- Haploids can not be obtained in high frequency required for selection.
- Selection cannot be imposed on the population in DH based breeding.
- The cost benefit ratio in haploid breeding is often not favourable, thus discouraging the use of haploid breeding despite its obvious advantages.
- Haploids will express recessive deleterious traits and deleterious mutations may arise during anther culture;
- In haploids produced from anther culture, it is observed that some plants are aneuploids and some are mixed haploid-diploid types.
- The over-usage of doubled haploidy may reduce genetic variation in breeding germplasm.
**Advances in haploid production in vegetables:**

**Cole crops:** Haploid production in cole crops is of significant importance as haploids can be used for the development of homozygous inbred lines. Microspore culture is successful in most crops types of *Brassica oleracea* vegetables (Duijs, 1992). More than 400 regenerants of R1 generation were derived in kohlrabi, cabbage and cauliflower by means of different modifications of microspore culture technique. Distinct genotype differences in embryogenic responsibility and regenerative ability of microspore embryos to whole plants were detected. The highest frequency of embryogenesis and subsequent regeneration of plants were achieved in cauliflower cultivar Siria F1, kohlrabi line P7 and some experimental F1 hybrids of cauliflower. The percentage of plant regeneration from subcultured embryos in kohlrabi ranged from 11.11 to 63.64%, in cauliflower from 23.53 to 46.19% and in cabbage from 5.88 to 52.00%. Cold pretreatment on flower buds have significant effect on microspore embryogenesis in cole crops (Klima, 2004). The addition of activated charcoal is reported to increase embryo yields in cole vegetables. In broccoli, embryo yield were significantly increased in most genotypes by incubating microspore cultures at 32.5 °C for 1 day as compared to standard incubation at 30 °C for 2 days (Dias, 2001). Whereas, in cabbage, the best yield in the temperature treatments were, when the microspores were cultured at 32 °C for two days.

**Carrot:** Production of new cultivars by hybridization is tedious in carrot, because carrot flowers are small to be controlled. Several advantages for plant breeding are given with haploid plants, including the rapid production of homozygous lines as well as the possibility to detect of recessive mutations directly. Haploidy technology in carrot can be used to develop uniform, true breeding lines as well as to accelerate breeding programs. (Hu, *et al.*, 1993) Carrot haploid has been induced through parthenogenesis. For parthenogenesis induction carrot flowers were pollinated with pollen of other species. However, ploidy analysis revealed the presence of diploids (98%) and no haploids were observed. Among the diploids 52% were homozygous. For microspore culture in carrot the uni-nucleate stage proved to be optimal for
embryogenesis. Anther culture at 27°C in the dark without sub-culturing had a significant beneficial impact on embryogenesis.

**Onion:** Doubled haploids are appealing for the development of breeding and genetic stocks due to high level of genetic variation and inbreeding depression observed in onion. The production of doubled haploid plants yields uniform inbred lines and is especially desirable as an alternative to sexual inbreeding of longer-generation crops such as onion. Onion (*Allium cepa* L.) is a biennial plant and amenable to the production of haploids from the female (gynogenic) gametes. Doubled haploid (DH) plants, obtained *via* tissue culture techniques, are equivalent to inbred lines but can be produced within 1-2 years. Thus DH techniques may cut up to eight years from the time usually required to develop uniform improved onion inbreds for applied use. Quality or pest-resistance traits controlled by multiple genes are particularly hard to stabilize by standard approaches. Production of doubled haploids have been practiced in New York state to speed up onion breeding. Hundreds of DH plants have been transferred out of culture into soil and provided to the onion breeding program. DH lines of onion were uniform, highly vigorous and lack of inbreeding depression.

**Tomato:** In tomato, pureline variety, Marglobe has been produced from haploid plants. Results on the induction of haploidy in tomato *via* both gynogenesis and microspore embryogenesis *in vitro* are far from satisfactory. The number of reports available on the gynogenic induction *via* *in vitro* non-fertilized ovary culture, wide hybridization and the use of irradiated pollen are limited. The main reason for this may be the difficulty experienced in working with this species. Non-fertilized ovary culture and wide hybridization using *Solanum sisymbriifolium* Lam. as the male parent seem to be promising (Bal and Abak, 2003). Several reports are available on anther culture of tomato but a working protocol is yet to be developed. For the induction of anther callus, anthers carrying microspores at the meiotic stages appear to be the most responsive. However, the callus and the regenerants obtained were mainly of somatic origin. Somatic tissues of tomato anthers carrying the meiotic stages are highly responsive to tissue culture manipulations in
comparison to anther tissues of the later stages. Therefore, reports on the
induction of callus from anthers carrying early microspore stages should be
met with caution. If culturing young anthers is of any help, then it may be
that the anther tissues are nursing the microspores and bringing them to the
responsive uninucleate stage. The future of tomato haploidy lies in the
technique of isolated microspore culture.

**Potato:** Haploidy offers promise of new efficient approaches to potato
breeding. There is an important application for use of haploids in interspecific
hybridization to overcome incompatibility barriers caused by the differences
in ploidy levels and endosperm balance numbers. Thus, the gene pool of the
potato can be broadened and certain valuable traits such as disease
resistance characters from the wild solanaceous species can be more
efficiently introgressed into cultivated potato. It further presents a unique
opportunity for accelerated genetic and cytogenetic study of the common
potato. Double haploids in potato were produced from tetraploid genotypes of
*Solanum tuberosum* by pollination with the diploid potato sp. *Solanum
phureja*. Methods of more effective chromosome number duplication were
developed more recently & production of haploids in potato can now be done
by androgenic methods with a better efficiency. Moreover, androgenesis is
applicable to a much wide range of *Solanum* species in comparison to crosses

**Beet:** Early attempts to obtain double haploids lines in beet (*Beta vulgaris*)
involve both androgenesis and gynogenesis. Gynogenesis induced from
isolated ovules appeared to be successful for sugarbeet. Cold pretreatment
and the addition of charcoal increased the embryo formation frequency in
beet, whereas AgNO3 decreased or completely inhibited it (Gürel *et al*., 1993).
Cold treatment of inflorescence at 8°C for 1 week combined with relatively
high temp (30°C) for the induction phase is beneficial (*Lux et al*., 2003).

**Conclusion:** Technological advances have now provided DH protocols for
most plant genera. The number of species amenable to doubled haploidy has
reached a staggering 250 in just a few decades. Response efficiency has also
improved with gradual removal of species from recalcitrant category. Hence it will provide greater efficiency of plant breeding. Production of doubled haploid (DH) plants via tissue culture techniques will substantially speed up the development of stable lines with improved yield, quality or resistance to diseases. The benefit is especially great with biennial crops like onion or complex traits controlled by multiple genes.

References:


Recent advances in integrated management of vegetable insect-pests

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Concept of IPM

Integrated pest management (IPM) is an approach that integrates practices for economic control of pests. IPM aims to suppress pest populations below the economic injury level (EIL). FAO defines IPM as "the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms." IPM allows for economically viable and safe pest control.

Principles of IPM

IPM system is designed around six basic components

1. **Acceptable pest levels**: The emphasis is on control, not eradication. IPM holds that wiping out an entire pest population is often impossible, and the attempt can be expensive and unsafe. IPM programmes first work to establish acceptable pest levels, called action thresholds, and apply controls if those thresholds are crossed. These thresholds are pest and site specific, meaning that it may be acceptable at one site to have a weed such as white clover, but not at another site. Allowing a pest population to survive at a reasonable threshold reduces selection pressure. This lowers the rate at which a pest develops resistance to a control, because if almost all pests are killed then those that have resistance will provide the genetic basis of the future population. Retaining a significant number of susceptible specimens dilutes the prevalence of any resistant genes that appear. Similarly, the repeated use
of a single class of controls will create pest populations that are more resistant to that class, whereas alternating among classes helps prevent this.

2. **Preventive cultural practices**: Selecting varieties best for local growing conditions and maintaining healthy crops is the first line of defense. Plant quarantine and ‘cultural techniques’ such as crop sanitation are next, e.g., removal of diseased plants, and cleaning pruning shears to prevent spread of infections. Beneficial fungi and bacteria are added to the potting media of horticultural crops vulnerable to root diseases, greatly reducing the need for fungicides.

3. **Monitoring**: Regular observation is critically important. Observation is broken into inspection and identification. Visual inspection, insect and spore traps, and other methods are used to monitor pest levels. Record-keeping is essential, as is a thorough knowledge target pest behavior and reproductive cycles. Since insects are cold-blooded, their physical development is dependent on area temperatures. Many insects have had their development cycles modeled in terms of degree-days. The degree days of an environment determines the optimal time for a specific insect outbreak. Plant pathogens follow similar patterns of response to weather and season.

4. **Mechanical controls**: Should a pest reach an unacceptable level, mechanical methods are the first options. They include simple hand-picking, barriers, traps, vacuuming and tillage to disrupt breeding.

5. **Biological controls**: Natural biological processes and materials can provide control, with acceptable environmental impact, and often at lower cost. The main approach is to promote beneficial insects that eat or parasitize target pests. Biological insecticides, derived from naturally occurring microorganisms (e.g. Bt, entomopathogenic fungi and entomopathogenic nematodes), also fall in this category. Further ‘biology-based’ or ‘ecological’ techniques are under evaluation.

6. **Responsible use**: Synthetic pesticides are used as required and often only at specific times in a pest's life cycle. Many newer pesticides are derived from
plants or naturally occurring substances (e.g.-nicotine, pyrethrum and insect juvenile hormone analogues), but the active component may be altered to provide increased biological activity or stability. Applications of pesticides must reach their intended targets. Matching the application technique to the crop, the pest, and the pesticide is critical. The use of low-volume spray equipment reduces overall pesticide use and labor cost.

**Recommended IPM practices for important vegetable crops**

**Tomato**

**Nursery**

- Raise marigold (tall African variety golden age bearing yellow and orange flower) nursery 15-20 days before tomato nursery.
- Prepare raised nursery beds about 10 cm above ground level for good drainage to avoid damping off.
- Cover the beds with polythene sheet of 45 gauge (0.45 mm) thickness for three weeks before sowing for soil solarisation for reducing the soil borne pests. Sufficient moisture should be present in the soil.
- Seed treatment with *Trichoderma viride* @ 4g/kg of seed in nursery to prevent infection of soil borne/ seed borne fungal 1 kg of FYM. Mix in 1m2. It can be applied even in main field.
- Spray nursery with it if insect is noticed.
- Spray Dithane M 45 or Ridomyl against Downy Mildew as this disease is generally seen in nursery.

**Main crop**

- Showing of resistant variety (Fruit borer-Avinash-2, Bacterial wilt- Arka Abha, Arka Alok, Shakti, Arka Abhijit, Arka Shreshta, Leaf Curl-Parbhani, Yeshree, H.24; Root-knot Nematodes, Hissar Anmol, SL 120, Pusa Hybrid 2; Powdery Mildew- Arka Ashish, Early Blight-Devgiri, Fusarium wilt-Pant Bahar).
• Before transplanting dip the roots of seedlings for 15 minutes in Imidacloprid @ 0.3 ml/litre for management of aphids, white fly & leaf miner.

• Transplant a row of marigold after every 16 rows of tomato as a trap crop. Marigold should be 15 days older than tomato plants so that they flower at the same time. Maximum egg laying by borer is observed on marigold flowers. First and last row of plots should be marigold and it should be sprayed with HaNPV.

• Adopt wide spacing of 60 x 45 cm (for varieties) and 90x 60 cm (for hybrids) to reduce the chance of spread of diseases.

• Apply neem cake @ 250 kg/ha at 20 DAP to reduce fruit borer, leaf miner and nematode.

• Bird perches @ 10/ acre should be erected for facilitating field visits of predatory birds.

• Spray of 5% NSKE at 15 DAP has also been found to be effective against leaf-miner & white fly. Spray Imidacloprid or Thiomethoxam at 15 DAP for leaf miner & white fly control, if needed.

• Pheromone traps @ 5/ ha be installed for monitoring fruit borer activity. Replace the lures with fresh lures after every 20-25 day interval. ETL for fruit borer is 8 to10 moths /day/trap.

• Monitor top three leaves for Helicoverpa eggs.

• Release of T. chilonis, T. braziliensis and T. pretiosum @ 1.0 lakh/ha 4-5 times from flower initiation stage at weekly intervals for fruit borer.

• Spray HaNPV 250 LE/ha (2 x 109 POB) + 1% jaggery along with sticker 0.5 ml/ liter 3 times at 28, 35 and 42 DAP during evening to reduce borer damage.

• Regular collection & destruction of damaged fruits i.e. clean cultivation helps in management of borer effectively.

• If the borer incidence crosses ETL (5% damage), apply Emmamectin Benzoate (proclaim) or Indoxacarb.

• Rouge out and destroy leaf-curl and wilt affected plants.
Spray 0.02% Chlorothalonil/Mancozeb/Captan @ 1.25-1.5 kg a.i./ha in 700 L of water for the control of early and late blight. Repeat after 10 days if necessary.

If red spider mite is noticed, spray neem soap or neem oil (0.1%) or any acaricide like Dicofol 18.5 EC (1.5 ml/l) or Ethion EC (1.5 ml/l) or Sulphur 80 WP (3g/l).

**Brinjal**

**Nursery**

- Always prepare raised nursery beds about 10 cms above ground level for good drainage to avoid damping off, etc.
- Cover the nursery beds with polythene sheet of 45 gauge (0.45 mm) thicknesses for three weeks during June for soil solarisation which will help in reducing the soil borne insects, diseases like bacterial wilt and nematodes. However, care should be taken that sufficient moisture is present in the soil for its solarisation.
- Mix 250 gm of fungal antagonist *Trichoderma viride* in 3.00 kg of FYM and leave for about seven days for enrichment of culture. After seven days mix in the nursery soil in a bed of 3 sq. meters.
- Seed of popular high yielding hybrid like F1-321 be sown in beds in the first week of July and properly mixed in soil for healthy nursery raising. Before sowing, seed be treated with *T. viride* @ 4 gm/kg seed. Weeding should be done from time to time and infected seedlings should be rogued out from the nursery.

