



E-ISSN: 2278-4136

P-ISSN: 2349-8234

www.phytojournal.com

JPP 2020; Sp 9(5): 190-198

Received: 20-06-2020

Accepted: 18-08-2020

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Review on seed production techniques in flowering ornamentals

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Abstract

Flowering annuals and perennials are an important component in landscape design and indoor gardening. Since it has short duration and colourful flowers, it is utilized more in landscaping to change the colour pattern of the gardens according to the season and need. Most of the annuals are propagated only through seeds. Due to the demand in flowering annuals in the world floricultural trade, the seed market of the same is too become a vital sector. Hybrid seeds of these plants have high vigorous and superior quality. The production of hybrid seeds for export market is also in essential. This review will discuss the seed production technique of some major flowering annuals, biennials and herbaceous perennials.

Keywords: Flowering annuals, biennials, ornamental herbs, ornamental seed production, flower seeds

Introduction

Seasonal flowers or flowering annuals, biennials and herbaceous perennials are much in demand all over the world for beautifying our landscapes. Each species of flower crop grown for seed has its own specific planting time, culture, problems of pollination and harvesting, and storage requirements. Mild climate with moderate rainfall favours the growth and development of most flowers and ornamental crops.

The real breakthrough in flower seed production occurred since 1950s and there have been tremendous advancements in this area, with numerous creative approaches being employed to produce seeds. There has been limited availability of quality flower seeds in our country. In the earlier days, most seeds were imported, particularly from Europe. Subsequently several leading flower seed producing companies set up production facilities in India for targeting domestic markets as well as exports. This also led to interest among Indian growers to take up commercial production in a few areas, like Punjab, Himachal Pradesh and Jammu & Kashmir in the North; Karnataka in the South and West Bengal and Bihar in the East, some of these companies took up custom production of cultivars for their clients abroad (Dadlani, 1999)^[1]. Now, the Commercial flower seed production of F1 hybrids and open pollinated is considered a profitable venture and, hence, it is popular amongst farmers on limited scale.

Mr. Man Mohan Attawar of M/s Indo American Hybrid Seeds, (India) Pvt. Ltd., and Bengaluru has started producing F1 hybrid seeds of Petunia for 100% export during mid-sixties. However, production of seeds of open pollinated flower crops was revolutionized by Mr. Avtar Singh, M/s Beauscape Farms, Sangrur, and Punjab who started flower seed production involving farmers on large scale.

To promote the availability of quality material, in the country, the government liberalized the import policies and now we came across excellent hybrids and a range of new cultivars in the Indian gardens too. The limiting factor of higher cost for these seeds could be overcome by standardization of technologies for large-scale production and maintenance of germinability of seeds, relatively inexpensive human labour, technical expertise, and other materials, it is possible to organize a strong flower seed production programme exclusively or export purpose (Salunkhe *et al.*, 1987)^[2].

Now many companies have started producing seed on large scale for export to Holland, U.K., USA, France, Germany, and Japan etc. At present in India, the area under flower seed production is around 600-800 ha. The main areas of flower seed production in India are: Punjab (Sangrur, Patiala, and Ludhiana); Haryana (Panipat, Sirsa); Karnataka (Bengaluru, Rani Banur); Himachal Pradesh (Kullu Valley); J & K (Sri Nagar Valley); and West Bengal (Kalimpong).

Climatic Requirement for Seed Production

In India, Summer, Rainy and Winter season flowering annuals are available. Summer and Rainy seasonal annuals in India are available in limited number whereas winter annuals are

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rich in kinds. Thus for commercial seed production, winter annuals need more importance. Ideal climate condition for seed production is long duration of cool and dry season which helps in good seed setting of bold size. While excessive hot and dry season hampers seed setting of summer annuals in north Indian plains. Excessive rain at the time of flowering washes away pollen grains resulting in poor seed set.

The cost of seed production per ha varies from Rs. 10,000 to 15,000 and generate a net profit of Rs. 25,000 to 75,000. However, flower seed production is labour intensive. According to climatic requirements, the production of flower seed is divided in following climatic zones.

1. Mild climate (Kashmir Valley, Kullu Valley etc.): *Delphinium*, *Giant Pansy*, *Zinnia*, etc.
2. Sub-Tropical area: *Antirrhinum*, *Anchusa*, *Ageratum*, *Calendula*, *Brachycome*, *Lineria*, *Californian poppy*, *Candytuft*, *Carnation*, *Dianthus*, *Daisy*, *Dimorphotheca*, *Nasturtium*, *Petunia*, *Portulaca*, etc.
3. Tropical: *Tagetes*, *Salvia*, *Ipomea*, etc.

