Review Article

OVERVIEW OF SEED PRODUCTION IN FLORICULTURE CROPS

Abstract

Floriculture, one of the potential components of horticulture industry, deals with cultivation, processing and marketing of ornamental plants and maintenance of garden and it includes annuals (seasonals), biennials and perennial ornamentals. Worldwide demand for flowering annuals is high to beautify our landscape. The majority of annuals can only be propagated by seeds. The flowering annual seed business has developed into a significant industry as a result of the demand for these plants in the global floricultural trade. The majority of the flower seeds are imported into India. As a result, flower seeds are very expensive and difficult to obtain for farmers. Every species of flower raised for seed has its own planting period, culture, difficulties, and harvesting processes. There is one fundamental prerequisite for good seed production-a mild environment with little rain during the growth and harvesting seasons. Hybrid seeds of these plants have high vigour and superior quality. Hybrid seed production for the export market is very crucial. The production of seeds in flower crops is covered in this review.

Introduction

The development of the Alsmeer market in the Netherlands in 1910 opened up the possibility of floriculture as a successful agricultural enterprise. Due to the enormous rise in demand and consumption for the floriculture business, it has turned into a viable source of income for third-world countries. As a result, there is a greater need for flower seeds to landscape homes, schools, roadways, farm complexes, and industrial buildings along with other ornamental crops. In India, during the decade after liberalization floriculture industries took giant steps in the export arena. This era has seen a dynamic shift from sustenance production to commercial production. Flowers are valuable products that are used in a variety of home and social contexts as well as in enterprises, including those that extract natural dyes, dry flowers, and essential oils. Farmers have the opportunity to improve their standard of living and produce more money per square foot by growing flowers. In recent years, politicians, scholars, and agricultural and horticultural planners in India have shown a great deal of interest in floriculture. The demand for flowers has expanded as a result of urbanization and rising per capita income. According to the National Horticulture Board, 322 thousand hectares are planted in flower crops, producing 828 thousand tonnes of cut flowers and 2152 thousand tonnes of loose flowers in 2020-21.

Compared to cereals, the income per acre is two to five times higher, but the production costs are correspondingly higher. Field labour accounts for more than half of the costs and must be performed with such dexterity that competent work is on the verge of becoming a craft. Every species of flower grown for seed has its own planting time, culture, problems and harvesting techniques, but there is one basic requirement for good seed production-a mild climate with little rain during the growing and harvesting seasons. While cooler climates are better suited for higher flower seed production, unreliable and often poorer conditions result in lower yields and germination percentages. The opportunity to grow flowers under natural settings for extended periods of time and under various conditions is made possible by the diverse agro-climatic conditions in India. In natural environments, this guarantees the yearly production of seeds. Favorable weather circumstances permit crops to have a long growth cycle, which results in good quality production.

Crops

Annual crop seeds like Ageratum, Aster, Antirrhinum, Balsam, Celosia, Cosmos, Candytuft, California, Poppy, Carnation, Galliardia, Gazania, Hollyhocks, Heliehrysum, Larkspur, Marigold, Pansy, Phlox, Petunia, Salvia, Verbena, Zinnia, Gypsophilla, and others have a lot of potential for commercialization and are in high demand.

Since the middle of the 1960s, a company Indo American Hybrid Seeds (India) Pvt. Ltd., Bengaluru, has been producing F_1 hybrid seeds of Petunia for 100 per cent export. However, Mr. Singh, M/s Beauscape Farms, Sangrur, Punjab, who began flower seed production involving farmers on a massive scale, revolutionized the production of seeds of open-pollinated flower crops.

Many companies have started producing seeds on a large scale for export to Holland, the U.K., the USA, France, Germany, and Japan, etc. At present, in India, the area under flower seed production is about 600–800 ha. Punjab (Sangrur, Patiala, and Ludhiana); Haryana (Panipat, Sirsa); Karnataka (Bengaluru, Ranebennur); Himachal Pradesh (Kullu Valley); J & K (Sri Nagar Valley); and West Bengal (Kalimpong) are the principal flower seed production regions in India. With a turnover of more than 60 million, Punjab alone contributes to 45–50 % of these, or 450 hectares, of seed production areas.

Employment generation and money minting venture: The labor-intensive process of producing seeds necessitates a sizable labour force. As a result, the floriculture industry has the potential to employ thousands of young people. Production of seeds has the potential to bring in revenue worth crores of rupees when done scientifically. Compared to other horticultural and agricultural products, this industry will generate more revenue, and basic inputs are the minimum to start a venture.