**Main crop**

- Bird perches @ 10/ acre should be erected for facilitating field visits of predatory birds.
- Delta traps @ 2-3/ acre should be installed for hoppers, aphids and white fly etc.
- Give two to three sprays of 5% NSKE against leaf hoppers, aphids and mites. Sprays of NSKE also brings down the borer incidence significantly. Neem oil (2%) application is also helpful in reducing borer
infestation, though marginally. If incidence of leaf hopper and other sucking insect pests is still above ETL, then apply Imidacloprid 17.8 SL @ 150 ml/ha.

- Pheromone traps @ 5/ acre should be installed for monitoring and mass trapping of shoot & fruit borer *Leucinodes orbonalis*. Replace the lures with fresh lures after every 15-20 days.
- Release egg parasitoid *T. chilonis* @ 1.0 – 1.5 lakh/ha for shoot & fruit borer, 4-5 times at weekly interval.
- Apply neem cake @ 250 kg/ ha (in two splits) in soil along the plant rows at 25 and 60 days after transplanting and give light covering with soil. This will be highly helpful in reducing nematodes and borer damage. Don’t apply neem cake when there is heavy wind velocity or temperature is above 30 degree C.
- Clipping of borer damaged shoots and collection & destruction of damaged fruits i.e. clean cultivation helps in management of borer and phomosis disease effectively.
- If the borer incidence crosses ETL (5% fruit infestation), then apply Cypermethrin 25 EC @ 200 g a.i/ha (0.005%) or Carbaryl 50 WP @ 3 g/litre of water.
- Continuous cropping of brinjal leads to more borer and wilt infestation. Therefore, crop rotation with non-solanaceous crops should be followed.
- Periodically collect and destroy the egg masses, larvae and adults of beetle.
- Rogue out the little leaf affected plants from time to time. Use of green manure, mulching with polythene, soil application with bleaching powder will reduce the infection of bacterial wilt disease.

**Cabbage and cauliflower**

**Nursery**

- Prepare raised nursery beds about 10 cm above ground level for good drainage to avoid damping off or raise seedlings in pro-trays in
nursery under net house conditions wherever such facility is available.

- Cover the beds with polythene sheet of 45 gauge (0.45 mm) thickness for three weeks before sowing for soil solarisation for reducing the soil borne pests. Sufficient moisture should be present in the soil.

- Seed treatment with *Trichoderma viride* @ 4g/kg of seed in nursery to prevent infection of soil borne/seed borne fungal 1 kg of FYM. Mix in 1m2. It can be applied even in main field.

- For aphid protection up to one month follow seed treatment with Imidachloprid (special formulation for seed treatment) @ 1 g/ 100 g seed.

- Spray nursery with *Bt* formulation (1ml or 1gm/l) at 10 days after sowing.

- Spray Dithane M 45 or Ridomyl @ 1 ml/litre against Downy Mildew as this disease is generally seen in nursery.

- Spray Indoxacarb 14.55 SC (0.5 ml/l) or Novaluron (0.75 gm/l) or Quinalphos (1.5 ml/l) a day before transplanting seedling to control head borer and early infestation of DMB.

**Main crop**

- Sow resistant varieties (Downy Mildew-Stone Head, Black rot-Puksa Drum Head, Pusa Mukta, K-1, Aphids-All season, Red Drum Head) in the epidemic regions.

- Growing of two rows of mustard after every 25 rows of cabbage as a trap crop at the time of planting. One row of mustard is sown 15 days before cabbage planting and second 25 days after planting of cabbage. Ensure that first and last row of plot are also mustard. This traps 80-90% of DBM population and other pests. Mustard may be sprayed with Dichlorovos @ 2ml/litre as soon as DBM larvae are observed.

- Adopt wide spacing of 60 x 45 cm to reduce the chance of spread of diseases.

- Use light traps for adult DBM @ 3 traps/acre. Hang a bulb over a bucket of water. Within 3-4 days most of the adults get killed.
• Spray Bt (1 g/litre) if DBM 1.0/plant is noticed early or Spray NSKE 5% at primordia formation (18-25 DAP- head initiation stage which is most critical stage). Repeat if DBM population is > 8-10 larva/plant at fortnight interval. Maximum of 3-4 NSKE sprays in one crop season are required. When NSKE are sprayed, thorough coverage of the entire plant surface is a must. If NSKE is not available spray Spinosad @ 0.4 ml/litre or Indoxacarb 1 ml/litre or Fipronil @ 1.5 ml/litre or Emamectin Benzoate @ 5 ml/10 litre r Dichlorvos @ 1.5 ml/litre whenever DBM population reach 8-10 larva/plant.

• Release egg parasitoid Trichogrammatatoidea bactrae at 0.5-0.75 lack/ha 3-4 times at weekly interval. (optional)

• For controlling Spodoptera mechanically collect and destroy gregarious young larvae and set up traps for mass trapping. However, to control grown up caterpillar, do baiting with Methomyl in rice grain/wheat grain (10 kg), jaggery (2 kg) and insecticide formulation 250 g/acre.

• For cabbage butterfly mechanically destroy yellow egg mass or early instar gregarious larvae. If necessary spray Dichlorvos @ 1.5 ml/litre.

• Install delta sticky traps @ 2/acre for aphids.

• For aphid whenever more than 30 aphids per plants are observed spray with Dimethoate @ 2 ml/litre or Imidacloprid 0.5 ml/l.

• Apply fertilizers judiciously. Overdose of nitrogen supplying fertilizer (e.g. Urea) may cause more incidence of sucking pests. Potassium promotes plant resistance towards insect pests, diseases and stress. Apply fertilizer in the balanced N: P: K ratio of 4: 2: 1.

• Periodically remove and destroy disease affected leaves.

• If required, spray Chlorothalonil or Mancozeb @ 1 ml/litre for Alternaria leaf spot and Blitox @ 2 ml/1 l + Streptomycin 1 ml/10 l for black rot disease. Wider spacing (60 × 50 cm) will reduce disease spread.

• Follow pesticide rotation to avoid resistance development.
Chilli and Capsicum

Nursery

• Prepare raised nursery beds about 10 cm above ground level for good drainage to avoid damping off and other soil born disease.

• Cover the beds with polythene sheet of 45 gauge (0.45 mm) thickness for three weeks before sowing for soil solarization which will help in reducing the soil borne pests. Sufficient moisture should be present in the soil for solarization.

• Mix 150 gm of fungal antagonist Trichoderma harzianum (c.f.u. 2×10⁹/gm) in 3 kg of FYM and leave for about seven days for enrichment. After 7 days mix in the soil in a bed of 3 sq. metre.

• Treat the seeds of popular hybrids with Trichoderma viride @ 4 gm/kg.

• To avoid fungal diseases like damping off in nursery, drench soil with any copper fungicide like Copper Oxy-chloride (Blue copper) @ 3 g/litre of water during 2nd or 3rd week after sowing.

• Erect khaskhas shading/support on one side of nursery beds to avoid the exposure to cold/frost during winter (December-January). Cover the beds with polythene sheets at night to avoid frost injury. However, remove the sheets during day time to expose them to sun.

Main crop

• At the time of planting, dip the seedlings in Pseudomonas fluorescens solution @ 5 ml/l for two minutes.

• Erect bird perches @ 10/acre for facilitating field visits of predatory birds.

• Install delta sticky traps @ 2/acre for hoppers, aphids and white fly, etc.

• Apply fertilizers judiciously. Overdose of nitrogen supplying fertilizer (e.g. Urea) may cause more incidence of sucking pests. Potassium promotes plant resistance towards insect pests, diseases and stress. Apply fertilizer in the balanced N: P: K ratio of 4:2:1.
• Need based spray of commercial neem product/NSKE 5% against aphids, thrips, hoppers and white fly etc. Spray NSKE 5% 2-3 times against thrips at 15-20 days after transplanting (DAT) when damage rating is between 1-2. This will reduce the population substantially. If the population of thrips & white fly is still high, then spray Spinosad or Fipronil or Imidaclopid @ 0.5 ml/litre or Acephate @ 2 ml/litre.
• For aphid whenever more than 20 aphids per plants are observed spray with Dimethoate @ 2 ml/litre or Imidaclopid 0.5 ml/l.
• Spray Abamectin @ 5 ml/litre or Propergite @ 1 ml/litre or Fenazaquin 1ml/litre for mite management.
• Install pheromone traps @ 5/ ha for Helicoverpa sp/ Spodoptera litura for monitoring of adults for egg laying.
• Periodic releases of egg parasitoid, Trichogramma sp. @ 1.5 lakh/ ha for fruit borer (Helicoverpa sp.)
• Spray of HaNPV 250 LE/ha 2-3 times at 60 DAP or in initial stages or as and when needed.
• Spray of biopesticide like Proclaim 5% (WDG) @ 0.25 gm/litre or Spinosad @ 0.6 ml/L when larvae are small. Apply these biopesticides preferably during evenings.
• Spray of chemical insecticides like Indoxacarb @ 8 ml/10 l or Fenvalerate @ 1 ml/ litre or Spinosad 5 ml/ 10 l during initiation of flowering to podding stage for fruit borer, Helicoverpa sp. is effective.
• Periodic removal and destruction of damaged fruits due to borer or fruit rot. Destruction of crop residues/debris will reduce the carry over load of many insect pests. After harvest crop will be immediately ploughed in the field.
• Rouging out and destroying of leaf-curl disease/mosaic complex affected plants periodically.
• Spray 0.02% Mancozeb/Captan for managing the leaf blight & fruit rot. Proper water management & drainage reduce the incidence effectively.
• Adequate fertility & proper water management will help develop the canopy of leaves & foliage required to protect the fruit from sun scald. Sometimes a shade crop like ‘Dhaincha’ can also be grown as a border line.
• Follow pesticide rotation to avoid resistance development.

**Cucurbitaceous Crops**

• Collection and destruction of infected fruits/vines
• Deep ploughing of field after the crop harvest to will the pupae.
• Earthing up of the soil around the vine to expose the pupae for desiccations and predation by birds.
• Soil application of neem cake @ 250 kg/ha after germination and repeat once at flowering.
• Plant maize as a border crop seven days before sowing.
• Management of leaf miner by i) removal of cotyledon leaves infected with leaf miner one week after germination ii) followed by spraying of neem seed powder extract @ 4% or neem soap @ 1% reduces the incidence of leaf miner.
• Spray neem seed powder extract 4% or neem soap or pongamia soap @ 1% or carbaryl @ 3gm/l or Indoxacarb 0.5 ml/l or Dimethoate 30 EC Sulphur @ 30 g/l after flowering at 10 days interval.
• Crush pumpkin 1 kg and add 100 gm jaggery and 10 ml malathion and keep in the plot (4-6 places per acre). Adults are attracted to the fermenting pumpkin and lay eggs and get killed. Repeat the process 2-3 times in a cropping season.
• Erect pheromone traps Cuelure @ 3 traps / acre and change after 60 days.
• **Pheromone application technique for the management of fruit fly in cucurbits**
  ➢ **Male Annihilation Technique (MAT):** 5 x 5 cm² wooden blocks soaked in solution of 6:4:1 ethanol : methyl eugenol : malathion for 48 hours hung @ 10/ha
➢ **Bait Application technique (BAT):** Spray liquid of 0.1% insecticide and 10% jaggery or 10% ripe banana at 200 spots/ha

**Okra**

- Deep summer ploughing to expose resting stages of the pests
- Sowing of YVMV resistant hybrids *viz.* Makhmali, Tulsi, Anupama-1 and Sun-40, etc. especially during *kharif* season of the crop.
- Grow maize/sorghum on borders as a barrier/trap crop for the entry of shoot & fruit borer adults.
- Set up yellow sticky and delta traps for white fly, etc.
- Erection of bird perches @ 10/acre in the field for facilitating bird predation.
- Give two to three sprays of NSKE @ 5% alternating with sprays of pesticides, if needed, for leaf hopper, white fly, mites and aphids, etc. Leaf hopper, if crosses ETL (5 hoppers/plant), spray Imidacloprid 17.8 SL @ 150 ml/ha. This will be effective in controlling other sucking pests as well.
- Install pheromone traps @ 2/ acre for monitoring of *Earias vittella* moth emergence. Replace the lures after every 15-20 day interval.
- Release egg parasitoid like, *Trichogramma chilonis* @ 1-1.5 lakh/ ha starting from 30-35 days after sowing, 4-5 times at weekly interval for shoot & fruit borer.
- Rogue out the YVMV affected plants, if any, from time to time.
- Periodically remove and destroy the borer affected shoots and fruits
- Need based application of chemical pesticides *viz.* Imidacloprid 17.8 SL @ 150 ml/ha or Propargite etc. 57EC @ 0.1 % for control of leaf hoppers, aphids, white flies, borers and mites. Shoot & fruit borer, if crosses ETL (5.3 per cent damaged fruits), spray cypermethrin 25 EC @ 200 g a.i/ha (0.005%) or Quinalphos 25 EC @ 0.05% or Emmamectin Benzoate (proclaim) 5% (WDG) @ 0.25 g/litre or indoxacarb 14.5 SL @ 500 ml/ha

**Onion/Garlic**

- Do seed treatment with thiram (2g/kg seed) to control seed and soil borne diseases in nursery.
• Apply *Trichoderma viridae* @5 kg/ha mixed with FYM to main field as well as in nursery.

• Surround the onion plots (at least 250 sq. m.) with two rows of maize planted 30 days before planting onion to block the thrips to enter onion plants.

• Avoid planting onion during peak incidence of thrips.

• Seedling root dip with Carbosulfan for 2 ha should be done before planting to protect the plants during initial stages whenever late planting is done.

• Grow the crop on raised beds and provide proper drainage during kharif season to minimize disease incidence.

• Thrips and foliar disease can effectively controlled by spraying Carbosulfan (2ml/l) +Carbendazim (2.5 g/l) + sticker (0.7 ml/l); Profenofos (1ml/l) +Mancozeb (2.5 g/l) +sticker (0.7 ml/l); Cypermethrin (60 g ai/ha) + Chlorthalon (2.5 g/l) + sticker (0.7 ml/l) in rotation.

• Bulbing stage (45-75 days) is crucial for thrips management and needs chemical intervention.

• Never use same pesticide repeatedly.