Mode of Pollination

- **Self pollination:** Balsam, *Clianthus*, Lupin, Sweet Pea
- **Often cross pollinated crops:** *Antirrhinum*, Aster, Dahlia, *Salvia*, Wall Flower, Linum, *Linaria*
- **Cross pollinated:** *Alyssum*, *Arctotis*, *Calendula*, *Cineraria*, *Gazania*, Stock, *Zinnia*
- **Outbreeds:** *Ageratum*, Corn flower, *Delphinium*, Marigold, *Verbena*, *Chrysanthemum*, *Nemasia*

Improves varieties in flowering annuals

- **Amaranthus:** Amar Kiran, Amar Poet, Amar Prithu, Amar Parvati, Amar Suikaran, Amar Tirang, Amar Raktab, and Amar Mosaic. A tetraploid cultivar Amar Tetra was evolved through colchiploidy, Amar Shola, a hybrid amaranth is a selection from a cross within *Amaranthus caudatus* complex involving a grain type and an ornamental type.
- **China Aster:** At Hessaraghatta has led 25 purelines were selected by single plant selection. Of these AST-1 and AST-2 were found to be promising.
- **Marigold:** An F1 triploid developed at NBRI, Lucknow by using male sterile African diploid marigold (*Tegetes erecta*) and male fertile French tetraploid (*T. patula*) has performed well in all climates. A few promising selections have also been made at UAS, Bangalore and PAU, Ludhiana.
- **Verbena:** At NBRI, Lucknow, four free flowering hybrid verbenas have been evolved by hybridizing *V. tenuisecta* and *V. hybrida*. The hybrid types obtained after repeated back crossing are summer hardy with genes that confer heat resistance. These verbenas are excellent both as for rockeries and for growing in beds. The hybrids can be propagated vegetatively (Gupta, 2012)^[3].
- **Zinnia:** Recurrent selection from the irradiated seeds of *Zinnia elegans* a mixed coloured variety resistant to leaf curl virus has been evolved at IARI, New Delhi (Swarup and Raghava, 1974)^[4].

F₁ hybrid seed production

F₁ hybrids are the result of crossing of two homozygous but genetically distinct parental lines. Shull (1911)^[5] gave his idea and coined the term heterosis and explained hybrid vigour. Hybrid vigour is entirely due to bringing together, a large number of favorable dominant genes contributing to vigour in the first generation period. Hybrid vigour is defined as the

increase in the size or vigour of a hybrid over its parents (Frankel, 2013)^[6].

Hybrid variety 'Prima Donna' in begonia (*Begonia semperflorens* Link et Otto) was probably the first F₁ released in floricultural crops by Benary Seed Company in Germany in 1909. In 1940s, Japan produced the first commercial F₁ hybrids in Petunia.

Later, F₁ hybrids were produced in flower crops like *Ageratum*, *Anemone*, *Gerbera*, *Primula*, *Petunia*, *Tagetes*, *Cyclamen*, *Pansy*, *Begonia*, *Geranium*, *Portulaca*, *Dianthus*, balsam, stock, wall flower, ornamental sunflower (*Helianthus annuus*), *Gazania*, hollyhock, *Calceolaria* and *Zinnia* by several seed companies in the U.S.A., China, Japan, the Netherlands, Denmark, Germany, the United Kingdom and Israel.

For the production of F₁ hybrid we require purelines in self pollinated species or inbred lines in case of cross pollinated species. A pureline is the progeny of a single, homozygous, cross pollinated plant. An inbred line is the progeny of a single, homozygous self pollinated plant (Gupta, 2012)^[3].

Two basic requirements for hybrid seed production are

1. Easy emasculation of the female parent
2. Effective pollen disposal from the male parent to ensure a satisfactory seed set in the female parent.

Methods of making a Cross Hybrid seed production can be achieved by

1. Hand emasculation and hand pollination.
2. Hand emasculation and natural pollination.
3. Hand elimination of male plants.
4. Genetic male sterility as in marigold and zinnia, *ageratum* and *calceolaria*.
5. Cytoplasmic male sterility as in *petunia*.
6. Self incompatibility as in *petunia*, *pansy*, *stocks* and ornamental *kale*.
7. Chemical emasculation- selective elimination of pollen production, that is, use of gameticides.
8. Use of marker genes to identify the selfs so that they can be eliminated as seedlings.

Techniques of hybrid seed production

Use of Self-incompatibility

The self incompatibility systems are of two types, gametophytic and sporophytic system. Among ornamentals, the self-incompatibility system is present in *Nicotiana* and *Petunia* is gametophytic and can be utilised in cross pollination under open field conditions. However, in these two flowering plants one additional advantage in that there are enough seeds per pollination, which can adequately compensate the high cost of F₁ hybrid seeds. Sporophytic system of self-incompatibility is observed in *Verbena*, and dominance relationship between two self-incompatibility (SI) alleles influences the seed set (Gupta, 2012)^[3].

Double Flower Condition

In double type of flowers all the anthers are modified to form ray florets. This is a character of compositae/asteraceae crops such as *Ageratum*, aster, *chrysanthemum*, cornflower, dahlia, daisy, *gaillardia*, marigold, *rudbeckia* and sunflower. In most cases, double flower results from a transformation of the anthers into petals. Therefore, the double flower character can be regarded as a form of the male-sterility.

Reimann-Philip (1969)^[7] developed a breeding scheme using the double flower character in garden carnation (*Dianthus*

caryophyllus) as a form of male sterility. There are also some floral abnormalities, like the 'cinderella' character in begonia and 'femina' in marigold and zinnia resulting in the male-sterility.

Triploidy

Triploid varieties is have little or no seed set. Among the flower species, in *Tagetes*, commercial triploid hybrid ($2n = 36$) results from a cross between diploid female *Tagetes erecta* ($2n = 24$) and tetraploid male *Tagetes patula* ($2n = 48$). The triploid hybrid 'Nugget' (*Tagetes erecta* x *Tagetes patula*) has the unique ability of holding the flowers on the plants for a longer period. However, in *Begonia semperflorens*, the loss of uniformity in triploids has been reported by Reimann-Philip (1983)^[8].