Prerequisites

1. **Policy initiative:** The production of seeds is either limited to individuals with backyard lawns or to a few commercial growers that do so on a somewhat bigger scale, but the production level is still insufficient to compete in the market. To increase seed production on a massive scale through contract farming, serious regional and national initiatives must be supported.

2. **Scientific intervention:** Seed production is still practiced on the basis of tradition, although modern agro-technology calls for growing crops according to scientific principles. To achieve both qualitative and quantitative results, it is important to address a few critical issues, including variety selection, production module, harvesting, and post-harvest management.

3. **Infrastructure:** The seed industry requires infrastructure for production, processing, and packaging, such as polyhouses, seed sowing equipment, processing machinery, *etc.*, which is absent in the case of annual seed production. For starting commercial manufacturing, a fundamental challenge is a lack of infrastructure support.

4. **Awareness about profitability and skill development:** Due to lack of knowledge regarding economics, flower cultivation with farmers has been confined to tiny regions. Farmers must be made more aware of the profitability of this industry and its potential advantages. The improvement of labour skills is one of the key requirements in order to handle the technologically complex activity of seed production.

5. **Efficient seed programme:** Effective seed programmes include defining cultivars for a particular crop, determining the best regions for high-quality seed production, surveying the market for local and exported seed demand, and fostering the seed trade.

6. **Financial sources:** The industry will be promoted through locating and enabling funding sources for the procurement of planting material, shade nets, irrigation and fertilizing systems, and other related items.

7. **System of marketing:** Connection to the country's diverse markets and the lack of appropriately located auction sites. This business initiative will be promoted using a structured marketing strategy.

F_1 hybrid seed production

Two homozygous yet genetically different parental lines are crossed to produce F_1 hybrids. Shull (1911) introduced the concept, coined the term heterosis, and described hybrid vigour. The combination of a large number of dominant genes that contributed to vigour in the first generation period is entirely responsible for hybrid vigour. Hybrid vigour is defined as the increase in the size or vigour of a hybrid over its parents (Reimann-Philipp, 2013). Prima Donna, a hybrid variety of begonia (*Begonia semperflorens*), was most likely the first F_1 plant introduced for use in floriculture by the Benary Seed Company in Germany in 1909. The first commercial F_1 hybrids in Petunia were produced in Japan in the 1940s. Later, several seed companies in the United States, China, Japan, the Netherlands, Denmark, Germany, the United Kingdom, and Israel produced F_1 hybrids in flower crops like Ageratum, Anemone, Primula, Petunia, Gerbera, Tagetes, Cyclamen, Pansy, Begonia, Geranium, Portulaca, Dianthus, balsam, stock, wall flower, ornamental sunflower (*Helianthus annus*), Gazania, Calceolaria, and Zinnia. We need purelines in self-pollinated species or inbred lines in cross-pollinated species to produce F_1 hybrids. The progeny of a single, homozygous, cross-pollinated plant are known as purelines.

The progeny of a single, homozygous, self-pollinated plant are known as inbred lines (De and Bhattacharjee, 2011). To enhance hybrid seed production there must be easy emasculation of the female parent and effective pollen disposal from the male parent to ensure a satisfactory seed set in the female parent.

Table 1: Flower crops and their mode of pollination

Mode of pollination	Flower crop
Self pollination	Balsam, Clianthus, Lupin, Sweet pea
Often cross-pollination	Antirrhinum, Aster, Dahlia, Salvia, Wall flower, Linum, Linaria
Cross pollination	Alyssum, Arctotis, Calendula, Cineraria, Gazania, Stock, Zinnia
Outbreds	Ageratum, Cornflower, Delphinium, Marigold, Verbena, Nemasia, Chrysanthemum

Crossing mechanisms for commercial hybrid seed production

1. Hand emasculation and pollination
2. Genetic male sterility (Marigold, Zinnia, Ageratum and Calceolaria)
3. Cytoplasmic male sterility (Petunia)
4. Self incompatibility (Petunia, Pansy, Stocks and Ornamental kale)
5. Chemical emasculation-selective elimination of pollen production by using gameticides such as FW -450 or Mendok, Maleic hydrazide, Coumarin

Hybrid seed production techniques (Ashok and Velmurugan, 2020)

Self incompatibility (SI): It is a prefertilization reproductive barrier controlled by a single locus, S, with multiple alleles that encodes the specificities and it was first discovered in a flower crop, *Verbascum phoeniceum*, when self pollinations of a fertile plant did not set seed. There are two different kinds of SI systems: sporophytic and gametophytic. In ornamentals, Nicotiana and Petunia have a self-incompatibility mechanism that is gametophytic and can be used for cross-pollination in open field conditions. The abundance of seeds produced by these two flowering plants, which can adequately compensate for the high cost of F_1 hybrid seeds, is an additional benefit. Lily, evening primrose, heliconia, etc., are also governed by gametophytic SI. Due to the sporophytic mechanism of self-incompatibility in verbena, ageratum, zinnia, marigold, chrysanthemum, dahlia the seed set is influenced by the dominance of two SI alleles.