**Ecological backlashes of intensive management**

Problems of 1. Resistance

2. Resurgence and

3. Pest replacement

**Insecticide Resistance Management endorsed by IRAC**

• Consult a local agricultural advisor or extension services in the area for up-to-date recommendations and advice on IPM and IRM programmes.

• Consider options for minimizing insecticide use by selecting early-maturing or pest-tolerant varieties of crop plants.

• Include effective cultural and biological control practices that work in harmony with effective IRM programmes. Adopt all non-chemical techniques known to control or suppress pest populations, including
biological sprays such as Bt’s, resistant varieties, within-field refugia (untreated areas) and crop rotation.

- Where possible select insecticides and other pest management tools that preserve beneficial insects.
- Use products at their full, recommended doses. Reduced (sub-lethal) doses quickly select populations with average levels of tolerance, whilst doses that are too high may impose excessive selection pressures.
- Appropriate, well-maintained equipment should be used to apply insecticides. Recommended water volumes, spray pressures and optimal temperatures should be used to obtain optimal coverage.
- Where larval stages are being controlled, target younger larval instars where possible because these are usually much more susceptible and therefore much more effectively controlled by insecticides than older stages.
- Use appropriate local economic thresholds and spray intervals.
- Follow label recommendations or local expert advice for use of alternations or sequences of different classes of insecticide with differing modes of action as part of an IRM strategy.
- Where there are multiple applications per year or growing season, alternate products of different MoA classes.
- In the event of a control failure, do not reapply the same insecticide but change the class of insecticides to one having a different MoA and to which there is no [locally] known cross resistance.
- Mixtures may offer a short-term solution to resistance problems, but it is essential to ensure that each component of a mixture belongs to a different insecticide MoA class, and that each component is used at its full rate.
- Consideration should be given to monitoring for the incidence of resistance in the most commercially important situations and gauge levels of control obtained.
- Withholding use of a product to which resistance has developed until susceptibility returns may be a valid tactic if sufficient alternative chemical classes remain to provide effective control.
**Tomato- A Potential and High Value Crop for Quality Seed Production**

**H R Sharma**

YSPUHF, HRS Kandaghat, Solan

**INTRODUCTION**

**BOTANICAL NAME-** *Solanum lycopersicum*

**FAMILY-** Solanaceae

- Tomato is one of the most popular and widely grown vegetables in the world ranking second in the importance to potato in many countries. It is one of the most important "protective foods" because of its special nutritive value and one of the most versatile vegetable with wide usage in Indian culinary tradition.

- Tomato is popular because it supplies Vitamin C and adds variety of colors and flavors and to the foods. The ripe fruits are taken as raw or made into salads, soups, preserve, pickles, ketchup, puree, paste and many other products (Chadha, 2001). It has very few competitors in the value addition chain of processing.

**IMPORTANCE**

- In terms of value, it comes next only to potato and sweet potato in India, but as a processing crop, it ranks first among vegetable crops (Sandhu et al., 1990).

- Its fruits are a good source of vitamin A and vitamin C as well as contain antioxidants such as lycopene which prevents cancer (Bhutani and Kallo, 1983).

- It is a rich source of vitamin-A (4.0-mg/100g), vitamin C (15-30mg/100g), total soluble solids (4-7%), acidity (7.5-10mg/100ml) and as well as contains antioxidants such as lycopene (1.82-5.24 mg/100g)
which helps to keep cholesterol down and bolster resistance to cancer (Watznman, 2000).

AREA AND PRODUCTION

- Worldwide production of tomatoes reached 170.75 million tonnes in 2014 over an area of 5.03 million hectares (FAO, 2017).
- It is one of the most popular vegetable in India and grown in tropical, subtropical and mild cold climate regions on an area of 791 thousand hectares with an annual production of 17398 metric tonnes (NHB, 2016).
- Tomato is also an important off-season crop of Himachal Pradesh and is grown during summer and rainy season as the climatic conditions are congenial for optimum plant growth and yield. The annual production of tomato in Himachal Pradesh is 430.79 metric tonnes from an area of 10.37 thousand ha (NHB, 2016).

HEALTH BENEFITS OF TOMATO SEEDS

- Improves vision - Tomato seeds are a rich source of Vitamin A help in improving the eyesight.
- Promotes bone health- Seeds are rich in Vitamin K and calcium.
- Improves immunity- Because of the presence of Vitamin C, it helps to improve the immnunity system of the body.
- Fights obesity- The fibre and niacin content of tomato seeds do the good job pf lowering the bad cholesterol level.
- Anti Inflammatory Properties- The lycopene and beta carotene present in tomato seeds helps in eradicating the free radical damage from the body which is in turn helps in reducing the problem of inflammation.
- Prevents heart diseases- The Vitamin B6, potassium and folate content of tomato seeds help in reducing the problem of hyper tension and reduce risk of harmful heart diseases.
IMPORTANCE OF QUALITY SEEDS

- They are genetically pure (true to type).
- The good quality seed has high return per unit area
- Less infestation of land with weed seed/other crop seeds.
- Less disease and insect problem.
- Uniform in plant population and maturity.
- The quality seed respond well to the applied fertilizers and nutrients.
- Good seed prolongs life of a variety.
- They are vigorous, free from pests and disease.
- High produce value and their marketability.
- Crop raised with quality seed are aesthetically pleasing.
- It is estimated that good quality seeds to improved varieties can contribute about 20-25% increase in yield.

FLORAL BIOLOGY

- Inflorescence - Extra-axillary cyme with dichotomous or polychotomous branching.
- Flower- Ebracteate, bright yellow, chasmogamous, pentamerous, actinomorphic, hypogynous, hermaphrodite, with pistil enveloped by a solid tube formed by the stamens. The flower cluster is called a truss.
- Calyx – 5 sepals, united, alternate with petals, persistant , possesses trichomes.
- Corolla – Bright yellow in color with 5 petals, alternate to sepals.
- Androecium- Stamens 5, greenish yellow, free at the base and united at the top. The anthers dehisce longitudinally.
- Gynoecium- Bicarpellory syncarpous superior ovary.
- Fruit – It is a berry.
- Anthesis starts in morning around 6 am and continues till 11.00 a.m. Anther dehiscence is longitudinal. It occurs 1-2 days after opening of corolla. Maximum flower opening is between 7 to 9 am.
Stigma receptivity is 16 to 18 hrs before anthesis and remains up to 5 to 6 days after anthesis.

Pollen remains viable for 2 to 5 days (18 - 25°C) & up to 6 months in a dessicator (5°C).

**BREEDING BEHAVIOUR**

- Tomato is a self-pollinating crop. Self-pollination varies between 94 - 99%. The best pollinator for tomato flower is a bee that Buzz and pollinate the flower or artificially hand shaking or the use of some brush may serve the purpose.
- Self-fertilization being favoured by the position of the receptive stigma within the cone of anthers and the normal pendant position of the flower.
- Though the stigma is receptive at the time of anthesis, anthers do not dehisce until about 24-48 hours later.
- Cross-pollination of tomato flowers to the extent of about 5 percent may occur through insects.

**Method of Seed Production in case of Open-pollinated and Hybrid Varieties**

1. **CLIMATE AND SOIL**
   - Tomato is a day neutral plant.
   - It is a warm season crop. It does not perform well at temperature 35 ‘C as well as below 15°C. Daily mean temperature of 22-26°C is more critical.
   - Optimum night temperature is 15-21°C.
   - Low night temperature of 13°C or below fruits fail to setting.
   - Mean daily temperature over 25°C decrease fruit setting in tomato.
   - Tomato grows practically in all soils from light sandy to heavy clay. Light soils are preferred for an early crop, while clay loam and silt loam soils are well suited for heavy yields.
2. LAND REQUIREMENTS

- The field selected for seed production should not have been grown with the same kind of crop during the preceding season.
- Selected land should be free from volunteer plants.
- Select a sunny spot to promote maximum production of flowers and fruit.
- Avoid fields where the previous crop was tomato; this prevents the new seed crop from being contaminated with seeds from volunteer tomato plants.
- Avoid fields where the previous crop was sweet potato or a solanaceous crop (tomato, pepper, eggplant or white potato); this prevents the build-up of diseases and insects.
- Growing tomato after paddy rice reduces the incidence of diseases and nematodes.

3. SOWING SEASON AND SEED RATE

- Tomatoes can be grown throughout the year. The nursery is raised from June to early November depending on the region and climatic conditions. But the best season for seed crop is May-June. The crop raised in this season produced the maximum quantity of good quality seed.
- Open pollinated varieties: 400-500g/ha
- Hybrids: 125-175g/ha
- 1 gram contains 250-300 seeds.

4. NURSERY SOWING AND SEEDLING PRODUCTION

- Tomato seedlings are raised in the nursery beds as well as in soilless cultures.

IN OPEN FIELD CONDITIONS
September-October is the optimum time for sowing seeds in the nursery for crop production in the plains.

For summer crop in the mountain areas the optimum time for raising seedlings is March/April depending on the altitude.

Seeds are sown in line on a well-prepared seedbed and lightly covered with soil.

After 7-10 days of sowing the young seedlings are transplanted on the second bed at a distance of 2-3 cm in both ways. The seedbeds should be irrigated immediately after transplanting.

The seedlings should be protected from strong sun and heavy rains.

300-350 g of urea dissolved in 30 liters of water can be sprinkled on nursery beds after about a week of transplanting the young seedlings in the second bed to get healthy seedlings.

**IN PLUG TRAYS**

- Fabricated by using 40 mesh UV stabilized nylon net and half inch GI pipes with white double door with a provision of a hanging yellow sticky card inside the net house is technically suitable for raising virus free healthy seedling of tomato, chilli and sweet pepper in small area of green house in plastic multi-celled plug tray by using soil less media for growing vegetables either for season or for off-season cultivation.

- To raise healthy, vigorous seedlings of different cucurbits.

- Coco peat, vermiculite and perlite is used in 3:1:1 ratio as a media for raising seedling.

5. **MAIN FIELD PREPARATION**

The field choosen for seed crop should not be grown with any variety or species of tomato as a previous crop. The field should be ploughed 3 to 4 times to get a fine tilth and formed ridges and furrows depending upon the variety for cultivation.

6. **TRANSPLANTING**
The seedlings will be ready for transplanting at 25-30 days after sowing. Healthy and vigorous seedlings that have produced five leaves should be used for planting in the main field, to have a good establishment and to achieve uniform stand in the field. Field should be irrigated to the field capacity and planted in the evening after 3.30 pm. Gap filling should be attended within a week of planting to maintain the desired population.

7. SPACING
- Open pollinated varieties are planted at a spacing of 90x90cm in case of indeterminate types while at 75x75cm in case of determinate types.
- Hybrid varieties are planted at a spacing of 90x60cm in case of indeterminate types while at 60x60cm in determinate types.

8. IRRIGATION
Tomato needs very careful irrigation, which should be sufficient at right time. Salinity of water has detrimental effect on flowering, fruit set, field and fruit quantity. A relatively dry period followed by sudden heavy watering during trinity period may cause cracking of fruits.

9. WEED MANAGEMENT
Application of pendimethalin @ 1.0 kg a.i./ha as pre-emergence and post emergence at 10 days after planting is recommended for seed crop.

10. ROUGING
- The lines should be as pure as possible. The volunteer plants and off types should be removed during Pre-flowering, flowering, post-flowering, and harvest stages.
- Know the plant habit, leaf type, immature fruit characters (e.g. shape, size, and shoulder colouring) of each line. Regularly inspect the plant. Remove any off type (usually inferior) or virus-infected plants immediately.
11. HARVESTING

- Harvest at full mature, preferably at pink or red ripe stage.
- This enables the seed to develop normally and fully.
- If fruits are harvested at an earlier stage, place them in a covered, cool dry place for three or four days until they become red ripe.
- Only completely colored and matured seed fruits are harvested.
- Maintain 30 fruits for large-fruited parent, 40 fruits for medium-fruited parent, 50 or more fruits for small-fruited parent.

HYBRID SEED PRODUCTION

ADVATAGES OF HYBRID VARIETIES OVER OPEN POLLINATED VARIETIES

- Higher yields
- Early maturity and more uniformity
- Better fruit quality and disease resistance
- With all of these advantages, many farmers prefer to sow hybrid seeds inspite of the higher seed costs. The demand for hybrid seeds can open a new market for growers interested in seed production. Hybrid tomato seed production is not easy. First, it requires much labor. Fortunately, this is not a problem in developing countries where affordable labor is available. Second, it requires the mastery of special skills and close attention in different aspects.

1. SELECTING PARENTS AND SOWING

- Hybrid seed production involves the crossing of a female line to a male line. Either line can be the female or male parent, but normally the best seed yielder is selected as the female parent.
Both parents should be pure, preferably being self pollinated for more than six generations (this is called *inbreeding*). The *inbred parents are selected* for their desirable traits (e.g., high yields, disease resistance, fruit quality, earliness, etc.).

- It is important to have plenty of pollen available for making hybrid crosses. Since tomato vines bloom profusely, a ratio of 1 male for every female plants is recommended.
- Seeds of male plants are sown three weeks earlier to ensure that pollen is available from the beginning of operations.

### 2. SPECIAL CULTURAL PRACTICES

#### 2.1 Plant Location and Spacing

- Male lines are usually planted in a different location to facilitate operations and avoid shading from competing plants. Select a sunny spot to promote maximum production of flowers and pollen.
- Male and female lines are planted in double-row raised beds, with centers of beds spaced 150 cm apart.
- For female lines, plants are spaced 50 cm apart within the row.
- Male plants are spaced 40 cm apart to maximize flower production per hectare.

#### 2.2 Staking and Pruning

- The female parent is staked. Staking facilitates the handling of plants during emasculation and pollination.
- Staking also keeps the ripening fruits above the ground and prevents rotting.
- Plants are trellised along with plants from the adjoining bed so that work operations are done on the raised bed rather than in the furrow.
- Among male lines, only indeterminate types need to be staked. If male lines are staked, trellising can be done within beds or across adjoining beds.
2.3 Removing off types

- The male and female lines must be 100% pure. Know the plant habit, leaf type, immature fruit characters (e.g., shape, size, and shoulder colouring) of each line.
- Regularly inspect the plant.
- Remove any off type (usually inferior) or virus-infected plants immediately before the hybridization procedures begin. Symptoms of viruses that attack tomato include yellow mottling of leaves; severe curling, cupping or other distortion of foliage; and stunting of plants.