Pollen Sterility

Male sterility in Sunflower has been used to produce ornamental varieties like, 'Sunrich Orange' (Japan) and 'Orit' (Israel), which have no pollen grains and allergic effects like in other male fertile varieties grown for their seed. In *Ageratum*, both the male sterility and self incompatibility-systems are prevalent. In *Petunia*, cytoplasmic male sterility has been observed but the use of this type of male sterility is not practically common because of breakdown of male-sterility in the maternal parent or malformation of flowers in F_1 plants. Wherever pollen sterility is governed by a single recessive gene, maintenance of the genetic stock is difficult as there will be continuous segregation of the fertile and sterile individuals in, 1:1 proportion. This phenomenon is present in *Tagetes*, *Zinnia*, *Delphinium*, *Antirrhinum*, *Calceolaria*, *Salvia* and *Impatiens*.

Seed production in flower crops

African Daisy (*Osteospermum sp.*): The transplanting was done in mid December at a spacing of 30 x 45 cm the first flowering appears after 95 days of transplanting i.e. 3rd week of March. The flowering duration was 60 days and the seed yield per square meter and per acre was 12.07 g and 39.83 kg respectively.

Amaranthus (*Amaranthus sp.*): *Amaranthus caudatus* belongs to Amaranthaceae family is grown for their beautiful flowers. It has pendulous, blazing-red inflorescences and is commonly used as an ornamental plant under the names such as "love-lies-bleeding", "red-hot cat-tail", "pendant amaranth", "tassel flower" etc. Amaranthus is a rainy season plant, but can also be grown during the winter in the plains. These annuals can be grown under sunny situation for the best performance to get the brightness of the inflorescence and foliage (Ahmed *et al.*, 2013)^[9].

The seeds should be sown in February-March for the hilly areas and June-July in tropical plains. In places, like Bangalore, Pune, etc., where the climate is of mild type, these plants can be grown throughout the year. The seed rate of Amaranthus is 2.5 kg/ha. From seed sowing to flowering it takes near about 3 months. Spacing should be given at 45 x 20 cm. The plant to plant spacing may be given 30 cm also (Mukherjee, 1999)^[10]. Harvest fully matured inflorescence when the glumes turned into brown and seeds to black colour. Pack the inflorescence in cloth bag and extract the seeds by beating with pliable bamboo sticks and dry the seeds to 7 - 8% moisture content. Recommended sieve size : BSS 22 x 22 wire mesh sieve. Seed yield will be 180 - 200 kg / ha. The treated seeds can be stored up to 12 months in aluminium foil

pouches. The amaranth seed is quite small (0.9 to 1.7 mm diameter) and seed weights vary from 1,000 to 3,000 seeds/g (Stalknecht and SchulzSchaeffer,1993)^[11].

Ammobium (*Ammobium alatum*): *Ammobium alatum* flowers are typical example of Compositae family and are bicolor (that is disc yellow and ray florets cream colored). The plant is spreading in nature till the flower initiation but afterwards the stalk length increases till anthesis. Due to its long stems, it is fairly useful for dry arrangement use if harvested at right stage. The branches are harvested by end of May/mid June for seed purpose, which is cleaned afterwards. Seed yield is around 50-60 kg/acre.

Aster (*Callistephus chinensis*): China aster belonging to the Compositae family, is a popular annual flowering plant with erect growth habit, about 20-75 cm tall with irregular or deeply cut margins and grooved petioles. The daisy like flowers varies in shape, form, sizes and color. They may be single or double-headed, in-curved, anemone, peony, quilled, ruffled, or comet types in form and small button like pompom or large in size. The single and semi-double varieties of aster are predominantly cross-pollinated, whereas the double-headed ones are generally self-pollinated. The common colors are white, rose, pink, red, blue-lavender, magenta, yellow, crimson, scarlet, mauve, purple, and primrose. The varieties vary in their keeping qualities.

An effective aster-breeding programme should ensure adequate isolation to safeguard against occasional cross-pollination through insects. All modern varieties have been developed from *C. chinensis*. The current breeding work concentrate on the production of aster-yellow virus-resistant lines and F_1 hybrids with attractive blooms suitable for both bedding and cut flowers.

Seed crops should be isolated from other crops, with a minimum distance of 400 m for single and semi-double strains, which are cross-pollinated. The seeds should be treated with 0.25% $ZnSO_4$ for two hours before sowing. Seeds germinate well at 20 °C, taking about a week to complete germination. After germination, the temperature can be reduced to 15.4 °C. It takes about 3 weeks for seedlings to be ready for transplantation. The seedlings are transplanted to well-prepared land. The spacing planted about 15-20 cm apart. Off – types and diseased plants, if any, should be rogued out from time to time (Phetpradap *et al.*, 1995)^[12]. Seeds comes to harvest 40 days after anthesis. The seed heads are ready to harvest when they become fuzzy. The seeds are then dried in the shade, cleaned, and stored in moisture-proof containers in a cool, dry place. Small seeds (450 – 600 seeds / g) remain viable for about one year. The highest seed yield of 18.5 g/plant was obtained at 30:20:20 g NPK/m² (Debnath and Maithi, 1999)^[13].