Double Flower Condition: All of the anthers in double flower types are changed to become ray florets. Ageratum, aster, chrysanthemum, cornflower, dahlia, daisy, gaillardia, marigold, rudbeckia, and sunflower are examples of compositae/asteraceae plants that exhibit this trait. The majority of the time, the conversion of the anthers into petals leads to a double flower. Therefore, it is possible to think of the double bloom character as a type of male sterility. In order to simulate male sterility, Reimann-Philip (1969) created a breeding strategy using the double bloom characteristic of garden carnations (*Dianthus caryophyllus*). Additionally, there are other floral abnormalities that cause male sterility, such as the "cinderella" character in begonia and "femina" in marigold and zinnia.

Triploidy: Triploid plants rarely or never set seed. A commercial triploid hybrid (2n = 36) of the flower species *Tagetes* is produced by breeding tetraploid male *Tagetes patula* (2n = 48) and diploid female *Tagetes erecta* (2n = 24). The triploid hybrid "Nugget" (*Tagetes erecta* × *Tagetes patula*) is remarkable for its capacity to keep the flowers on the plants for an extended period of time. However, in *Begonia semperflorens*, the loss of uniformity in triploids has been reported by Reimann-Philipp (2013).

Male Sterility: With the use of male sterility, ornamental sunflower varieties like "Sunrich Orange" (Japan) and "Orit" (Israel) have been created that do not produce pollen grains or allergic reactions like other male fertile kinds grown for their seed do. Both the male sterility and the self-incompatibility mechanisms are present in Ageratum. Cytoplasmic male sterility in Petunia has been observed, but due to the breakdown of male sterility in the maternal parent or the flower deformity in F_1 plants, this type of male sterility is rarely used on a regular basis. Where a single recessive gene controls genetic male sterility (pollen sterility), maintaining the genetic stock will be challenging since there will always be a 1:1 segregation of fertile and sterile individuals. Tagetes, Zinnia, Delphinium, Antirrhinum, Calceolaria, Salvia, and Impatiens all exhibit this phenomenon.

Agronomic principles of seed production and seed storage

Agronomic principles

Agronomic concepts are employed in seed production technologies to maintain the high quality of seeds. The following headings can be explored in relation to agronomic principles:

- **Agro-climate and location**

The type of crop that will be grown for seed production needs an appropriate agro-climate that is adapted to the prevailing photoperiod and temperature conditions in that location. For crop varieties sensitive to photoperiods and temperature to be grown profitably, certain locations must be chosen. It is far more advantageous for seed production to have moderate rainfall and humidity.

Seasonals are categorized into three seasons, as the name suggests: summer, rainy season and winter. In contrast to the abundance of winter annuals, summer and rainy season annuals are scarce in India. Winter annuals hence require greater relevance for the production of commercial seed. It is best for seed production to have a prolonged period of cool, dry weather since it encourages healthy seed germination and large seeds. In the northern Indian plains, an excessively hot and dry season hinders summer annual seedlings. Pollen grains are washed away by excessive rain during flowering, which leads to poor seed set.

The following climatic zones are designated for the production of flower seeds based on their climatic requirements:

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

The following are desirable traits of land chosen for seed crops:

i. The soil should have the fertility and texture that the crop requires
ii. The plot should be clear of weeds, other crop plants, and volunteer plants
iii. The chosen plot's soil should be comparatively free of pests and diseases that are transmitted through the soil
iv. On the same plot, the same crop or variety shouldn't have been grown the season before

- **Plot selected for seed production and isolation distance**

The plot must be level, free from volunteer plants and feasible for isolation as per the requirements of certification standards.