2.3 Emasculation

To prevent self-pollination, remove the stamens from the flower buds of the female line before they shed their pollen. This process is called emasculation. Emasculation begins about 55-65 days after sowing. Flower buds from the second cluster which will open in two to three days are chosen for emasculation. The petals will be slightly out of the flower bud but not opened, and the corolla color is slightly yellow or even paler. Flowers from the first cluster are removed. To help identify the fruits from selfed fruits at the time of harvest, cut the corolla and calyx.

2.4 Pollen collection

- Collect flowers from the male parent to extract pollen. The best time for pollen collection is during the early morning before the pollen has been shed.
- Remove the anther cones from the flowers and put them in glassine envelopes.
Dry the anther containers. Put the dried anther cones in a plastic pan or cup. Cover the cup with a fine mesh.

Shake the cup about 10-20 times so that pollen is collected in the lid cup. Transfer the pollen into a small convenient-to-handle container for pollination.

2.5 Pollination

Emasculated flowers are generally pollinated two days later. Try to avoid pollination on rainy days.

Expose the stigma to facilitate pollination. Dip the stigma into the pool of pollen in the pollen container.

Pollination is usually done 3 times weekly over a 3-5 week period. Successful pollinations are easily seen within one week by the enlargement of the fruit.

Any non-crossed flowers on the female plants are removed to lessen the chance of contamination from selfed seeds before harvest.

2.6 Fruit Production

The number of hybrid fruits produced per plant depends on the fruit size of the maternal parent. Maintain 30 fruits for large-fruited parent, 40 fruits for medium-fruited parent, 50 or more fruits for small-fruited parent.

Remove non-hybrids from female plant.

2.7 Harvesting

Tomato fruits ripen about 50-60 days after pollination, but may take longer if temperatures are cool.

Harvest when fruit is fully mature, preferably at pink or red ripe stage. This enables the seed to develop normally and fully.
If fruits are harvested at an earlier stage, place them in a covered, cool dry place for three or four days until they become red ripe. Only completely colored and matured seed fruits are harvested.

Collect in non metallic containers, such as nylon net bags, plastic buckets or crates. Metal containers may react with acids in the tomato juice and affect seed viability.

12. **SEED DRYING**

- Use mesh bags and hang them in open air
- Or
- Spin dry them in a washing machine
- Spread seeds in a container and put them in seed dryer for 3-4 days at 30 °C.

13. **SEED PACKAGING**

- Pack according to specifications seeds company or contract agency.
- Note the names of the hybrid and parents, the year, and any other information.
- Carefully label each container
- Store in cool dry place at 20°C and R.H. 65 %.

14. **SEED YIELD AND RECOVERY**

- Seed yield in case of round shaped varieties is 125-150 kg/ha while 75-100 kg/ha in pear shaped varieties.
- Seed recovery is more in care of round shaped varieties, less in case of pear shaped varieties and higher in case of cherry tomatoes.

15. **SEED REPLACEMENT RATE**
Seed Replacement Rate is the rate at which the farmers replace the seeds instead of using their own seeds.

Seed Replacement Rate is the percentage of area sown out of total area of crop planted in the season by using certified/quality seeds other than the farm saved seed.

Ideally seed should be replaced every year for hybrids and every three to four years for non-hybrids.

In tomato SRR is 99.3%.

16. SEED MULTIPLICATION RATIO

It is nothing but the number of seeds to be produced from a single seed when it is sown and harvested.

\[ \text{SMR} = \frac{\text{Seed Yield}}{\text{Seed Rate}} \]

In tomato SMR is 1:100.

17. SEED EXTRACTION METHODS

The fruits from first and last one or two harvests should not be used for seed extraction.

The fruits from in between 6-7 harvest should be used for seed extraction.

The seed viability is depends on the method on which the seeds were extracted and hence, it is more important to choose proper methods of seed extraction.

Before seed extraction, the fruits are to be graded for true to type and selection of medium to large size fruits for getting higher recovery of quality seeds.

A. FERMENTATION METHOD

Selected ripe fruits are harvested and kept in wooden or plastic containers for two to three days until the fruits become soft.

Then crushed by hand and no fruit juice is allowed to drain out.
Entire mass is kept as such for 24 to 72 hours depending upon temperature.

- Flesh will float at the top and seed will settle down at the bottom.
- The fermented mass is removed and the seeds are sieved and cleaned with fresh clean water and dried.
- Longer fermentation may damage the seed.

B. ALKALI METHOD

- Separation With Sodium Carbonate (Washing soda)
  - This method is relatively safe and can be used for small quantities of seed in cooler temperate areas where the fermentation method is not used.
  - The pulp containing the extracted seeds are mixed with equal volume of a 10 percent solution of sodium carbonate.
  - The mixture is left up to two days at room temperature after which time the seed is washed out in a sieve and subsequently dried.
  - The sodium carbonate method of extraction tends to darken the testa of the seed and is, therefore, not normally used for commercial seed.

C. ACID EXTRACTION METHOD

- The acid method of seed extraction is the best method for tomato seed extraction.
  - In this method, the fruits are to be crushed into pulp and taken in a plastic containers (or) cement tank.
  - And then add 30 ml of commercial Hydrochloric acid per kg of pulp, stir well and allow it for ½ hour.
  - In between this duration the pulp may be stirred well for one or two times. This facilitates the separation of seed and pulp.
  - After ½ hour, the seeds will settle down at the bottom and then the floating fraction is to be removed.
The collected seeds should be washed with water for three or four times.

**SEED CERTIFICATION STANDARDS**

**Field Standards**

1. **General requirements**

a.i. **Isolation (Open pollinated varieties)**

<table>
<thead>
<tr>
<th>Contaminants</th>
<th>Minimum (meters)</th>
<th>Distance</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>Certified</td>
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<td>2</td>
<td>3</td>
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<td>not conforming to varietal</td>
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<tr>
<td>purity requirements for</td>
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<td></td>
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<tr>
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a.ii. **Isolation (Hybrid varieties)**

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<td>certification</td>
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Between blocks of parental lines 5

**Specific requirements**

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<th>Factor</th>
<th>Maximum permitted (%)*</th>
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<tr>
<td>Off-types</td>
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<tr>
<td><strong>Plants affected by seed borne disease</strong></td>
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</table>

*Maximum permitted at final inspection.

**Seed borne diseases shall be:

Early blight (*Alternaria solani* Sorauer).

Leaf spot (*Stemphylium solani* Weber.)

Tobacco Mosaic
Specific Requirements (Hybrids)

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<td><strong>Plants affected by seed borne disease</strong></td>
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<tr>
<td><strong>Seed borne diseases shall be:</strong></td>
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<tr>
<td>Early blight (<em>Alternaria solani</em> Sorauer).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaf spot (<em>Stemphylium solani</em> Weber.)</td>
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<tr>
<td>Tobacco Mosaic Virus (TMV)</td>
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Seed Standards

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<th>Factor</th>
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<tr>
<td>Other crop seeds (maximum)</td>
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<tr>
<td>Weed seeds (maximum)</td>
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<tr>
<td>Germination (minimum)</td>
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<tr>
<td>Moisture (maximum)</td>
<td>8.0%</td>
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<tr>
<td>For vapour-proof containers (maximum)</td>
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</table>
FIELD INSPECTION STAGES

Inspection stages for Open pollinated varieties

- Vegetative- Isolation, volunteer plants.
- Flowering – Isolation, off types
- Maturity and pre- harvest – Isolation off types, designated diseases.

Inspection stages for Hybrid

- Vegetative – Isolation, volunteer plants, out crosses, planting ratio.
- Flowering – Isolation, off types, pollen shedding cymescin in case of male sterile line used, accuracy in emasculation.
- Maturity and pre- harvest – Isolation, off types, designated disease.

REFERENCES


Seed Processing, Packaging, Labelling and Storage

Manish K Sharma and Cherry Nalwa

Department of Seed Science and Technology

Dr YS Parmar University of Horticulture and Forestry

Nauni, Solan (HP)

Introduction

Seed processing, packaging and storage are integral components of the technology involved in transforming the genetic engineering of the plant breeder into a supply of improved seed. Adequate provisions for establishment of necessary capabilities in these areas must be included in seed program development plans from the very beginning. Traditional practices of seed processing, packaging and storage are not adequate for the needs in a developing seed program of any substantial scope. Seed lots received from the field are often at high moisture content and contain trash and other inert materials (Agrawal RL, 2013). Major function of seed processing is to remove or minimize seed contaminants to a level that meet the minimum seed certification standards. The objective of seed processing is to achieve clean and pure seeds of high Physical quality which can be stored and easily handled during succeeding process. The ultimate aim of seed processing is to improve the real value/planting value of the seed. Seed processing lowers the cost of further processing and storage including transport, increase the longevity of the seeds drying and treatment, reduces the variability in vigour by invigorating the seeds and removing the low vigour seeds and improve the uniformity in seed shape or size by grading or by pelleting (Khare D and Bhale MS, 2014).
Seed processing plant layout and planning

Layout plan should be planned carefully to ensure thorough seed cleaning, upgrading, seed treatment without mixing and damaging seed lots (Padmavati S, 2012).

Factors in planning and designing a SPP

✔ Kind of crop seeds to be handled and kind of contaminating crops and weed seeds usually present in the seed lots

✔ Size of operation

✔ Whether drying facilities should be required

✔ Selection of suitable equipments

✔ Location of the plant

✔ Source of power for running machinery

✔ System of seed delivery to the processing plant

✔ Availability of labour

Improvement in physical quality of seed lot by removal of undesirable material and upgrading of seed quality through removal of damaged and undersized seed with highest efficiency is defined as seed processing. It involves drying, pre-conditioning, basic cleaning and grading as major steps.

Drying of seed

It is the most important factor in influencing the longevity and germination percentage of seed. Two common methods are sun drying and forced air drying.

Seed Cleaning

Major operations

• Pre conditioning or pre cleaning operations
• Basic seed cleaning operations
• Upgrading the quality of cleaned seed

**Preconditioning and pre-cleaning**

Common equipments

• Scalper and rough cleaners- Large trash
• Huller scarifier
• De beader
• Pebble mill
• Maize Sheller

**Basic Seed Cleaning**

Three cleaning elements

• Aspiration
• Scalping
• Grading

**The separations can be broadly grouped into following**

1. Dimensional separations (Length, width & thickness)
2. Gravity or weight separations (Density separators)
3. Air separations
   • Pneumatic separators
   • Aspirator separators
4. Surface texture separations
5. Electronic separations
6. Other separations

- Spiral separation
- Electric separation
- Vibratory separation

**Seed Treatment**

Seed treatment refers to exposing the seeds to certain agents, physical or chemical or biological, which are able to protect them from pests and provide good health to the seed and emerging plant.

**Mainly three types**

1. Physical treatments (Temperature treatments)
2. Biological treatments
3. Chemical treatments (Seed dressing & fumigation)

**Seed Packaging or labeling**

Seed packaging or bagging is essentially the last operation before storage or marketing. After processing and treatment, seeds are packaged into containers of specified net weight (Vanangmudi, 2014). The packaging consists of the following operations:

- 1. Filling of seed bags/ containers to an exact weight.
- 2. Placing leaflets in the seed bags/ containers regarding improved cultivation practices
- 3. Attaching labels, certification tags on the seed bags / containers, and closing them.
- 4. Storage/shipment of seed bags / containers.

**Types of packaging material**

1. Moisture vapour permeable container
e.g., jute bag, cloth bag, paper bag, multiwall paper bag, non-wooven bags

2. **Moisture vapour resistant container,**

e.g., jute bag laminated with thin polythene film, polythene bags (200-300 gauge)

3. **Moisture vapour proof container,**

e.g. tin can, polythene bags (>700 gauge), aluminium foil pouches, glass bottles

**Labeling**

All seed bags/containers must carry information about

1. Crop
2. Variety
3. Class of seed
4. Address of the producer

Bags/containers should be labelled with tags according to the class of seed.

Seed tag should contain information about

1. Physical purity (%)
2. Genetic purity (%)
3. Moisture (%)
4. Germination (%)
5. Date of test

**Seed Storage**

Seed storage is the “preservation of seed with minimum loss in viability and vigour until needed for sowing”. The importance of seed
storage has been recognized ever since humans began to domesticate plants. The duration of successful storage depends upon both the objectives and the species concerned. The objective of seed storage is to maintain the seed in good physical and physiological condition from the time they are harvested until the time they are sown.

Harrington suggested the following thumb rules regarding optimum storage conditions.

1. For every 1% reduction in seed moisture the storage life of seed doubles.
2. For every 10°F reduction in temperature doubles the life span of the seed.
3. The sum of relative humidity in percentage and temperature in F should not exceed 100.

The thumb rule applies only when the seed moisture is in between 5 and 14% and temperature 32 to 87°F.

Classification of seed based on storage potential

1. Orthodox Seeds:

Orthodox seeds are long-lived seeds. They can be successfully dried to moisture contents as low as 5% without injury and are able to tolerate freezing temperatures.

2. Recalcitrant Seeds:

They are short-lived seeds. They cannot be dried to moisture contents below 30% without injury and are unable to tolerate freezing. They are difficult to store successfully because of their high moisture content encourages microbial contamination and results in more rapid seed deterioration. These seeds are from perennial trees in the moist tropics such as coconut, coffee, cacao, citrus etc.

3. Intermediate seeds:

A third category intermediate between orthodox and recalcitrant categories has been identified. They tolerate drying to around 40-50% eRH (~8%mc) and generally lose viability more rapidly at low temperature
and do not withstand storage at -20°C. e.g. *Coffea arabica, Azadirachta indica*

**References:**


Seed Production of Leguminous Vegetable Crops

Amit Vikram
Department of Vegetable Science
YSP University of Horticulture & Forestry
Nauni, Solan (HP)

Peas (*Pisum sativum*, 2n = 14) and Snap Beans (*Phaseolus vulgaris*, 2n = 22) are the two major leguminous vegetables. Both the crops are a major source of dietary protein in human diet. The seed production technology of these crops is described below in brief:

**Peas**

- India
  - Area: 5,40,000 ha
  - Production: 5,252,000 mt
- Himachal Pradesh
  - Area: 24,000 ha
  - Production: 271,000 mt (NHB, 2017, 2015)

**Cultivar Groups**

**According to** Kelly (1988) various cultivar groups in peas are:

- **Vining peas**
  - Harvested while the seeds are still tender and are used for immediate freezing, or canning as ‘garden peas’.
- **Picking peas**
  - Grown as a horticultural crop for harvesting as a fresh vegetable, also harvested while the seeds are still tender. Some cultivars in this group have tender pods which are consumed complete with immature seeds (frequently referred to as ‘mange tout’).
- **Combining peas**
  - Harvested for their dry seeds. This group has two main uses for human consumption, used either for the production of canned
‘processed peas’ or as dried peas. The other purpose is for animal fodder.