Calendula (*Calendula officinalis*): Calendula or pot marigold belonging to the Compositae family, is an important bedding plant grown primarily during the cooler months of winter and early summer in the plains and during the fall and summer in the hills. It can be grown in shady locations receiving ample indirect sunlight in hot, humid climates. The inflorescence or head is fully double with ray florets. Flowers rang in colour from light yellow to deep yellow and orange to dark orange. There are several open – pollinated cultivars, which are suitable as cut flowers.

Calendulas prefer cool and dry climates with ample indirect sunlight or partial shade. Temperatures beyond 30-35 °C are

harmful. A well drained, light – textured soil with adequate organic matter is best suited for the growth of calendula. Heavy soils with poor drainage drastically reduce its growth and flowering. Soils with pH of 6.0 – 6.5 are optimum for growth.

Seed plots should be separated from those of other Compositae varieties by at least 400 m to avoid contamination. It is usually propagated through seeds, which are dark brown in color (125 -200 seeds / g). They germinate at 20-21 °C within about 7-8 days, and seedlings are ready to transplant in about 3 weeks. In the plains, seeds are best sown in September – October, while in the hills they should be sown in February – March or July – August. Seedlings are planted in well – prepared land at 30 x 30 cm, preferably in the evening.

Seed crops should be irrigated frequently as and when needed; fields should be weeded or hoed to keep them clean. Periodical roguing should be carried out to remove off-types and diseased plants, if any. Because calendulas are cross-pollinated, all atypical plants and cross – compatible species should be rogued as soon as they are noticed (Desai *et al.*, 1997)^[14].

Carnation (*Dianthus caryophyllus*): Carnations belong to the Caryophyllaceae family. Flowers are borne terminally, either singly or in clusters. The petal margins smooth, fringed, or frilled. The flowers are in white, creamy yellow, pink, red-orange, mauve, or a combination of two or more colors. The florist-type carnation can be tinted to give any color.

Perennial carnations and pinks are started from seeds by direct sowing or transplanting seedlings. The seedlings are raised on flat or raised seedbeds, which are transplanted after one month. The best time for planting is September-October in the plains and February-March in the hills. The spacing can vary from 22.5 to 45 cm, depending upon variety and species. The intercultural operations are similar to those for flowering annuals. Seeds are harvested before shattering begins. The pods are usually picked manually and dried in the shade. The seeds are extracted by hand or by threshing. After cleaning, seeds are stored in a dry, cool place in an airtight container.

Celosia (*Celosia cristata*): Celosia belongs to the family Amaranthaceae. This is a common bedding plant that sometimes grown commercially outdoors as a cut flower. The tall cultivars suitable for cut flowers have either yellow or red flowers. For planting outdoors in May the seed should be sown about April 1. The seed germinates in 1 ½ weeks at 21C. For later flower crops, the seed may be sown directly outdoors. The common name of Cockcomb identifies the shape of the flower, but there are plumose types in which the flowers are feathery plumes (Balasubrahmanyam *et al.*, 2000)^[15].

Chrysanthemum (*Chrysanthemum morifolium*): A genus of more than 200 species of annual perennial herbs, sometimes partly woody, chrysanthemum belongs to the family Compositae. The chrysanthemum societies of various countries have classified the chrysanthemums grown in their respective countries on the basis of number, size, form and arrangement of disc and ray florets. Some of the important species of chrysanthemum are *Chrysanthemum cinerifolium*, *C. frutescens*, *C. Indicum*, *C. japonicum*, *C. morifolium*, *C. omatum* and *C. sinense*.

Being cross-pollinated crop, new varieties arise mainly as seedlings obtained either by natural or conscious cross-

pollination. The latter method enables one to obtain seeds even from those cultivars which naturally fail to do so due to several reasons like long ray florets which physically prevent pollination, protandry or sporophytic self-incompatibility (Fryxell, 1957; Drewlow *et al.*, 1973)^[16, 17]. The hybridization technique followed in chrysanthemum is given below:

- Select male and female parents depending on characters desired to be combined.
- Clip anthers of disc florets before dehiscence in blooms of female parent and cover them with wax-paper bag to prevent natural pollination.
- Trim long ray florets in female parent to expose stigma. This is done in stages as the florets open centripetally starting from outermost whort. Expose only ripe stigma.
- Collect pollen from male parent in petri dish.
- Dust pollen on stigma on female parent after temporarily opening wax bags.
- Tie the bags giving details of male and female parents.
- Remove the paper bags after all stigmas wilt.
- Collect seeds when completely dry (1-2 months after pollination) and store in dry place (Kher, 1995)^[18].

Most of the small flowered chrysanthemum cultivars in India have been developed by natural or artificial pollination followed by seedling selection. This is so because of the comparative ease with which seeds are obtained in small flowered varieties.

For raising seedlings 650 to 800 g seeds will be required per ha. Transferring plants from higher to the lower temperature greatly enhanced seed production relative to those kept continuously at the higher temperature i.e. 22 – 26 °C to 14 °C (Aken and De, 1995)^[19].

Cultivars, which bloom with conspicuous disc generally, produce ample seeds. The seeds are collected after the blooms are completely dry. The small seeds require care in handling before and after sowing. Fine compost is used to cover the seeds after sowing. Watering is done either by soaking from bottom hole of pot or with fine rose so as not to allow the seed to be exposed. Seeds germinate within a few days after sowing (Dhua, 1999)^[20].