According to the requirements of certification standards, crops must be appropriately separated from neighboring fields of some or all contaminated crops called *i.e*. maintaining proper isolation distance is pre-requisite. Leaving enough space between seed plots and contaminated areas will help to isolate the seed crop. Self-pollinating plants like *Impatiens balsamina*, *Dianthus chinensis, Dianthus caryophyllus, Dianthus barabatus*, *Lathyrus odoratus*, and *Lupinus* sp. Do not need to be isolated from other plants, where as *Antirrhinum* sp., *Godetia sp*., *Linaria* sp., *Lobelia* sp., *Petunia* sp., *Phlox* sp., *Salvia splendens*, *Verbena* sp., and *Viola tricolor* are often cross-pollinated and require 100 m isolation distance and *Althea rosea*, *Alyssum* sp., *Calendula* sp., *Celosia plumosa*, *Centaura* sp., *Chrysamthemum* sp., *Clarkia* sp., *Cosmos* sp., *Coreopsis* sp., *Gailardia* sp., *Gomphrena* sp., *Helianthus* sp., *Helichrysum* sp., *Iberis* sp., *Impatiens* sp. and *Zinnia* sp. are cross-pollinated and require 400 m isolation distance.

- **Variety**

The choice of an appropriate variety is crucial for seed production. Normally, it is best to choose cultivars that yield lots of seeds. The chosen variety should be high-yielding and suitable for the local agro-climatic conditions.

The highest number of seeds per peduncle (461.67) were obtained by genotype TEG 20 of the African marigold, while the highest values for the parameters weight of seeds per peduncle (3.100 and 2.65, respectively) and seed yield per plant (164.47 and 123.67, respectively) were held by germplasm TEG 26 and TEG 29 (Deepti *et al*., 2008). In comparison to Poornima and Sarpan purple, the Kamini genotype of China aster had the highest values for the parameters measuring seed yield, including capitulum diameter (4.43 cm), capitulum weight (1.49 g), filled seed percentage (80.53 %), filled seed weight per capitulum (0.23 g), 1000 seed weight (1.70 g), seed weight per capitulum (0.26 g), seed yield per plant (3.54 g), and seed yield per hectare (262.67 kg) (Rakesh *et al*., 2008). In contrast, Arka Poornima had the maximum seed yield per plant (3.45 g), while Arka Aadya had the lowest yield (1.93 g), thus Arka Poornima was shown to be the best genotype for West Bengal conditions (Chakraborty *et al*., 2019). The Purple cultivar of zinnias produced the highest seed yield per inflorescence (0.235 g) during the first season of experimental trial, whereas the Yellow cultivar produced the highest seed yield during the second (0.224 g). The highest seed yield per plant was produced by Red and Yellow cultivars of plants, respectively, in the first and second growing seasons (Dorgham, 2019).

- **Pre-conditioning of seeds**

Seeds should be procured from authorized official agencies and be of recognized purity and quality. Before sowing, the seeds may need to be treated. Pre-conditioning refers to this. There are several methods for it, including:

i. Abrasion (such as rubbing with sandpaper or tumbling in drums with loose sand or gravel)

ii. Immersing the seed in hot water and letting it cool over a period of twelve to twenty-four-hour.

iii. Soak the seeds in concentrated sulfuric acid until the seed coat is paper-thin but the embryo is unaffected.

- **Sowing time**

Winter season annual seeds should be sown between mid-September and mid-November, while summer season annual seeds should be sown between mid-April and mid-May. Planting date is influenced by the environmental conditions and geographic location of the area that have an impact on growth and flowering. Planting times cannot be standardized on a national scale since natural environmental circumstances greatly vary plant development and flowering dates. To acquire the best growth, flowering, and seed yield of various annuals, it is necessary to determine the planting period for the specific zone because environmental circumstances vary from one place to another.