- **Forage peas**
  - Used for animal grazing, silage or haymaking.

**Cultivar Description**
- Season of use and suitability for specific purpose, e.g. processing, fresh use
- Seed: round or wrinkled, relative size, colour (influenced by colour of testa and cotyledons which are recorded separately).
- Plant height: number of nodes to first flower.
- Stem: presence or absence of pigmentation, degree of fasciation.
- Leaf: leaflets, relative size, colour, marbling.
- Stipules: developed or vestigial.
- Flower: number per raceme, colour.
- Pod: relative colour, length, shape, form at tip (apex), degree of parchment.
- Resistant to *Erysiphe pisi*, *Fusarium oxysporum* and *Ascochyta pisi*, Seed-Borne Mosaic Virus (SbMV), Bean Yellow Mosaic Virus (BYMV) and Pea Enation Mosaic Virus (PEMV)

**Pea Plant Types**
- Three kinds of plant growth habits
  - Dwarf
  - Intermediate
  - Tall
- No. of node at which flower initiation occurs is nearly constant for a given genotype
  - Early cultivars initiate flowering from node 5 – 11
  - Later cultivars flower from 13-15 nodes
  - Very late cultivars flower beyond 25 node

**Floral Biology**
Stigma receptive from several days prior to anthesis to one day after wilting of flower. Highly self-pollinated crop less than 1% cross-pollination. In South Americas cross-pollination up to 60% reported due to insects such as
Paratrigona lineata. However, elsewhere crop is cleistogamous and pollination takes place one day before anthesis. Pollen germinates in 8-12 hrs after pollination and fertilization occurs 24-28 hrs after pollination (Gritton & Wierzbicka, 1975)

**Land Requirements**
- Land to be used for seed production of pea shall be free of volunteer plants.

**Field Standards**
- **General**

<table>
<thead>
<tr>
<th>Contaminants</th>
<th>Minimum distance (meters)</th>
</tr>
</thead>
<tbody>
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<td></td>
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<tr>
<td>Fields of other varieties</td>
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</tr>
<tr>
<td>Fields of the same variety not conforming to varietal purity requirements for certification</td>
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- **Specific**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Maximum permitted (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Foundation</td>
</tr>
<tr>
<td>Off-types</td>
<td>0.10</td>
</tr>
</tbody>
</table>

**Climate for Seed Production**
- Seed peas are adapted to regions with
  - A relatively cool growing season,
  - Comparative freedom from diseases, insects, and spring frosts,
  - Ample moisture either from rain or irrigation, and
  - A relatively dry atmosphere at harvesting time.

Peas grow best in those areas where there is a slow transition from cool to warm weather in the spring

**Soil**
- Peas may be grown on a wide range of soils provided they are well drained and fairly retentive of moisture.
• A moderately rich, clay-loam soil is preferred for peas produced on irrigated soils.
• On non-irrigated land, heavier soils having a high water-holding-capacity are more desirable.
• Peas are grown on soils with a pH 5.5–6.5

Seed Rate
• Early Cultivars: 120-150 kg/ha
• Mid-Late Cultivars: 60-75 kg/ha

Spacing
• Early Cultivars: 30 x 7.5 cm
• Mid-Late Cultivars: 60 x 7.5 cm

Nutrition
• FYM: 20 tonnes per hectare
• Nitrogen: 25 kg/ha
• Phosphorous: 60 kg/ha
• Potash: 60 kg/ha

Manganese deficiency can be a serious problem which causes a disorder Marsh Spot. Brownish hollow centres in the cotyledon seen when unripe seeds are split open. Manganese sulphate is included in base dressings at a rate of 40–100 kg/ha where manganese deficiency is known to occur. Alternatively, Manganese Sulphate is applied as a foliar spray at a rate of 10 kg/ha in 200–1000 litres of water as soon as the symptoms are diagnosed.

Irrigation
• Apply water regardless of plant size if they turn a bluish or bluish-grey colour, thus showing signs of drought.
• Moisture-sensitive stage from the start of anthesis until petal fall.
• Over irrigation may result in heavy plant growth, which is not desirable in the production of seed peas.
• Late irrigation should be avoided because the plants tend to lodge and some rotting of the vines may occur if the soil is kept too wet.

Roguing
The term rogue has been used to mean a particular degenerate type of pea plant having narrow stipules and leaflets which was also called rabbit-ear
rogue. The term rogue as used today, however, applies to any off-type plant. Rogues may originate as a result of mechanical mixture, volunteer mixtures from earlier plantings, natural crossing, or as morphological changes caused by mutations.

- Rogues originating from mechanical or volunteer mixtures that have a different seed colour or maturity may be of considerable concern to processors.
- Mechanical mixtures can be avoided by the use of clean equipment, clean sacks, and by precautions against mixing varieties when the seed is produced.
- Volunteer mixtures can be prevented by sowing peas only on land not planted to peas the previous year.

**Roguing Stages**

- **After emergence** (when plants are approximately 15 cm high): remove the taller off-types. For basic seed production particular attention is given to checking that foliage, including stipules, is typical of the cultivar.

- **Flowering**: remove early flowering plants from late flowering cultivars, check flower colour and remove any plants with flower colour which is not true to type. Check flower number per node.

- **Pods formation**: check that pod shape, size and colour are typical of the cultivar; remove late flowering plants; remove non- or low-yielding plants.

**Harvesting**

The crop may be harvested from the time the peas become hard in the pod up to the time they have become completely mature. Approximately 30 days are required after the peas have reached their green stage until they are sufficiently mature to germinate. A common test for maturity is to squeeze the pea seed between the fingers, and if the cotyledons break away from each other and no free moisture is visible, the crop is mature enough to be cut.

Seed quality is reduced if seeds are harvested when their moisture content is above 30–36% (Biddle and King, 1977). Mature seed with a
moisture content of 12% or less is subject to mechanical damage (George, 2009).

**Seed Yield**

The average yield of a pea seed crop is approximately 20 q/ha. The 1000 grain weight varies from the small to the larger seeded types. It is 330 g for the larger seeded types to 150 g for the smaller ones.

**Seed Standards**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Standards for each class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Foundation</td>
</tr>
<tr>
<td>Pure seed (minimum)</td>
<td>98.0%</td>
</tr>
<tr>
<td>Inert matter (maximum)</td>
<td>2.0%</td>
</tr>
<tr>
<td>Other crop seeds (maximum)</td>
<td>None</td>
</tr>
<tr>
<td>Weed seeds (maximum)</td>
<td>None</td>
</tr>
<tr>
<td>Other distinguishable varieties (maximum no.)</td>
<td>5/kg</td>
</tr>
<tr>
<td>Germination including hard seeds (minimum)</td>
<td>75%</td>
</tr>
<tr>
<td>Moisture (maximum)</td>
<td>9.0%</td>
</tr>
<tr>
<td>For vapour-proof containers (maximum)</td>
<td>8.0%</td>
</tr>
</tbody>
</table>

**Beans**

- India
  - Area: 2,30,000 ha
  - Production: 2,408,000 mt
- Himachal Pradesh
  - Area: 3,750 ha
  - Production: 46,370 mt (NHB, 2017, 2015)

**Plant Types**

I Determinate Bush,
II Indeterminate Bush,
III Indeterminate straggling,
IV Indeterminate, Climbing (Debouck and Hidalgo, 1984)

**Cultivar description**

- Season and use: flowering and cropping season, suitability for specific market outlets, e.g. green, processing or dried, suitability for mechanical harvesting.
- Seed: relative length, testa colour and patterning, bars or mottle, if bicoloured, shape resistance to mechanical damage.
- Plant habit: dwarf or climbing, bush types degree of branching.
- Leaf: colour, shape, texture, size.
- Flower: colour of standard; colour of wing.
- Pod: length, including beak character, shape of transverse section (through seed).
- Seed: weight, size, shape, colour.
- Resistance to Bean Common Mosaic Virus, Bean anthracnose, Halo blight and Common blight.

**Floral Biology and Pod Development**

The anthers dehisce just before anthesis. Fertilization occurs within 12 hrs of pollination. Cultivars take about 25 days from pollination to green tender stage and Another 20-30 days, thereafter, to ripe pod or dry seed stage. Modern cultivars do not have the strings. Stringless pod is a recessive trait. Suppression of lignification of pod wall tissue is another development which has extended the period of edibility of pods.

Determinate cultivars (type I) develop flower primordia in the axil of the uppermost leaf of the main stem and flowering then proceeds downwards. Indeterminate Bush (type II) cultivars, first flowers normally open from node 6-7 and then flowering proceeds upwards and downwards Resource allocation is towards earlier formed pods. Hence, later formed flowers are dropped. Even under optimum conditions 60-70 % of the flowers and young pods are shed by plants. This tendency increases uniform pod set and is being selected for by the breeders.
Land Requirements
- Land to be used for seed production of beans shall be free of volunteer plants.

Field Standards
- General

<table>
<thead>
<tr>
<th>Contaminants</th>
<th>Minimum distance (meters)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Foundation</td>
<td>Certified</td>
<td></td>
</tr>
<tr>
<td>Fields of other varieties</td>
<td>10</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Fields of the same variety not conforming to varietal purity requirements for certification</td>
<td>10</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

- Specific

<table>
<thead>
<tr>
<th>Factor</th>
<th>Maximum permitted at the final inspection (%)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Foundation</td>
<td>Certified</td>
<td></td>
</tr>
<tr>
<td>Off-types</td>
<td>0.10</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td><strong>Plants affected by seed borne diseases</strong></td>
<td>0.10</td>
<td>0.20</td>
<td></td>
</tr>
</tbody>
</table>

**Seed borne diseases shall be:
Bacterial blight (*Xanthomonas* spp.)
Anthracnose (*Colletotrichum lindemuthianum* (Sacc. & Magn.) Br. & Cav.)
Ascochyta blight (*Ascochyta phaseolorum* (Sacc.) Michelia) (for hill areas only)
Bean mosaic (*Macrosiphum pisi* Kalt.)

Climate for Seed Production

Though beans are a warm-season crop, they do not thrive where temperatures are extremely high. A monthly mean temperature of 65° to 75° F. (18.3° to 23.9° C.) is best for the crop. Hot days at blossoming time may result in a loss in yield due to dropping of blossoms. Cool, humid, and rainy weather is also unfavourable. The plants are not tolerant to frost or to prolonged weather that is near freezing. Even though seed crop of some
varieties matures in approximately 90 days, most varieties require a growing season of between 120 and 130 days. Beans are not resistant to drought, but some varieties are able to withstand short dry periods better than others.

**Soil**

The soil for the crop should be fertile, well-drained, and of such a nature that it will not interfere with the germination and emergence of the seedlings. *Phaseolus vulgaris* tolerates slightly acid soil conditions. Soils with a pH 5.4–6.5 are suitable.

**Seed Rate**

- **Bush Cultivars:** 75 kg/ha
- **Climbing Cultivars:** 30 kg/ha

**Spacing**

- **Bush Cultivars:** 45 x 15 cm
- **Climbing Cultivars:** 90 x 15 cm

**Nutrition**

- **FYM:** 20 tonnes per hectare
- **Nitrogen:** 50 kg/ha
- **Phosphorous:** 100 kg/ha
- **Potash:** 50 kg/ha

**Irrigation**

Beans are shallow-rooted and sensitive to an oversupply of water. Frequently good crops are produced with very little moisture applied during the Season. The land should be furrowed uniformly and deeply enough to prevent flooding and to keep the vines out of the water. Reduced yields may result from improper use of water. As a rule it is advisable to use light irrigations, because heavy application not only waste water but may result in excessive vine growth and may delay maturity. Water may be applied in every furrow or every other furrow, depending upon the rate of lateral penetration of the soil.

**Roguing**

It is highly important to rogue stock-seed plantings carefully to maintain their purity. More crossing occurs in this crop than in peas, a fact which tends to increase the number of off-types which must be removed.
Characters Such as pod type, plant type, and foliage colour should be carefully checked.

**Roguing Stages**

- **Before flowering:** check plant habit, vigour and height according to type; check foliage, leaf shape and colour.
- **At onset of flowering:** check plant vigour and flower colour; remove plants showing symptoms of seed-borne pathogens.
- **Seed set and first pods formed:** check pod characters, including shape and colour; remove late flowering off-types and plants showing symptoms of seedborne pathogens.

**Harvesting**

The dwarf or bush types are generally considered to be ready for a once-over harvest when the earliest pods are dry and parchment-like, and the remainder of the pods have turned yellow. The seeds’ moisture content at the time of harvesting should be between 20 and 25%. Seed maturity is confirmed by opening sample pods, wherein the seeds should be fully developed with a mealy texture.

**Seed Yield**

The seed yield is 15q/ha although under ideal production and harvesting conditions yields may be up to 20 q/ha. The 1000 grain weight for *Phaseolus vulgaris* is 250 g. Although this can be up to 600 g in the smaller seeded cultivars.

**Suggested Reading**

Prospectus and constraints in vegetable seed production of India

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Indian seed industry has been growing awfully in quantity and value over the past fifty years. Both public and private sector corporations/companies are actively involving in quality seed production. The public sector component comprises National Seeds Corporation (NSC), State Farm Corporation of India (SFCI) and 15 State Seeds Corporations (SSCs) (APEDA, 2013 and Nandi et al, 2013), Indian Council of Agricultural Research (ICAR) institutions and State Agricultural Universities. ICAR launched an All India Coordinated Research Improvement project (AICRP) on seed production called National Seed Project in 1979 with 14 centres in different Agricultural Universities (Nandi et al., 2013). AICRP on production of breeder seed in vegetable crops is started under National Seed Project in 1994. Twenty two State Seed Certification Agencies and 104 State Seed Testing Laboratories are involving in quality control and certification (Nandi et al., 2013). The private sector comprises around 150 seed companies of national and foreign origin.