Coleus (*Coleus scutellarioides*): Coleus is an excellent pot-plant for indoor and outdoor decoration. It can also be grown on the ground as an edging plant or a bedding plant, or in the shrubbery. The plants thrive best in summer and rains where the winter is prolonged and severe. The plant needs protection from frost during winter. In places with mild winter, the seeds are sown in September-October to have the plant in their best from in January and February.

Coleus is usually propagated from seeds. The seeds of coleus are very fine and should be sown very carefully. The seed compost should be very light and may be mixing one part each of soil, screened leaf mould and sand. While watering, care should be taken that the very fine seeds should not be washed away. Within a month of sowing the seedlings will be ready for transplanting. The seedlings should preferably be transplanted in small (8-10cm) pots. About a month after the first transplantation, the young plants should be transplanted to bigger pots (25-30 cm) and cowdung manure will make a good compost for plants. To make the plants bushy, they should be pinched at a height of 10-15 cm (Mukherjee, 1999)^[10].

Cosmos (*Cosmos bipinnatus*): Cosmos belongs to the family Compositae and are highly cross – pollinated. *Cosmos*

sulphureus and *C. bipinnatus* are the two important species. *C. sulphureus* flower is sulphur yellow / orange in colour whereas *C. bipinnatus* is available in pine, white, magenta, purple, etc.

The field should be about 1000 m from one another for having pure seed. *C. sulphureus* is transplanted in July and *C. bipinnatus* is in the August. The prior species comes in bloom by August and flowering is over till mid September and the latter one at end of September and October is favourable period for their best seed set.

Sowing on 15th July resulted in the best growth and flower production and highest seed yield per plant. Seeds of both crops are very susceptible to shattering, and are collected individually by hand after 25-30 days of flowering and the seed yield is about 60-80 kg per acre. *C. sulphureus* cv. Super Sunset recorded the highest seed yield of 9.1 q / ha. N at 20 g/m², P at 10 g/m² and K at g/m² (Jana and Pal, 1991) [21] is recommended for seed production.

Cuphea (*Cupea ignea*): *Cuphea ignea* belongs to Lythraceae family, is a dwarf annual with a bushy habit bearing minute cigar-shaped tubular flowers of bright scarlet colour with black tips. It is grown either as pot-plants or in beds. The plants grow well under sunny condition on a well – drained soil. These plants can also tolerate partial shade. In the plains, these plants produce flowers in February – March and, hence, the seeds should be sown in September – October. In the hills, the seeds are sown in March – April to get flowers during June – September. Plant to plant spacing is 25-30 cm (Mukherjee, 1999) [10].

Dahlia (*Dahlia variabilis*): The dahlia belongs to family Compositae. The flowers vary in size, form and color. Flower sizes range from a few centimeters to about 25-30 cm (giant or large varieties). Breeding in dahlias is very simple because no emasculation or bagging is necessary. As in other Compositae plants, the ray florets are shiny when mature. Transferring pollen from the central disc florets of one flower to another with a fine brush can effect controlled pollination. Dahlia requires ample sunlight and low temperatures will restrict the growth. Dahlias can be multiplied both sexually and vegetatively. The dwarf bedding types are usually sexually propagated, but together varieties, especially the double types, do not bred true to type when grown from seeds. Dahlias are usually planted in September and October in the plains or in March to May in the hills. In coastal areas and southern parts of India, seeds can also be sown in May. Seeds germinate in 1 or 2 weeks, and seedlings are ready to transplant in 3-4 weeks. The seed yield was highest (0.52 g/plant) from sowing on September (Han and Hongyang, 1996) [22].

Dahlias can be grown either in beds or in 25 to 30 cm pots. Beds are prepared well and organic manure. Seeds are harvested when the pods turn yellow, which are dried on canvas or plastic sheets. Seeds are extracted by threshing or rolling. The threshed seeds must be cleaned immediately and stored in air – tight containers.

Delphinium (*Delphinium ajacis*): Delphinium belongs to Ranunculaceae family, is a very popular garden annual from Southern Europe comprises of two species, viz., the hyacinth – flowered larkspur (*D. ajacis*) and the stock – flowered larkspur (*D. consolida*). These tall plants with a height of one meter or so are very free flowering and produce flowers of blue, purple, mauve, pink, white, etc. the seeds of larkspur fail

to germinate until and unless the climate is not sufficiently cool. In the plains, it is grown as a winter annual and the seeds are sown in id-September to October. In the hills, the seeds are sown in February – March to have the flowers in summer. It is commonly grown in beds for garden decoration and for cutflower production and also as pot plants. For cutflower production, the seeds are sown directly to the bed, with a spacing of 10-15 cm between the plants rows (Mukherjee, 1999) [10].

Gaillardia (*Gaillardia pulchella*): Gaillardia also belongs to family ‘Compositae’ and thus facilitating cross-pollination. Before sowing seed treatment with conc. sulphuric acid for 30 seconds followed by soaking in GA3 200 ppm for 16 hours improves germination. The plant attains a height of 60-90 cm and flower color is yellow with red tinge or carrot colour with maroon tinge. The seeds collectively form a ball. Therefore less prone to shattering. These seed balls are harvested individually by hands after about 40 days of flowering and harvesting period continues till the first shower of monsoon rains. Seed yield ranges from 200-250 kg/ acre.

Geranium (*Pelargonium hortorum*): The geranium a member of the family Geraniaceae has many forms. The leaves have zonal markings of band (blotch) variegation. The stem is fleshy but turns woody with age. The umbel-like inflorescence is borne on a long pedicel. The flowers are irregular with five petals, of which the upper two are relatively larger and more prominently colored. The most popular flower colors are pink, red, white and purple. Geraniums are used as potted flowers and bedding plants.