The dahlia that was sown early, on September 25^{th}, produced a maximum seed yield of 11.13 g, and the dahlia that was sown on October 10^{th} produced a value of 8.75 g per replication. The 25^{th} of October's sowing treatment produced the minimal yield of 5.88 g (Afzal *et al*., 2000). The seed yield in *Coreopsis lanceolata* decreased as the planting was delayed beyond the first week of November; this was measured as being the highest, 90.32 g/m^2 under the first planting, followed by 76.97 g/m^2 under the second planting in the third week of November. The other species, *Coreopsis tinctoria*, recorded a maximum seed yield of 98.68 g/m^2 after a second planting in the third week of November (Dhatt and Kumar, 2007). When compared to other plantings (September, November and December), October planting of China asters had larger capitula (4.31 cm in diameter), heavier capitula (1.42 g), and higher number of capitula per plant (15.25) (Rakesh *et al*., 2008). In the case of the French marigold, flower yield per plant (96.49 g), number of seeds per flower (44.00), and seed yield per plant (4.86 g) and in the case of the African marigold, significantly higher numbers of seeds per plant (165), seed yield per plant (14.51 g), and test weight (2.63 g) were recorded during the Kharif season under Bengaluru conditions (Pramila *et al*., 2011). According to *et al*. (2017), annual chrysanthemum planted on September 17th produced the highest number of heads per plant (308), number of seeds per head (243.95), seed yield per plant (77.40 g), and 1000 seed weight (1.67 g), whereas the December planted treatment produced the lowest results. As a result of the early, favourable warm weather on September 17th, candy tuft plants produced considerably more siliquae per plant (3467.72), seed yield per plant (10.25 g), and 1000 seed weight (2.18 g) than those planted later. The flowering period and flower size may have contributed to an increase in seed output. Higher seed yields were obtained from larger flowers, and heavier seeds were set when a plant bloomed for longer periods of time. The treatment that produced a higher yield could have produced more flowers. According to Vaagdevi *et al*. (2020), *Gaillardia pulchella* planting in the first week of January produced the highest seed yield per plant (37.05 g), per plot (0.81 g), and per hectare (20.25 q), whereas planting in the first week of October resulted in the highest germination percentage (63.50 %). The first week of January may be the ideal planting period among all others for seed production.

- **Sowing method and plant population**

Mechanical drillers are generally used to sow the seed crop in rows, making it possible to plant the desired quantity of seeds at a consistent depth. To prevent infection, the sowing tools must be thoroughly cleaned. To ensure proper planting, small seeds are often placed shallowly and large seeds slightly deeper. In sandy soils as opposed to clayey soils and from warmer soils, seed emergence is better from higher depths.

In flowering annuals, the plant population per unit area has a significant impact on the final seed yield. To allow air and sunlight to reach each developing inflorescence at the base of the plant, adequate spacing is provided both within rows and between rows, depending on requirement of the crop. The practice of spacing varies according to cultivar habits and agro-climatic regions. Various changes to plant growth are brought about by high plant density.

According to the findings of study by Shivakumar (2001), marigold produced the highest net returns per hectare (Rs. 17,863) and had a greater yield of high-quality seed (579.7 kg/ha) when 270:72:72 kg of NPK were applied per hectare with 60 × 30 cm of spacing. In ageratum, broader spacing (45 × 45 cm) was shown to produce much more capitula (372/plant) and significantly more seed per plant (3.96 g) than narrower spacings (30 × 30 cm and 30 × 45 cm) (Balachandra *et al*., 2004). Maximum seed yield for *Coreopsis tinctoria* was 83.97 g/m at a planting density of 60 × 60 cm compared to 81.31 g/m at 60 × 30 cm (Dhatt and Kumar, 2007). Wider plant spacing was associated with higher seed yield per plant. The increased number of plants per unit area led to a higher seed yield per hectare (453.5 kg) when the plants were spaced closer in African marigold (Sunitha and Hunje, 2010). Compared to wider (30 plants/m^2) spacing seed production (436.15 kg/ha) rose with higher planting density (42 plants/m^2) (436.15 kg/ha and 485.55 kg/ha, respectively). Denser planting produces more seeds since there are more plants per unit space as opposed to fewer plants per unit area with broader spacing (Wani *et al*., 2019).

- **Rouging and pollination**

The most crucial process in seed production is timely and adequate rouging. Rogues that are out of the ordinary (weak or sickly plants, bolters, and off-types) are removed and discarded as soon as possible phase.

There is tremendous scope for seed production of open pollinated variety and F_1 hybrids of seasonal flowers. An outcome in successful pollination is good amount of viable seed set. To make the seed production more successful, it is necessary to have information on floral biology, mode of pollination and their effect on seed set. For a satisfactory seed set and consequent increase in seed production, additional pollination by honey bees may be required in close proximity to insect-pollinated seed crops.

Hand pollination was proved to be the best method in glory lily as it revealed superior pod characters, higher seed weight per pod (3.04 g), number of seeds per pod (74.0) and shelling percentage (61.78 %) accompanied with higher germination (54 %) and vigour index (1252) of the seeds (Venudevan *et al*., 2011) and stigma continued to attain the maximum receptivity one day post anthesis. Capsule set in pansy (*Viola* × *wittrockiana*) with open pollination was 32–64 %, with self-pollination by hand 18–49 % and with cross-pollination by hand 14–43 per cent. Hence, Dalbato *et al*. (2013) suggested an agent-mediation for successful pollination in self-compatible pansy. Bhondave *et al*. (2016) concluded that Phule Ganesh Pink and open pollination method is suitable for mixed seed production and close planting and bagging method of crossing is used for pure seed production in China aster. Pollination traits in orchid strongly influenced seed set with self-pollination highest (59-95 %), followed by sexually deceptive autumn or winter-flowering (18–39 %), visual deception (0-48 %) and sexually deceptive spring-flowering (13–16 %) as concluded by Brundrett (2019).