The Indian public sector seed industry used to dominate the private sector in the very beginning. The order of type of seeds dominating the market in terms of quantity and value has been open-pollinated varieties followed by public hybrids and private hybrids (APEDA, 2013). The situation is quite reversed currently. Seeds of the private hybrids are forming a significant portion of the total vegetable seed market. The availability of vegetable seeds with NSC as on 2013 is 133.43 t of which 131.68 t of varietal seeds and only 1.75 t of hybrid seeds. Due to new seed policy in 1988, the business of private seed companies taken a new height. Now a day the public sector is mostly confined to certified seeds of high volume, low value segment of high yielding
varieties of cereals, pulses and cotton with a limited presence in the high value hybrid sectors of cotton and cereals (APEDA, 2013 and Kumar et al., 2011).

In vegetables most of the public sector varieties and hybrids are replaced by private sector varieties and hybrids, seed production of which is solely done by the particular manufacturers. Corporate seed firms are mainly concentrating on vegetables like tomato, cabbage, brinjal, chilli, okra and cucurbits where the seed production of OPVs and hybrids is comparatively easy and more profitable. Private seed corporations are spending 10-12% of their turnover in R&D. Medium sized seed companies annual investment in R&D is growing 20% annually (Anonymous, 2013 and APEDA, 2013). The gargantuan seed manufacturers with multinational base can assemble germplasm from any part of the world which cannot be done by the public sector institutions in easy way. As germplasm serves invaluable resource for any crop improvement programme, this makes the big difference. Moreover, these mega seed giants employ paramount technical personnel with opulence and extravagance, which can never be done by the public sector institutions.

At present Indian seed industry is the fifth largest seed market in the world accounting for 4.4% global seed market after US, China, France and Brazil. Indian seed market has grown at 12% rate where the growth rate of global seed market is 5% (Vanitha et al., 2013) while the Indian vegetable seed market is growing at a rate of 10-15% in a year. There has been an increase of 194% in Indian vegetable hybrid seed market during 1998-2008 (Kumar et al., 2011). The estimated turnover of Indian seed industry (50000 m Rs.) is four percent of the global seed turnover (1250000 m RS.) (Kumar et al., 2011). The vegetable seed business in India, at present, amounts for 9000 million Rs. accounting for 18% value wise share of different crops in Indian seed business (Kumar et al., 2011). In future, according to National Seed Association of India (NSAI), the size of Indian seed market is expected to grow at a rate of 11% p.a. to $3.2 bn till FY 2016 on account of favourable global grain supply demand fundamentals, grain productivity well below world’s major grain producing regions and government’s continued focus on improving seed replacement rate.

**Factors promoting vegetable seed industry in India**
1. Ever Increasing Demand: The worldwide production of vegetables has doubled over the past quarter century and the value of global trade in vegetables now exceeds that of cereals. India is emerging as the second largest producer of vegetables (17.3 t/ha) after China (22.5 t/ha). In the past two decades, the vegetable production in India has been increased 2.5 times from 58.5 m t in 1991-92 to 146.5 m t in 2010-11 (Koundinya et al., 2014). Increase in yield is mainly attributed to expanding areas under high yielding vegetable varieties and hybrids. Total cultivated area under vegetables has been increased from 5.59 m ha in 1991-92 to 8.49 m ha in 2010-11 (Koundinya et al., 2014). Finally, it leads to ever increasing demand for the quality vegetable seed. Moreover, the yield of crops are higher when produced from and replaced seeds than own saved seeds (Table-1). Seed replacement rates are high for vegetables like cabbage (100%), tomato (99.3%) compared to other cereals and oil seeds (Mazumdar, 2012). Total quantity of vegetable seeds produced in the country is not sufficient to meet the country’s ever increasing demand. Currently quality seeds are met to the extent of 20% only. Framers themselves meet the 75% through own saved seeds (Nandi et al., 2013). India is still importing the vegetable seeds from other countries major being radish followed by cabbage and pea (Sudha et al., 2006). India has imported 1525.38 t vegetables seed valuing 1503.1 m Rs. in the year 2007-08 (Table 2) (Sudha et al., 2006).

2. Varied Agro Climatic Conditions: India is blessed with assorted agro climatic conditions ranging from tropical to temperate which make possible the cultivation and seed production of all most all vegetables belonging to different temperature regimes. Seed production of warm season vegetables is possible in Indian plains and Deccan Plateau and seed production of winter vegetables like cabbage, cauliflower, broccoli, beetroot, European carrot and radish is possible in hill stations of Himalayan range. Some winter vegetables like Onion, Asiatic Carrot, Asiatic Radish and tropical cauliflower produce seeds during winter season in North Indian Plains and Solanaceous vegetables, Cucurbits and Legumes set seeds throughout the year under South Indian conditions (Prasad et al., 2009).
3. **Cheap labour availability:** Vegetable seed production particularly hybrid seed production demands much labour. Labour is needed for performing various cultural operations. Though mechanization reduces the human effort up to some extent, high cost fuel and energy limitations reduce full scale mechanization. Moreover, emasculation and pollination steps during hybrid seed production of vegetables solely depend on human labour (Sharma, 2011). Smaller flower structure of some vegetables need more devotion of time and reduces human efficiency. These operations require specially trained and skilled labour. India is ranked second in hand pollinated vegetable seed production in Asia next to China (Prasad et al., 2009 and Hazra et al., 2006). Average number of man-days per acre required for hybrid seed production of various vegetables as follows: tomato-480; Chilli -1800; okra-180; brinjal-600; cucurbits -150 to 450 (Gadwal, 2003). India is having huge human resources availing at reasonably cheaper rates Prasad et al., 2009). This is attracting various corporate sectors of national and international origin to invest in seed business in India.

**Vast Domestic and International market:** Due to high profits in vegetable cultivation area under vegetable cultivation is expanding enormously year by year. This creates huge demand for vegetable seed in the market. Requirement of vegetable seed is increasing annually. Requirement of the seed of open pollinated varieties is increased to 48000 t in 2005 from 30550 t in 2001-02 and the requirement of hybrid vegetable seed is increased from 346.2 t in 2001-02 to 994 t in 2005 (Prasad et al., 2009 and Gadwal, 2003). This must have further increased due to increase in area to 8.49 m ha in 2010-11. Now a day hybrids are replacing the open pollinated varieties (OPV) largely due to higher yield, uniformity and their improved quality for instance India is second largest user of hybrid tomato seed after USA (Hazra et al., 2006). Vegetable seed exports consist of 70% of total seed exports (Hazra et al., 2006). Vegetable seeds of either OPV or hybrids from India are having cosmic demand in foreign countries like Pakistan, Bangladesh and Saudi Arabia. The percentage share of various countries importing fruit and vegetable seeds from India is showed in Fig 1 (DESDACMoA). The magnitude
of fruit and vegetable seed exports has been increased from 12302 m t in 2001-02 to 17174 m t in 2012-13.

**Influence of vegetable seed industry on economy**

1. **Income generation:** Seed production of vegetables is a highly remunerative business. Even from small land holdings very huge income can be generated. On an average the cost of seed production per acre of both OPV and hybrids ranges from 15000 to 30000 depending upon crop. In general 40-50 kg of OPV seed of tomato and brinjal can be produced from one acre land. Ten gram OPV seed of tomato and brinjal cost around 60-70 RS. in the market. When compared to OPVs hybrids fetch more price as the cost of hybrid seed production is more due to the involvement of more labour in crucial emasculation and pollination and also due to their higher yield than OPVs. Hybrid seed production of sweet pepper is highly remunerative generating an income of 136000 Rs. per 0.75 acre followed by hot pepper generating an income of 41500 Rs. per 0.25 acre (Prasad et al., 2009). The hybrid seed production of tomato is having a benefit cost ratio of 2.77 whereas it is 2.02 for okra under Karnataka conditions (Table 3) (Sharma, 2011). It does mean that for every single Rs. invested in hybrid seed production of tomato will fetch 2.77 Rs. to the farmer.

2. **Employment generation:** As discussed earlier seed production is a labour intensive task. On an average one million people are employed in vegetable seed production activity (Prasad et al., 2009). Hybrid seed production of tropical vegetables is leading to an employment generation of 2.71 million man-days annually generating a net income of 373 million RS. with the involvement of 10394 farm families (Hazra et al., 2006). Manual emasculation and crossing require skilled labour and it is very sensitive toil to perform. Hence, it is being performed mainly by women and young girls and they are being paid higher than other regular activities (Sharma, 2011). From an analysis based on Karnataka, it is apparent that emasculation and crossing have generated additional 313.6 and 276.89 working days (both male and female) in hybrid seed production of tomato and okra respectively (Table 4) (Sharma, 2011). Hybrid seed production of Solanaceous vegetables contribute
56.46% towards employment generation, followed by cucurbits 28.08% and okra 15.46% (Gadwal, 2003, Hazra et al., 2006 and Prasad et al., 2009). Since recent past contract seed production is largely being taken place where seed production by private firms is done in farmers’ fields. Corporate bodies are providing inputs to the farmers and their technical staffs periodically visits the seed production fields and provide necessary guidance to the farmers. Finally they purchase the produced seed back from the farmers. This reduces farmers risk and uncertainty in farming. So, huge number of farmers is showing interest in contract seed production. Approximately 0.17 million farmers are engaged in such contract seed production (Gadwal, 2003).

3. Foreign Exchange Earning: There is vast demand for vegetable seeds in the foreign countries. India is the ninth major exporter of fruit and vegetable seeds in the world there by earning good foreign exchange reserves. The major seed importing countries from India are Pakistan, Bangladesh, Saudi Arabia, Netherland and Korean Republic (APEDA, 2013). Fruit and vegetable seed exports consisted 3.37% of total horticultural exports from India in the year 2012-13 (DESDACMoA). Trends in fruit and vegetable seed exports from India over the past few years are presented in Fig 2. The foreign exchange generated through import of fruit and vegetable seeds have increased from 675 m Rs. in 2001-02 to 3477.2 m Rs. in 2012-13 (DESDACMoA).

Suggested Readings


Rules and regulations in Seed act for quality seed production

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Seed is the most important input for agricultural production. Efficacy of other agricultural inputs such as fertilizers, pesticides and irrigation is largely determined by the quality of seed. Seed quality accounts for 20-25% of agricultural productivity. It is therefore, important to ensure that the farmers of the country use quality seeds. The seed quality regime in the country is governed by the Seeds Act, 1966, the Seed Rules, 1968 made there under and the Seeds (Control) Order, 1983. In addition to these legal instruments, various guidelines and policy parameters have been laid down in the National Seeds Policy, 2002.

Various committees formed and their function in the seed act are:

(i) Central Seed Committee

The Central Government shall, as soon as may be after the commencement of this Act, constitute a Committee called the Central Seed Committee to advise the Central Government and the State Governments on matters arising out of the administration of this Act and to carry out the other functions assigned to it by or under this Act.

The Committee shall consist of the following members, namely:-

i Chairman to be nominated by the Central Government;

ii eight persons to be nominated by the Central Government to represent such interests that Government thinks fit, of whom not less than two persons shall be representatives of growers of seed;

iii one person to be nominated by the Government of each of the States.
The Committee may, subject to the previous approval of the Central Government, make bye-laws fixing the quorum and regulating its own procedure and the conduct of all business to be transacted by it.

The Committee may appoint one or more sub-committees, consisting wholly of members of the Committee or wholly of other persons or partly of members of the Committee and partly of other persons, as it thinks fit, for the purpose of discharging such of its functions as may be delegated to such sub-committee or sub-committees by the Committee.

The functions of the Committee or any sub-committee thereof may be exercised notwithstanding any vacancy therein.

The Central Government shall appoint a person to be the secretary of the Committee and shall provide the Committee with such clerical and other staff as the Central Government considers necessary.

**Power to notify kinds or varieties of seeds**

If the Central Government, after consultation with the Committee, is of opinion that it is necessary or expedient to regulate the quality of seed of any kind or variety to be sold for purposes of agriculture, it may, by notification in the Official Gazette, declare such kind or variety to be a notified kind or variety for the purposes of this Act and different kinds or varieties may be notified for different States or for different areas thereof.

**Power to specify minimum limits of germination and purity, etc.**

The Central Government may, after consultation with the Committee and by notification in the Official Gazette, specify-

- the minimum limits of germination and purity with respect to any seed of any notified kind or variety;

the mark or label to indicate that such seed conforms to the minimum limits of germination and purity specified under clause (a) and the particulars which such mark or label may contain.
Regulation of sale of seeds of notified kinds or varieties

No person shall, himself or by any other person on his behalf, carry on the business of selling, keeping for sale, offering to sell, bartering or otherwise supplying any seed of any notified kind or variety, unless-

a. such seed is identifiable as to its kind or variety;

b. such seed conforms to the minimum limits of germination and purity specified under clause (a) of section 6;

c. the container of such seed bears in the prescribed manner, the mark or label containing the correct particulars thereof, specified under clause (b) of section

(ii) Central Seed Laboratory and State Seed Laboratory

The Central Government may, by notification in the Official Gazette, establish a Central Seed Laboratory or declare any seed laboratory as the Central Seed Laboratory to carry out the functions entrusted to the Central Seed Laboratory by or under this Act.

The State Government may, by notification in the Official Gazette, establish one or more State Seed Laboratories or declare any seed laboratory as a State Seed Laboratory where analysis of seeds of any notified kind or variety shall be carried out by Seed Analysts under this Act in the prescribed manner.

(iii) Certification agency

The State Government or the Central Government in consultation with the State Government may, by notification in the Official Gazette, establish a certification agency for the State to carry out the functions entrusted to the certification agency by or under this Act.

Grant of certificate by certification agency

Any person selling, keeping for sale, offering to sell, bartering or otherwise supplying any seed of any notified kind or variety may, if he desires to have such seed certified by the certification agency, apply to the certification agency for the grant of a certificate for the purpose.
Every application under sub-section (1) shall be made in such form, shall contain such particulars and shall be accompanied by such fees as may be prescribed.