Both seedling and vegetatively propagated geraniums have been available for commercial production since the 1970s. With the introduction of newer seed-propagated cultivars, several growers have begun growing seed geraniums that have shown better performance than the vegetatively propagated cultivars. The former are more tolerant to pests and diseases and have lower production costs (no need to raise stock plants). They can be made available in large quantities through breeding, since the exact time of flowering can be predicted more easily.

Geraniums for seed are usually grown in pots under controlled conditions. Since plant height must be in proportion to pot size, growth regulators are generally used to produce plants of the desired size and shape. Chlormequat or CCC can be used as a foliar spray or soil drench to reduce plant height, to hasten flowering, and to increase the number of flowers per plant (Salunkhe *et al.*, 1987) [2]. Geraniums are benefited by CO₂ enrichment in the greenhouse, especially during winter months, when ventilation is a problem. At a CO₂ of 500-700 ppm concentration, plants grow faster and flower earlier. Wider plant spacing have been used to regulate plant height and produce better-shaped plants. Seeds are harvested when the pods are fully ripe. They are dried and then seeds are extracted, cleaned and stored in a cool, dry place.

Gomphrena (*Gomphrena globosa*): Gomphrena belongs to Amaranthaceae family. It is very easy to cultivate. The flower heads are papery in texture and bear flowers of purple, white, magenta, pink and other colours. Gomphrena is grown in beds for garden decoration and for cutflower production. Seeds are sown in February to June in succession to get the flowers in summer and monsoon. The plants take two and a half to three months to come to flowering. When the plants get established

after 2-3 weeks of transplantation, they should be made the plants bushy with more flowers (Mukherjee, 1999)^[10].

Gypsophila (*Gypsophila elegans*): *Gypsophila elegans* belongs to Caryophyllaceae family. This annual prefers sunny situation and a porous soil. This is grown as a winter annual in the plains and as summer or autumn flower in the hills. As the plants remain in flowering for a very short period, the sowing of seeds should be made in succession to have flowers for a long period. Addition of lime to the soil during the bed preparation will be beneficial to the plants. Plant to plant spacing is 25-30 cm.

Helichrysum (*Helichrysum bracteatum*): *Helichrysum* belongs to Compositae family. It is a cross – pollinated flower commonly known as strawflower, size of flower varies from 3.0 to 6.5 cm. A large number of varieties are available in different color, and similarly the height of plant varies depending the varieties. But on account of seed production purpose, tall varieties are preferred due to ease in seed harvesting. Individual pods are harvested when the disc (centre of flower) shows the signs of drying. The seeds carry wings on the top, therefore easily blown by winds. So keeping this in view harvesting of mature pods is suggested daily or after one day.

Balsam (*Impatiens balsamina*): *Balsam* belongs to Balsaminaceae family. The flowers are single, semidouble and double type. The plants bear the flowers in leaf axils of the branches, however, in the bush – flowered plants, the flowers appear in clusters on the top of the stem. The annual is ideal for beds and is also grown in mixed borders and along walks. The seeds are sown from February to June for the summer and monsoon flowering. The seedlings become ready for transplanting with 2-3 weeks of sowing. In places with mild climate, it can be grown throughout the year.

Linum (*Linum grandiflorum*): *Linum* were transplanted by 3rd week of December, at a spacing of 30 x 45 cm. the first flower appeared after 75 days of planting and flowering period was 45 days. The seed yield per square metre was 22.5 g and it was 75 kg per acre.

Marigold (*Tagetes* sp.): The plants of *Tagetes* are quick growing, bushy perennials but are as annuals. Marigolds vary in height from 10 to 100 cm or more. The leaves are dark green, deep cut, with a typical color. Flower heads vary in size, form, and color from small (1 cm) to large (15 cm). The African types (*Tagetes erecta*) are usually yellow, orange, yellow – orange, or greenish – yellow and white. French marigolds (*T. petula*) have still wider colour variation. The form range from carnation like peony and chrysanthemum – flowered, quilled to fully heads.

Marigold seeds (black, 300 -350 seeds/g) remain viable for a couple of years. French marigold seeds germinate to an extent of about 90-95%. Seedlings are grown on raised beds; seeds are sown in May – June, August – October or February – March (in the plains) of March – April (in the hills). The seed recovery is high when planted during October than November – December planting. Seeds germinate best at 20 °C within 8-10 days and are ready to transplant in 3 weeks (Desai *et al.*, 1997)^[14].

Land is prepared well by ploughing and two or three harrowing. A minimum distance of 400 m should be provided to prevent contamination of the seed plot from other varieties.

Plant spacing varies with cultivars, growth habit, and soil type from 15 to 60 cm. The highest seed yield (30 to 40% increase) was recorded by planting African marigold at a spacing of 40 x 20 cm and in French marigold it was 30 x 10 cm (20 – 35% increase) (Kobza, 1995)^[23]. Excessive nitrogen fertilization promotes vegetative growth at the cost of flowering. Yadav and Bose (1998)^[24] observed that application of 300 kg N and 200 kg P per hectare recorded the highest seed yield (12.6 q/ha) (Das *et al.*, 2020)^[25] in African marigold and (13.9 q/ha.) in French marigold. The highest seed yield of (12.33 q/ha.) was obtained in African marigold cv. African Giant form plants treated with a foliar application of 0.1% CaSO₄ (Bandyopadhyay *et al.*, 1994)^[26].