- **Application of plant growth regulators (PGRs)**

The PGRs can be biostimulant or bioinhibitor and are active even at very low concentrations in plant cells and have ability to alter the growth and development. The use of PGRs to suppress vegetative growth, reduce plant height, change plant shape, size, and form, and promote flower initiation and uniformity are among the chemically manipulated plant growth techniques that are attracting more and more attention in floriculture (Davis and Andersen 1989). Growth regulators applied prior to flowering increases not only the quantity and quality of flowers but also the seed production, primarily by increasing the number of seeds. These have recently been very important in overcoming the limitations restricting the yield and quality to obtain benefit from seed production. It is realised that the exogenous application of growth regulators stimulates flowering, pollination, fertilization, and seed setting to yield better quality seeds.

PGRs affect the balance of plant hormones in treated plants. This can primarily be achieved by applying exogenously naturally occurring hormones or their synthetic analogs, by inhibiting the biosynthesis of endogenous hormones or their translocation from the site of production to the site of action and by blocking hormone receptors. The “classical” groups of plant hormones are the auxins, gibberellins, cytokinins, abscisic acid, and ethylene. To date, brassinosteroids and jasmonates should also be regarded as having phytohormonal functions.

In hybrid dahlia 'Unwins Mixed,' paclobutrazol (@ 1.0 kg a.i./ha), sprayed at the first visible bud, enhanced seed output (8.62 g/plant) and the number of seeds/seed head (46.4) (Phetpradap *et al*., 1994). Pasian and Bennett (2001) observed that soaking seeds of marigold (*Tagetes patula* L.) var. Bonanza Gold in 500m g L^{-1} paclobutrazol for 6, 16, or 24 hours resulted in 30, 38 and 41 per cent of growth restriction respectively. Gopichand *et al*. (2014) found that the best treatment for obtaining the maximum flower weight (4.42 g), seed yield per flower (0.99 g), number of filled seeds (200.13), thousand seed weight (3.14 g), germination percentage (77.18 %), and seedling vigour index (695) in African marigold was foliar spray of MH at 1000 ppm + boron at 0.2 per cent. Spraying GA_3 at 200 ppm on annual chrysanthemum increased the number of capitulum per plant (91.60), amount of seeds per capitulum (265.33), dry weight of the capitulum (0.747 g), the weight of 1000 seeds (2.14 g), and seed yield (6.75 g/plant and 500 kg/ha) (Sainath *et al*., 2014). In China aster *cv*. Kamini, GA3 200 mg/l spray, the number of flowers per plant (84.96), flower yield per plant (109.66 g), flower yield per hectare (16.58 t), seed production per plant (9.98 g), seed yield per ha (1509.31 kg), and 1000 seed weight (2.01 g) were all significantly greater (Pavankumar *et al*., 2015). African marigold plants had maximum plant height, seed yield, weight of seeds per flower and longevity of intact flower with the treatment of GA_3 300 ppm (Patil *et al*., 2016). The application of GA_3 at 200 ppm in zinnia led to considerably larger numbers of seeds per flower (48.22), seed production per plant (2.91 g) and per hectare (1.332 q), thousand seed weight (7.57 g), and germination (85.14 %), according to results by Surabhi *et al*. (2018). Salicylic acid at 200 ppm produced the maximum seed yield per hectare (3.27 q), flower diameter (7.40 cm), test weight (2.77 g), and number of seeds per flower (197.61) among the various chemical concentrations treated to African marigold (Khobragade *et al*., 2019). Results of the study by Kumar *et al*. (2020) suggested that foliar spray of 250 ppm gibberellic acid at 25 days after transplanting enhanced growth, and improved seed yield and quality parameters of marigold.

- **Irrigation and nutrition**

To get a good seed production, irrigation is necessary. It might be necessary prior to planting and then periodically up to the flower. Many seed crops could benefit from just one or two irrigations. The physical texture of the soil, rainfall, and crop needs all affect how often and how much water is delivered. At the vegetative, blooming, and mature stages, seed crops are quite vulnerable to moisture stress. In order to create the dry conditions required for harvesting, irrigation should be stopped two to three weeks prior to seed maturity.