(3) On receipt of any such application for the grant of a certificate, the certification agency may, after such enquiry as it thinks fit and after satisfying itself that the seed to which the application relates conforms to the minimum limits of germination and purity specified for that seed under clause (a) of section 6, grant a certificate in such form and on such conditions as may be prescribed.

**Revocation of certificate**

If the certification agency is satisfied, either on a reference made to it in this behalf or otherwise, that-

a. the certificate granted by it under section 9 has been obtained by misrepresentation as to an essential fact; or

b. the holder of the certificate has, without reasonable cause, failed to comply with the conditions subject to which the certificate has been granted or has contravened any of the provisions of this Act or the rules made thereunder;

then, without prejudice to any other penalty to which the holder of the certificate may be liable under this Act, the certification agency may, after giving the holder of the certificate an opportunity of showing cause, revoke the certificate.

**Appeal**

Any person aggrieved by a decision of a certification agency under section 9 or section 10, may, within thirty days from the date on which the decision is communicated to him and on payment of such fees as may be prescribed, prefer an appeal to such authority as may be specified by the State Government in this behalf:
Provided that the appellate authority may entertain an appeal after the expiry of the said period of thirty days if it is satisfied that the appellate was prevented by sufficient cause from filing the appeal in time.

(2) On receipt of an appeal under sub-section (1), the appellate authority shall, after giving the appellant an opportunity of being heard, dispose of the appeal as expeditiously as possible.

(3) Every order of the appellate authority under this section shall be final.

Seed Analysts

The State Government may, by notification in the Official Gazette, appoint such persons as it thinks fit, having the prescribed qualifications, to be Seed Analysts and define the areas within which they shall exercise jurisdiction.

Seed Inspectors

The State Government may, by notification in the Official Gazette, appoint such persons as it thinks fit, having the prescribed qualifications, to be Seed Inspectors and define the areas within which they shall exercise jurisdiction.

Powers of Seed Inspector

The Seed Inspector may-

a. take samples of any seed of any notified kind or variety from-
   i. any person selling such seed; or
   ii. any person who is in the course of conveying, delivering or preparing to deliver such seed to a purchaser or a consignee; or
   iii. a purchaser or a consignee after delivery of such seed to him;

b. send such sample for analysis to the Seed Analyst for the area within which such sample has been taken;

c. enter and search at all reasonable times, with such assistance, if any, as he considers necessary, any place in which he has reason to believe that an offence under this Act has been or is being
committed and order in writing the person in possession of any seed in respect of which the offence has been or is being committed, not to dispose of any stock of such seed for a specific period not exceeding thirty days or, unless the alleged offence is such that the defect may be removed by the possessor of the seed, seize the stock of such seed;

d. examine any record, register, document or any other material object found in any place mentioned in clause (c) and seize the same if he has reason to believe that it may furnish evidence of the commission of an offence punishable under this Act; and

e. exercise such other powers as may be necessary for carrying out the purposes of this Act or any rule made thereunder.

(2) Where any sample of any seed of any notified kind or variety is taken under clause (a) of sub-section (1), its cost, calculated at the rate at which such seed is usually sold to the public, shall be paid on demand to the person from whom it is taken.

(3) The power conferred by this section includes power to break-open any container in which any seed of any notified kind or variety may be contained or to break-open the door of any premises where any such seed may be kept for sale:

Provided that the power to break-open the door shall be exercised only after the owner or any other person in occupation of the premises, if he is present therein, refuses to open the door on being called upon to do so.

(4) Where the Seed Inspector takes any action under clause (a) of sub-section (1), he shall, as far as possible, call not less than two persons to be present at the time when such action is taken and take their signatures on a memorandum to be prepared in the prescribed form and manner.

(5) The provisions of the Code of Criminal Procedure, 1898 (5 of 1898), shall, so far as may be, apply to any search or seizure under this section as they apply to any search or seizure made under the authority of a warrant issued under section 98 of the said Code.
Procedure to be followed by Seed Inspectors

Whenever a Seed Inspector intends to take sample of any seed of any notified kind or variety for analysis, he shall-

a. give notice in writing, then and there, of such intention to the person from whom he intends to take sample;

b. except in special cases provided by rules made under this Act, take three representative samples in the prescribed manner and mark and seal or fasten up each sample in such manner as its nature permits.

When samples of any seed of any notified kind or variety are taken under sub-section (1), the Seed Inspector shall-

a. deliver one sample to the person from whom it has been taken;

b. send in the prescribed manner another sample for analysis to the Seed Analyst for the area within which such sample has been taken; and

c. retain the remaining sample in the prescribed manner for production in case any legal proceedings are taken or for analysis by the Central Seed Laboratory under sub-section (2) of section 16, as the case may be.

If the person from whom the samples have been taken refuses to accept one of the samples, the Seed Inspector shall send intimation to the Seed Analyst of such refusal and thereupon the Seed Analyst receiving the sample for analysis shall divide it into two parts and shall seal or fasten up one of those parts and shall cause it, either upon receipt of the sample or when he delivers his report, to be delivered to the Seed Inspector who shall retain it for production in case legal proceedings are taken.

Where a Seed Inspector takes any action under clause (c) of sub-section (1) of section 14:

a. he shall use all despatch in ascertaining whether or not the seed contravenes any of the provisions of section 7 and if it is
ascertained that the seed does not so contravene, forthwith
revoke the order passed under the said clause or, as the case may
be, take such action as may be necessary for the return of the
stock of the seed seized;
b. if he seizes the stock of the seed, he shall, as soon as may be,
inform a magistrate and take his orders as to the custody thereof;
c. without prejudice to the institution of any prosecution, if the
alleged offence is such that the defect may be removed by the
possessor of the seed, he shall, on being satisfied that the defect
has been so removed, forthwith revoke the order passed under
the said clause.

(5) Where as Seed Inspector seizes any record, register, document or any other
material object under clause (d) of sub-section (1) of section 14, he shall, as
soon as may be, inform a magistrate and take his orders as to the custody thereof.

Report of Seed Analyst

(1) The Seed Analyst shall, as soon as may be after the receipt of the sample
under sub-section (2) of section 15, analyse the sample at the State Seed
Laboratory and deliver, in such form as may be prescribed, one copy of the
report of the result of the analysis to the Seed Inspector and another copy
thereof to the person from whom the sample has been taken.

(2) After the institution of a prosecution under this Act, the accused vendor
or the complainant may, on payment of the prescribed fee, make an
application to the court for sending any of the samples mentioned in clause
(a) or clause (c) of sub-section (2) of section 15 to the Central Seed Laboratory
for its report and on receipt of the application, the court shall first ascertain
that the mark and the seal or fastening as provided in clause (b) of sub-section
(1) of section 15 are intact and may then despatch the sample under its own
seal to the Central Seed Laboratory which shall thereupon send its report to
the court in the prescribed form within one month from the date of receipt of
the sample, specifying the result of the analysis.
(3) The report sent by the Central Seed Laboratory under sub-section (2) shall supersede the report given by the Seed Analyst under sub-section (1).

(4) Where the report sent by the Central Seed Laboratory under sub-section (2) is produced in any proceedings under Section 19, it shall not be necessary in such proceedings to produce any sample or part thereof taken for analysis.

During the last four decades, seed production technology has changed and new technologies like transgenic, tissue culture, soil-less agriculture etc. have emerged. There is greater emphasis on seed quality assurance particularly to safeguard the interest of the farmers. In addition, significant changes have occurred in the country’s socio-economic conditions. The economy has been substantially liberalised and the private sector is playing an increasing role in various spheres including agriculture. India is also increasingly engaged with the rest of the world through Organization for Economic co-operation and development (OECD) and International Seed Testing Association (ISTA), etc. In the liberalized and changed environment, imports and exports of seeds and planting materials into the country have increased. These ongoing changes require upgradation of seed production, quality and regulatory standards. Therefore, a need has arisen for updating the seed quality regulatory regime by enacting a new legislation.

**Scope of the Seeds Bill, 2004**

Seeds Bill, 2004 covers all the crops and varieties of agricultural, horticultural, forestry, plantation, medicinal and aromatic plants. With respect to fruit nurseries, the Bill proposes compulsory registration of fruit nursery of above one hectare area with State Governments.

**Objectives of The Seeds Bill, 2004**

The objectives of the Seeds Bill, 2004 are to regulate the quality of seeds and planting materials of all agricultural, horticultural and plantation crops to

i. Ensure availability of true to type seeds for Indian farmers

ii. Curb the sale of spurious and poor quality seeds
iii. Protect the rights of farmers, increased private participation in seed production
iv. Distribution and seed testing
v. Liberalize imports of seeds and planting materials, etc.

**Status of Seeds Bill, 2004**

The Seeds Bill, 2004 was introduced in the Rajya Sabha in December, 2004. Thereafter, it was referred to the Parliamentary Standing Committee on Agriculture on 16th December, 2004. Parliamentary Standing Committee on Agriculture submitted the report on 12th October, 2006. The Bill is now pending in Rajya Sabha.

**The Seeds Bill, 2004 mainly seeks to advance the following objectives:**

i. Enhance the quality of seeds marketed in the country by mandated compulsory registration of varieties.

ii. It enhances penalties for offences, compared to the existing Seeds Act 1966.

iii. It makes provision for labelling of expected performance of seeds and also provides for compensation to farmers in case of seed failure.

iv. It adds seed health as an additional standard for seed quality

v. It brings conformity with existing National Laws and regulations, especially those relating to the import and export of seeds and use of Genetically Modified seeds

vi. It imposes a ban on the use of Genetic Use Restriction Technology (GURT).

vii. It provides for registration of seed producers, seed dealers and seed processing units.

viii. Farmers’ Rights: The Bill proposes to emphasize the rights of the Farmers in conformity with the PPV & FR Act, 2001. The farmer will have the right to save, use, sow, re-sow, exchange, share or sell his farm seeds and planting materials except when he sells such seeds or
planting material under a brand name. However, the farmers will be exempted from compulsory registration of varieties/nurseries.

**SALIENT FEATURES:**

i) **Compulsory registration of varieties:** No person will be allowed to carry on the business of selling or supplying any seed which is not of a registered kind/variety. Farmers are to be exempted from compulsory registration.

ii) **Period of registration:** 10 years for annual & biennial crops and 12 years for long duration perennials. Re-registration for a like period after re-establishment of performance in the multi-location trials.

iii) **Registration of transgenic varieties:** Registration of transgenic varieties will be subject to environmental clearance from MOEF&CC under the Environmental (Protection) Act, 1986 and Rules 1988 made there under.

iv) **Enhancement of penalties:** It is proposed to enhancement of penalty from Rs. 500/- Rs. 1000/- with or without imprisonment in the Seeds Act 1966 to Rs. 25,000/- Rs. 5,00,000 with or without imprisonment.

v) **Expected performance:** Provision for labelling of expected performance of seeds has been included so that the farmers are assured of quality of seeds purchased by them.

vi) **Compensation to the farmers on seeds failure:** Provision for compensation to the farmer in case of seed failure has been made.

vii) **Farmers’ rights:** The bill proposes to emphasise the rights of farmers in conformity with the PPV&FRA (PPV&FR Act, 2001) . The farmer will have the right to save, use, sow, re-sow, exchange, share or sell his farm seeds and planting materials except when he sells such seed or planting material under a brand name.

viii) **Exclusion of certain kind of variety of seeds from registration:** The Government will have the right to exclude certain kind or variety of seeds from registration to protect public order or public morality or human, animal and plant health or to avoid serious prejudice to the environment.
ix) **Seeds health:** Seed health has been included as an additional standard for quality seed.

x) **Cancellation of Registration of varieties:** The Registration of varieties under the Seed Bill will be cancelled on the following grounds:
   a. Violation of terms and conditions of the registration.
   b. Registration obtained by misrepresentation or concealment of essential data.
   c. Non-performance of variety and obsolete variety.
   d. Commercial exploitation of a variety.
   e. Public interest.
   f. Protect human beings, animal and plant life and health to avoid serious prejudice to the environment.

xi) Provisions to regulate import and export of seeds have been largely incorporated into the Seeds Bill itself as given below:
   a) All import of seed shall be subject to Plant Quarantine (Regulation of Import into India) Order, 2003 and other relevant Acts.
   b) All imported seeds shall conform to minimum standards of seeds health in addition to other conditions already in existence.
   c) All imported seeds shall be subject to registration on the basis of information furnished by the importer on the basis of multi location trials.
   d) Exports can be restricted if such exports adversely affect the food security of the country.
   e) Genetic Use Restriction Technology (GURT): **restriction technology including terminator technology** has been prohibited. Any person intending to import seed or planting material will declare that such material is, or is not, as the case may be a product of transgenic manipulation or involves Genetic Use Restriction Technology.

**Comparative Analysis of the Seeds Act, 1966 and the Seeds Bill, 2004**
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<tr>
<td>Covers seeds of food crops, fruits, vegetables, fodder, cotton &amp; jute only.</td>
<td>It covers all the crops.</td>
</tr>
<tr>
<td>No explicit farmers’ exemption.</td>
<td>Explicit farmer’s exemptions. The Bill shall not restrict the right of the farmer to save, use, sow, re-sow, exchange, share or sell his farm seeds and planting material except when he sells such seed or planting material under a brand name.</td>
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<td>Voluntary notification of variety by Central Government.</td>
<td>Dispensed with the provision of notification of varieties. In place of notification, registration of varieties will be compulsory. Registration of State varieties by the SSC and national varieties by the CSC.</td>
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<tr>
<td>The Central Government notifies the varieties based on the recommendations of the CSC for indefinite period.</td>
<td>The registration Sub-Committee based on the performance in the MLT shall register the varieties for a period of 10 years for annual and biennial crops and 12 year for perennial crops.</td>
</tr>
<tr>
<td>The standards to be prescribed will be for germination and purity with respect to notified variety.</td>
<td>The standards to be prescribed will be for germination, physical and genetic purity, seed health and standards for transgenic seeds of all registered varieties sold in the market.</td>
</tr>
<tr>
<td>No provision for giving expected performance of variety on the seed label.</td>
<td>Information about expected performance of variety shall be compulsory to be given on the seed label.</td>
</tr>
<tr>
<td>No separate provisions for notification of transgenic varieties.</td>
<td>Special provisions for registration of transgenic varieties.</td>
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<tr>
<td>Minimum limits of germination and purity required for import of seeds.</td>
<td>The imported varieties will also be required to be registered if it will meet all the seed quality standards.</td>
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<tr>
<td>Mild penal provision of Rs.500/1000 with or without imprisonment (6 months).</td>
<td>Enhanced penalty for offences i.e. Rs 25,000/5,00,000 with or without imprisonment (1 year).</td>
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<tr>
<td>Seeds Inspector may enter into the premises of seed dealer to take samples without approval of any authority.</td>
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<tr>
<td>Seed Inspector can stop the sale of seeds of suspicious quality up-to 30 days for regulating the quality.</td>
<td>Seed Inspector can stop the sale of seeds of suspicious quality up-to 15 days for regulating the quality.</td>
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<tr>
<td>New provisions.</td>
<td>Seed price regulation</td>
</tr>
<tr>
<td></td>
<td>Prohibition of GURT including Terminator technology.</td>
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</table>
Compensation to farmers in case seed failure.