Monarda (*Monarda citridora*): *Monarda* belongs to family Labiatae and is a cross-pollinated one. The plants of *monarda* attain a height of 70-100 cm at full bloom stage. Plants come in bloom in July when transplanting is done by end of November. The flower color is mauve and flower structure is such that it facilitates the cross-pollination and requires the same isolation distance as for other cross-pollinated flower. In this crop flowers are arranged on a stem as in gladiolus. At the time of seed harvesting the flowers are completely dry and this stage is attained after 40-50 days of flowering. The branches are harvested collectively from the base only once or twice.

Pansy (*Viola tricolor*): Pansies belong to Violaceae family and are native to Europe. The common florist-type pansy belongs to the species *Viola tricolor* var. *hortensis*, growing 15-25 cm tall. It has a compact trailing habit. The inheritance of flower color has been shown to be somewhat complex, indicating gene interactions. The prostrate growth habit is dominant to erect plant types. Variegation has been shown to a non-Mendelian characteristic depending upon plastids in the cytoplasm. The development of velvety block color is controlled by the expression of three genes and five inhibitor genes suppressing the characteristic. Although pansy is predominantly a self-pollinated crop, some cross-pollination does occur. An isolation distance of 100-200 m from other varieties has been recommended for seed production.

The seeds are sown in September-October in the plains and a little earlier in the hills to enable the plants to become established before the cold weather sets in. Seeds are sown in shallow rows and covered lightly, and the beds irrigated. Mid weather favours seeds germination (20 °C), and seedlings with three to four true leaves are used for transplantation. Seedlings are planted in rows, 15-25, cm apart, ensuring adequate fertilization and irrigation. Application of 30 g N and 20 g P per sq. metre with closest spacing 20 x 20 cm recorded the highest seed yield (Kaur and Kumar, 1998)^[27]. Hand pollination and use of growth regulator (NAA) may be necessary to obtain good seed yields. Seeds should be harvested before shattering begins. Since plants flower continuously, handpicking of seedpods may be necessary. The capsules are collected in boxes and dried in a well-ventilated place. Seeds are usually extracted manually by rubbing or crushing. They are then cleaned, dried in the shade, and stored in a dry, cool place.

Petunia (*Petunia hybrida*): *Petunias* belonging to the Solanaceae family, are the most popular bedding plants. A wide range of variation in color, size, and plant height makes it more attractive. The flower colors include all shades of white, pink, rose red, scarlet, violet, blue, yellow, cream,

salmon-rose, magenta, and lavender or combinations of these. Several F1 and F2 strains of petunia are available to the trade. Both double-flower forms and large-flowered grandifloras are products of hybridization, the double-form characteristic being dominant over single form and lined to female sterility, producing only occasional functional pistil, which permits maintenance of the line. Using seed of single-flowered parents and a homozygous double clone for pollen breeds double-flowered types.

Major efforts in petunia breeding are being made to develop varieties with better color, increased flower size, freedom from bloom, compact plant growth, and earliness. Resistance to Botrytis and petal spotting is also being sought through breeding. Use of cytoplasmic male sterile lines in petunia has been limited due to factors such as production of inferior F1 hybrids, increased flower bud blasting, and inferior flower quality (size and colour). Genetic male-sterile lines and incompatibility systems are also being used to a limited extent: because of the higher cost of maintaining these lines by vegetative means as compared to the cost incurred by pollination via hand-emasculatation.

Cooler climate with moderate rainfall and 13-16 °C, soil temperatures are optimum for petunia. Petunia seed crops should be isolate, with a distance of at least 100 m from other varieties.

The seeds are very small (10,000 seeds/g). Usually sown in September-October in plains and February-March in hills. Soak the seed in GA₃ 100 ppm or KH₂PO₄ 2% for 16 hours to promote germination. Seeds germinate well at 20-25 °C and require light for better germination. Seedlings are ready to transplant about one month after sowing. All double-flowered varieties are propagated through terminal cuttings. Uniform seedlings are transplanted in well-prepared fields enriched with FYM at 10 kg/m². Adequate supplies of P and K should ensure at the time of transplanting. Foliar spray with MgSO₄ @ 2% at 50% flowering stage will be effective in increased seed yield. Pollination may be brought about either by hand-emasculatation or using certain equipment to facilitate the operation. Harvest the seeds at 25 days after anthesis when the pod and seed attained brown colour. Harvest the pods at alternate days, first 20 pickings can be used for seed extraction. The seeds are extracted from the pods, dried in the shade to reduce seed moisture content, and stored in air-tight containers in a cool, dry place. Density grading with acetone may be done to remove the floaters. The yield per square meter is 50 kg/acre.

Phlox (*Phlox sp.*): Phlox belonging to the Polemoniaceae family can be grown as both an annual and a perennial crop in the garden. Because of its wide variation in flower size, shape, colour, phlox is an excellent plant for flower beds, edging, rock gardens, and flowering hedges. Flowers are produced terminally in clusters. Each flower contains three to five stamens and a three-celled ovary. The petals are attractively colored with shades of white, yellow, red, pink, orange, purple and mauve or a combination of two or more colors.