The effective growth and development of seed crops depends on the availability of sufficient levels of N, P, and K as well as other necessary elements. In order to maintain optimal nutrition at all phases of crop growth, it is important to understand the nutritional needs of each specific seed crop. Chemical fertilizers are a significant source of nutrients, but they are also expensive and may face additional limitations due to growing environmental concerns and the limited availability of non-renewable resources. Chemical fertilizer use poses a serious challenge to maintaining healthy soil and crop productivity. The greatest choice at this time is to use chemical fertilizers less frequently and in combination with other nutrient sources as we are unable to entirely stop using them. Usage of environmentally acceptable, economically viable, and widely accessible biofertilizers is required for the development of a more effective fertility management programme in order to reduce the use of these inputs (chemical fertilizers) without affecting the overall production and the ecosystem. For sustainable floriculture, these are viable, renewable alternatives to chemical fertilisers as plant nutrients. The negative effects of current practise can be fully avoided by using biofertilizers in addition to chemical fertilisers (Maurya and Beniwal, 2003).

According to Shivakumar (2001), marigold produced the highest net returns per hectare (Rs. 17,863) and had maximum yield of high-quality seed (579.7 kg/ha) when 270:72:72 kg of NPK were applied per hectare with 60 × 30 cm of spacing. With the application of 240:180:80 kg NPK per ha in China aster, Doddagoudar *et al*. (2002) observed an increase in the number of capitula per plant (24.2), weight of the capitulum (1.77 g), capitulum diameter (5.10 cm), seed weight per capitulum (0.33 g), weight of the filled seed per capitulum (0.26 g), the filled seed percentage (78.7 %). Higher fertilizer dosages (100: 100: 60 kg NPK ha^{-1}) compared to lower doses in ageratum resulted in the highest number of capitula per plant (370) and seed yield per plant (3.91 g) (Balachandra *et al*., 2004). African marigold plants supplied with 50% RDF + 50% RDN through vermicompost (F_5) recorded higher number of flowers per plant (66.2) higher seed yield (18.6 g/plant and 499.0 kg/ha) compared to F_1 (RDF-225:60:60 kg NPK/ha)(9.2 g/plant and 325.3 kg/ha) (Sunitha and Hunje, 2010). When compared to control, the treatment combinations of NPK 21:12:7.5 g m^{-2} + Azotobacter + PSB + KSB produced the highest number of primary branches (9.73), plant spread (66.55 cm^2), shortest days to anthesis (48.88 days), longest flowering duration (42.42 days) and highest seed yield per plant (21.19 g) in zinnia (Slathia *et al*., 2019). K-citrate produced considerably more seeds per flower and per plant during both of the study's seasons (0.255 and 0.250 g and 3.593 and 3.505 g, respectively), results that were comparable to those of K-humate and K-nitrate in zinnia (Dorgham, 2019).

- **Harvesting or seed collection**

The irrigation should be withheld for a fortnight before starting flower picking or seeds of annuals. As soon as the plants have completed their life cycle, the seed harvest should begin before the pods split or the seeds fall apart at the correct maturity. The maturity of seeds is not attained at a uniform time in the majority of the seasonal flowers. For the whole crop of seeds, 3–4 pickings are required. From the first week of April and onward, the seeds of the majority of winter annuals are ready for collection. In August and September, seed is collected for summer annuals like zinnias and cosmos (if cultivated as a summer annual), and in mid-September and later for cockscomb and Celosia species.

Methods of seed collection

i. Hand Picking: Individually collecting mature seeds from flowers, pods, or complete flowers is the simplest way to collect seeds. This process takes a lot of time and effort. This method is used to harvest *Cosmos sp*., *Calendula sp*., *Gaillardia sp*., *Gazania sp*., *Helichrysum sp*., *Tagetus sp*., *Nicotiana sp*., *Voila sp*., *Petunia sp*., *Verbena sp*. and *Zinnia sp*.

ii. By Shattering: By gently tapping a cluster of flowers with a hand or wooden frames on plastic sheets, come trays, etc., to shatter the seeds. This method is simple since it allows quicker seed collection than the earlier method. This approach is used to harvest *Alyssum sp*., *Bellis sp*., *Celosia sp*., *Amaranthus sp*., *Linaria sp*., and *Dianthus sp*.

iii. The seeds are collected manually, and the inflorescence is removed when more than half of the seeds or pods have attained full maturity. To avoid the seeds shattering, the plant's inflorescence is first placed into a plastic basket or on a plastic sheet before being cut with secateurs. All species of amaranthus, antirrhinum, celosia, coreopsis, delphinium, verbena, and petunia are harvested by this method.

iv. Whole plant harvesting: It is the simplest way to collect seeds. For the purpose of shattering seeds from flowers, the entire plant is removed when the seeds are fully matured. The seeds are then collected by thrashing or gentle rubbing the plant. It is necessary to dry seeds in the shade and clear them of floral traces, weed seeds, inert broken seeds, etc. The simple collecting and cleaning of seeds is now made possible by a variety of vacuum-based machinery. This type of harvesting is used for *Tropeolum sp*. and *Linaria sp*.