Compulsory registration of Seed producer, Seed Processing Unit and Seed Dealers.

Regulation of fruit nurseries.

Accreditation of Government organizations as Certification Agency

Exemption of Educational, Scientific and Research Organization from all the provisions of this Act.

References:

i. http://seednet.gov.in/
ii. http://www.plantauthority.gov.in/
iii. Note for the Cabinet on Seed Bill, 2004.
Recent Advances in Hi-Tech Vegetable Nursery Production

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‘A vegetable nursery’ is a place or an establishment for raising or handling of young vegetable seedlings until they are ready for more permanent planting. The seeds of some vegetable are first sown in the nursery beds and the seedlings from these beds are later transplanted in the main field. Such vegetables are generally small seeded crops which belong to solanaceous, cruciferous and cucurbitaceous family besides onion, lettuce, asparagus etc.

Advantages of nursery raising: Nursery raising is an essential practice owing to the following reasons (Nandpuri and Surjan Singh, 1986):

- It is convenient to look after the ‘baby seedlings’ with better care in nursery bed.
- The size of seeds being small, it is almost impossible to do direct sowing properly.
- The hybrid seeds being expensive can receive better care and thus ensuring uniform crop stand.
- The land can be economically used as it can be put under some other crop when the nursery is being raised.
- Less expense is involved in controlling insect-pests and diseases in nursery beds.
- Undesirable seedlings can be discarded at the time of transplanting.
- Availability of sufficient time for field preparation, manure and fertilizer application after harvesting the previous crop.

Disadvantages of nursery raising: Besides benefits of nursery raising it has some limitations as well, which are as follows:

- Transplant shock, which delays crop growth but it is less severe on cell raised seedlings as compared to bare rooted seedlings.
Cost of seedlings, which adds to production cost.
Extra labour to transplant/establish the crop.

**Selection of site:** The following points should be taken into consideration while selecting an area for nursery production:
- The land should be well drained, fertile and rich in organic matter.
- The area should be free from the water logging.
- It should always be away from shade to get desired sunlight.
- The nursery area should be near to a water source.
- The area should be fenced from the pet and wild animals.

**A. Conventional method:** For raising healthy nursery through conventional method following protocol is mainly adopted (Anonymous, 2009):

i) Raised nursery beds of well pulverized soil with $3 \times 1 \times 0.15$ m size are prepared.

ii) The beds are fertilized with 20 to 25 kg well rotten FYM, 200 g SSP and 15-20 g Dithane M-45.

iii) To prevent damping off disease, nursery beds are treated with formaldehyde (25 ml/litre of water) and are covered with air tight polythene for one week and after removing the polythene the soil is turned up and down for three weeks to remove the remains of the formalin fumes.

iv) Pre treatment of seed with Captan and Bavistin (2 -3 g/kg of seed) is also practiced to check the attack of damping off.

v) The treated seeds are sown in the lines 5 cm apart at 0.5-1.0 cm depth and are covered with thin layer of well rotten FYM and soil mixture.

vi) In order to conserve soil moisture, beds are mulched with dry grass and are irrigated in morning and evening hours regularly till the seedlings emerge out.

vii) Mulched grass is removed as soon as the seedling emergence is observed and nursery beds are drenched with a mixture of Dithane M-45 (0.25%) and Bavistin (0.1%) to avoid damping off disease.

viii) In case seedlings are weak/deficient in nitrogen, urea is sprayed @ 0.3% when seedlings are 8-10 cm tall.
ix) The seedlings become ready for transplanting in 4-6 weeks or when they attain a height of 10-15 cm.

x) Irrigation is withheld 3-4 days prior to transplanting so that plants become hardened. But, on the day of transplanting, sufficient water is applied in the nursery bed and then seedlings are taken out for transplanting.

xi) The transplanting is mainly carried out during evening hours for better crop establishment.

B. Hi-tech nursery raising techniques

i) Covering with polythene sheets
In order to ensure early germination, thatching can be swapped with transparent/white polythene sheet (150 micron thickness). After seed sowing, irrigation water is applied in the nursery beds up to field capacity. Then the beds are covered with transparent/white polythene sheet and are made air tight by covering the sheet edges with soil. The polythene sheath is removed after the completion of germination process. Rest of the cultural practices are similar to conventional method of nursery raising.
Covering nursery bed with polythene sheet

Seedlings after germination

**ii) Poly tunnels for normal weather**

The nursery beds are covered with pre fabricated tunnels of size 3m long, 1.5m wide and central height of 1.0m. The semi circular structure is clad with UV-polythene sheath (200 micron) with 75 per cent transmittance. Once the seed sowing, covering and irrigation to field capacity is over, the bed can be covered with the tunnels. Both the openings can be closed if nursery is grown in winters.

Emerging seedlings inside poly tunnel

Seedlings ready to transplant

**iii) Sunken nursery for weather extremes**

i) Prepare a trench of any length, 1.2m wide and 50cm deep.

ii) Prepare a raised bed of 5-10 cm height at the bottom of the trench. The soil should not be imported from outside the trench. Albeit, FYM (25kg) and inorganic fertilizer mixture (100g) may be added as recommended earlier. Precautions must be observed in applying FYM. It may be treated with fungicide/Trichoderma (1kg/100kg dung) at least 15 days prior to bed preparation.
iii) Seed treated with Captan/bavistin may be sown in lines at 5cm width and cover the seed with the same soil.
iv) Drench the beds with water to the field capacity of the soil.
v) Cover the trench with white, transparent polythene sheath, providing taper to both sides.
vi) Make the sheath air tight from all sides.
vii) Start observing the emergence of the seed through the poly sheath from tenth day onwards.
viii) Once the emergence is over, irrigation may be regulated, as required till the 4 leaf stage is achieved.

Viii) Polythene cover may be removed in sunny days or converted into a roof in rainy days.

iv) Naturally ventilated polyhouse
For commercial nursery production, naturally ventilated polyhouses can be used. In a polyhouse of 100 m$^2$ area, 40,000 seedlings can be raised in one batch and we can have a total of five such batches per year.


v) Poly bags for cucurbits
Most of the cucurbits are seed propagated and in situ sowing is practiced. In some cases where early crop is desired, seeds can be sown in alkathene bags and germinated under protected cover from low temperature. The seedlings are transplanted from the bags at 2-true-leaf stage. This practice is prevalent in Punjab, especially in the case of muskmelon and it can be done in the hills to get early crop in July. Normally, the cucurbits do not stand transplantation beyond this stage due to injury to tap root. There is considerable saving in seed quantity, nearly 50 to 60 per cent as compared to in situ sowing (Bose and Som, 1986).


vi) Plug tray technique
• The seedling tray (pro-tray) is filled with the growing medium (coco peat, perlite and vermiculite).
• A small depression (0.5 cm) is made with fingertip in the center of the cell of the pro tray for sowing.
• One seed per cell is sown and covered with medium.
• Coco peat with 300 to 400 per cent moisture is used and hence no immediate irrigation is required until germination.
• After sowing 10 trays are kept one over other for 3 to 6 days, depending on the crops.
• The entire stack will be covered using polyethylene sheet to ensure conservation of moisture until germination. The stacked trays are spread once the germination commences to avoid etiolation.
• The trays are shifted to net house on germination of seedlings and spread over the beds.
• The trays are irrigated lightly every day depending upon the prevailing weather conditions by using a fine sprinkling rose can or with hose pipe fitted with rose.
• Drenching the trays with fungicides as a precautionary measure against seedling mortality is also being done.
• Spraying of 0.3 per cent (3g/litre) water soluble fertilizer using poly feed (19 all with trace elements) twice (12 and 20 days after sowing) is practiced to enhance the growth of the seedlings.
• The trays are provided with protective cover from rain by covering with polyethylene sheets in the form of low tunnel whenever it rains.
• The seedlings at right stage of planting are hardened by withholding irrigation and reducing the shade before transplanting or selling to the growers.
• Systemic insecticides are sprayed 7-10 days after germination and before transplanting for managing the insect vectors.
• The seedlings would be ready in about 21-42 days for transplanting to the main field depending upon the crop.
Pro-tray for sowing
Growing media
Trays filled with media
Seed sowing
Matured seedlings
Seedlings ready to transplant

**Seedling production using pro-trays**

**Conclusion**

The advent of different nursery growing technique has opened the new vistas for growing vegetable crops in any month of the year irrespective of any vegetable crop. Such innovative techniques are facilitating the growers in producing off season vegetables for fetching remunerative prices.

**References**


Lawwa R and Balraj S. Centre for Protected Cultivation Technology, Indian Agricultural Research Institute, New Delhi, india.

Public-private partnership in vegetable seed production and marketing

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Agriculture sector accounts for 13.9 per cent to India’s gross domestic product (GDP) and employ just a little less than 54.6 per cent of the country’s workforce. The Department of Agriculture and Cooperation under the Ministry of Agriculture and farmer's welfare is the nodal organization responsible for the development of the agriculture sector in India. The Immediate challenge to the Ministry of Agriculture, is to sustain the increasing agricultural output of the country. This can be addressed by developing Technology transfer and seed Innovation systems. Indian seed sector is characterized by diverse crops & vegetables with both public and private sector playing pivotal role.

Of the various technological interventions seed is considered as critical basic input for aiming sustained long term growth in agricultural production. Successful vegetable production begins with good seed, and many farmers are prepared to pay for such a valuable input. Everything else in vegetable production is profoundly affected by the quality of the seed used, the characteristics of the variety, and the potential quantity and quality of its marketable produce. Farmers invest in something that has such significant payoffs, and the private sector invest in marketing such valuable commodities. Because of its value to all parties involved, vegetable seed production and marketing is a key area for successful public-private partnerships for development.

What is PPP?

Public private partnership (PPP) is a contractual agreement between a public agency (Government at central or local level) and a private sector entity, in which the private party provides a public service and assumes substantial financial, technical and operational risks and rewards inherent in it. PPP is essentially a business venture which is funded and operated through a partnership of government and one or more private sector companies. The key
is partnership between the government and private business sector(s). The structure of the partnership should be designed to allocate risks to the partners who are the best able to manage those risks and thus minimize costs while improving performance. Risk transfer is one of the major components through which PPP projects can generate better value for money. Different types of risks such as public risks, market risk, economic and financial risk, construction risks, environmental risks etc are included in the PPP model (NPC, 2011).

**Why PPP:**

Public private partnership reduces public capital investment and improves efficiency due to strong profit incentive. Private entity is more accountable than government and results in expedited project completion by grouping multiple responsibilities into a single contract. Public private partnership results in specialized expertise and relieves the government from staffing issues. Further it shares risk/responsibility involved in the project. Government can still step in when private entities are not acting in the desired manners. In public and private partnership, the two players are government and private agencies. The public sector has the social responsibility, whereas, the motive of the private sector is profit oriented. Public sector has extensive infrastructure and higher institutes of learning which can generate knowledge through basic research. In contrary to this private sector is known to have better marketing skills, operational efficiencies, efficient product delivery system, quality service providing capability, and better up-scaling technologies. The main objective of public sector organisation is to conduct research, whereas in private sector research, production and marketing are integrated activities.

For developing any model of public private partnership, Identifying and negotiating the common interest is of utmost importance. How the project will be financed should be clear to the partners in the model. All regulatory/contractual and legal issues must be settled before entering into a contract for its successful completion. So keeping these facts in mind, an
appropriate organizational design should be adopted. Provisions for monitoring should also be kept.

The basic reason why our policy makers over the years pushed for PPP model was to tap the efficiency and management skills of the Private Sector. The other fundamental reason was to cut red tape and improve flexibility. Government bodies are bound by inflexible rules and regulations which makes decision making very difficult. The PPP model was supposed to change the rules of the game ensuring speed of implementation and avoiding cost overruns. In addition to maximising efficiencies and innovations of Private Enterprise PPPs can provide much needed Capital to finance Government Programs and Projects, thereby freeing public funds for core Economic and Social Sector. Inspite of all these noble intentions and so called support from policy makers why is this proving to be a failure? Why the Private sector is now no longer as enthusiastic as it was in being a “Partner in Progress” needs the attention of the governments. Public Private Partnership (PPP) model is supposed to be a collaborative model between Govt. Agency and the Private Sector. The inflexibility of the Govt. partner in a PPP model some time go to silly extremes. Hence the PPP model in its current ‘form’ needs to be given a decent burial or suitably tweaked to respond to changing Economic & Political environment of the country. Govt. Agency and the Private Sector have to be partners in progress and not adversaries. The bureaucrats manning the Govt. Agencies need to get down from their high horses and should be equally made accountable for the success or failure of the Projects. If Private Sector can fire executives for non-performance what stops Govt. from demanding same from its officers. All this requires a change in mind-set. And will be helpful in achieving the objectives of PPP models in ensuring the economic growth.
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<td>Dr Ramesh Kumar Bhardwaj</td>
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<tr>
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<td>Assistant Professor (Chemistry)</td>
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</tbody>
</table>
## List of Participants of National Level Advanced Training on “Advances in Quality Seed Production of Vegetable Crops” under Centre of Advanced Faculty Training in Horticulture (Vegetables) CAFT w.e.f 6th September to 26th September, 2017 at UHF Campus, Nauni (Solan) HP

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