Seeds are sown directly in the field or seedlings may be raised for transplanting. Seedlings are ready for transplanting about one month after sowing with a spacing of 25 x 20 cm. Application of 10 kg FYM/m² at the time of land preparation and top dressing with nitrogenous fertilizer at 10 g/m² improves growth and flowering. Flowering begins about 45-60 days after transplanting, and seeds taken another 30-40 days to mature. Mature pods should be harvested before seed

shattering begins. Seed stems should therefore be harvested before the pods are completed dried. The harvested pods are then dried on canvas and threshed to extract seeds. Seeds are cleaned and stored in a dry, cool place using appropriate containers.

Salvia (*Salvia splendens*): Salvia belongs to Lamiaceae Family. The most popular and common type is *Salvia splendens* with bright scarlet pink, salmon and violet flowers are also available. The species is grown during winter in the plains and during summer and monsoon in the hills. *Salvia coccinea* is a tall plant (70-80 cm) with white, pin, red and scarlet flower. This species is popularly grown in South India. Salvia is an excellent annual for cultivation in beds and mixed borders for garden decoration and also in pots. The plants appear very attractive when grown in a group. For the best performance, Salvia requires a sunny location and a well-drained rich and moist soil. This annual can tolerate well a semishady condition. In the plains, it is grown as a winter annual in March-April and also in August-September. Salvia cannot withstand frost. The small seeds taken about two weeks to germinate and the seedlings are planted 30-45 cm apart. The plants start flowering within three and half months of sowing.

In salvia, low levels of nitrogen and phosphorus show marked reduction in vegetative growth and number of flowers; on the other hand, too much of nitrogenous manuring encourages excessive vegetative growth and delays of flowering. *Salvia splendens* and *Salvia farinacea* can be grown well in the plains, whereas the other species thrive best in the hills. Application of liquid manuring once a week encourages good flowering. In places with moderate climate, the plants may be severely pruned when they finish their flowering. Regular watering should be given to salvia as they require plenty of moisture (Mukherjee, 1999)^[10].

Snapdragon (*Antirrhinum majus*): Snapdragon belongs to Scrophulariaceae family, is a low-growing tender herb with side shoots arising very near to the ground. The leaves are usually opposing and entire. The Corolla is gibbous or saccate at the base and personate or closed near the throat. The flowers are borne on spikes and florets in open succession.

Present day F₁ hybrids combine the winter-flowering and stout vegetative characteristics of their parents. Cross-pollination in snapdragons occurs mainly through larger insects like bumblebees. The soil should be at least 20 cm deep. Hannan and Langhans (1963)^[28] reported a ratio of soil to sand or perlite mixture of 3:1 to produce a high quality crop. The soil should have adequate nutrient-supplying capacity for all necessary major and minor elements. Short-term waterlogging during the initial stages of crop growth can severely damage seedlings. Maintaining soil moisture and air can produce an excellent quality crop at 24-34% by volume and 45-55% of total pore space in the root zone, respectively.

Snapdragon seeds are very small (6000/g) and are sown in raised nursery beds. The germination is about 80-85%. Seeds germinate well at 18-21 °C when supplemented with light. The recommended seedling density is up to 300/m². Seeds are shallowly sown and lightly covered. Seeds germinate within 5-7 days, and seedlings are ready to transplant in about 3-4 weeks. Seedlings can be stored for up to 6 weeks at 2-7 °C with supplemental fluorescent light.

The seed crop needs to be isolated from other varieties by at least 100m. The spacing of 20, 30 and 40 cm is recommended

for dwarf, medium and tall cultivars, about 115-125 cm²/seedling. Plants are pinched when they are 15 cm high to induce development of side shoots. Pinching delays flowering. Following pinching, the axillary shoots develop from leaf axils. Only the desired number of shoots should be maintained to produce a high-quality seed crop.

Sweet allysum (*Alyssum maritima*): Alyssum belongs to the Cruciferaceae family. It is a short-growing plant (20-30 cm) with narrow light green leaves and white, pink or yellow inflorescence covering the entire top surface. The optimum temperature and relative humidity are 21-24 °C and 90-95%, respectively. First flower appeared on 3rd week of February, when transplanted on 2nd week of December.

The seeds are very small (3500-4000 seeds/g). A minimum isolation distance of 400 m must be maintained from other crops. Flowering period was 60 days. The crop is harvested before shedding of seeds begins. Individual pods of Alyssum are removed when they begin to dry. The seed yield/m² and per acre was 15.08 g and 49.76 kg respectively.

Zinnia (*Zinnia elegans*): Zinnia is an all-time favourite annual for its easy cultivation, its difference in height and flower colour, good keeping quality of flowers, etc. The flowers are white, yellow, crimson, orange, rose, etc in colour.

In the plains, zinnias can be grown throughout the year and the seeds are sown in succession. Soak the seeds in GA3 100ppm for 16 hours to improve germination. The seeds are sown in nursery beds and are transferred to the permanent positions when the seedlings are at 4 leaf stage. The seeds can also be sown directly in permanent positions. As the zinnias are susceptible to frost, in the hills, seeds are sown in March-April. They start sprouting within 2-3 days. When the seedlings are about 15-20 cm height they should be pinched back to make the plants compact and bushy. About a month after transplanting, a fertilizer mixture as top dressing will encourage good growth and better flower production. Regular watering is essential for this annual (Mukherjee, 1999) [10]. Harvest the seeds at 40 days after anthesis.

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