Harvesting a crop at a suitable stage increases the seed yield and its parameters. From 14 days after anthesis (0.56 g) to 28 days after anthesis (0.69 g), African marigold seed yield increased gradually. The highest seed yield per flower was reached at 28 days after anthesis, which was attributed to its optimum physiological maturity, at which time seeds are said to be fully developed due to maximum accumulation of food reserves, phosphorous active substances, dry matter, sugar, aminoacids, water soluble proteins, acids, and nicotinic acid levels in seeds (Gopichand *et al*., 2014). Seeds harvested 49 days after flowering had the highest percentage of germination (67.91 %), closely followed by seeds harvested 42 days after flowering (66.15 %). According to Ambia *et al.* (2017), China aster seeds harvested at 42 days after flowering possessed the highest root length (3.38 cm), shoot length (3.27 cm), seedling vigour index (439.56) and seedling dry weight (12.10 mg/seed). Capitulum diameter (4.30 cm), capitulum weight (1.44 g), number of capitula per plant (14.58), filled seed percentage (77.44), filled seed weight per capitulum (0.19 g), 1000 seed weight (1.65 g), seed weight per capitulum (0.25 g), seed yield per plant (3.64 g), and seed yield per hectare (269.91 kg) were significantly higher in China aster plants harvested at 140 days after transplanting (DAT).

Seed Storage

The two key elements that affect how long seeds last in storage are seed moisture and storage temperature. Research on seeds has traditionally placed a greater emphasis on storage temperature than seed moisture in order to prolong seed viability. However, a number of studies have indicated that, particularly in tropical environments, seed moisture may be more important than temperature in extending the vitality of seeds (Justice and Bass, 1978). To ensure long-term preservation, the seeds are dried to a moisture content of 5-6 per cent and stored at a subzero temperature (Anon, 1994). Less than 4-5 per cent moisture content in seeds was considered to be detrimental to their viability. However, research has revealed that seeds can be dried down below 4-5 per cent and, in certain species, even below 1 % without harming the viability and genetic fidelity of the species.

Successful storage requires properly ventilated, moisture-free storage. Ornamental seed crops are stored using standard, temporary shelters or stores, storage in vapour-proof containers, storage in polythene bags, air-cooled seed storage, and refrigeration.

China aster seeds stored at 15 °C for 18 months maintained high viability (57 %) and vigour despite packing material and seed moisture levels. However, in case of ambient storage, drastic decreases in germination (6 %) and vigour were seen in all packing materials at all seed moisture levels. Seeds should be kept at 15 °C and 30 per cent relative humidity for optimum storage (Yogeesha *et al*., 2004). After six months of storage, China aster seeds stored in aluminum foil showed the highest germination percentage (85.17 %), maximum germination index (31.29) and greatest seedling vigour index (350.33) while those stored in cloth bag showed the lowest value (Thu, 2015). Cornflower exhibited the highest rate of germination among the winter annuals right after harvesting (90 %) while annual chrysanthemum and poppy showed no signs of germination. Five months after harvest, cornflower had the highest germination rate, while saponaria and lupin had the lowest (64.66). The annual chrysanthemum had the lowest pool germination percentage (46.72) over the course of the season and cornflower had the highest (81.88). Acroclynium had the highest pooled vigour index for the season (659.05) and poppy had the lowest (222.56). A minimum germination rate of 60 per cent is required by the seed standard for flower crops. This experiment revealed that all the winter annuals under study maintained a 60 per cent germination rate over the first five months of storage (*i.e*., the following planting season) in desiccators (Kumari *et al*., 2017). China aster seeds stored in an aluminium foil packet for four months showed the highest germination (66.53 %) and vigour index (403.87) compared to other treatments. So an aluminium foil packet is good after four months after storage. Seeds stored in aluminium foil packets had the highest germination rate (46.54 %) and vigour index (269.58) as of eight months after storage. It is advised to maintain improved seed quality storage when preserving China aster seeds (Mahato *et al*., 2019).

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