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Cultivation and Cultural Practices Followed in Carnation (*Dianthus caryophyllus* L.) for Better Production: A Review

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ABSTRACT

Carnation (*Dianthus caryophyllus* L.) from dicotyledonous Caryophyllaceae family is one of the important floricultural crop is cultivated all-year-around in temperate areas. In addition, the lengthy vase life of carnations may have great implications for wholesale and retail markets. It is genetically a quantitative long day plant and sensitive to temperature, which is a major factor that influences the growth and flowering, color, grade and the quality of cut flowers. Commonly grown Chaubad and Marquerite carnation are propagated by seed and other different types can be propagated through different ways of propagations like terminal cutting and tissue culture. The soil should be ploughed thoroughly up to 80-100 cm. deep and organic manure is to be mixed with soil properly. Soil sterilization should be done prior to planting. Rooted cuttings of standard carnations are planted on raised beds with a spacing of 20×20 cm and spacing of 30×30 cm is ideal for spray carnations. However, the lateral shoot development is best at a density of 50 plants/m^2. Apart from major nutrients like N, P and K, Ca, Mg, B and Fe also play a crucial role in carnation nutrition. Spray of 0.1% urea and potassium nitrate (KNO_3) and 1 ppm Boron at 10 days interval till flowering produces good quality flowers. The plastic nets having a mesh of 7.5-10cm supported by stakes of metal fixed at the corner of beds is an ideal method. During pinching, the tip of the stem is removed to encourage the growth of the standard or Sim Carnations. Only 4-6 well grown lateral shoots will be allowed to grow. Splitting carnation flower calyces; is one of major limiting factor that affect both pre and post-harvest quality of carnation flowers. The problem of calyx splitting can be controlled by regulating temperature. Higher nitrate to ammoniacal nitrogen ratio during low light periods are recommended to reduce splitting. The optimum stage of standard carnation for distant market is paint brush stage when petals have started to elongate outside the calyx. The spray varieties are harvested with 2 open flowers on each stem. The flowers after harvesting and grading should be pulsed with 10% sucrose+1mm silver thiosulfate (STS) for 8-10hr before transportation to increase storability and vase-life of cut carnations.

Key words: Carnation, Cultural practices, Cut flower, Growth pinching, Sucker.

India is bestowed with several agro-climatic zones conducive to the production of sensitive and delicate floriculture products. The government of India has identified floriculture as a sunrise industry and accorded it 100% export-oriented status. Owing to the steady increase in demand for flowers, floriculture has become one of the important commercial trades in Agriculture. As per National Horticulture Database published by National Horticulture Board, during 2021-22 the area under floriculture production in India was 283 thousand hectares with a production of 2295 thousand tonnes loose flowers and 833 thousand tonnes cut flowers (Source: Ministry of Agriculture and Farmers Welfares, 3rd Advance Estimates, 2021-22). There is a huge demand supply gap in ornamnetals and presently it is being met by supply of cut flowers. The said gap was highest in rose with 244 lakh bunches followed by gerbera with 174 lakh bunches and lastly with 81 lakh bunches of carnation. The combined demand supply gap was 499 lakh bunches of cut flowers. The technical efficiency measures that the carnation is the most efficient one to fulfil the gaph at earliest (Thulasiram *et al*., 2022). Floriculture is now commercially cultivated in several states with Karnataka (15.85%), Tamil Nadu (15.16%), Madhya Pradesh (13.66%) and West Bengal (10.61%), having gone ahead of other producing states like Mizoram, Gujarat, Andhra Pradesh, Orissa, Jharkhand, Haryana, Assam and Chhattisgarh. Hence commercial floriculture has emerged as a hi-tech activity-taking place under controlled climatic conditions inside a greenhouse. Floriculture in India is being viewed as a high growth Industry. Commercial floriculture is becoming important from the export angle. It has been found that commercial floriculture has higher potential per unit area than most field crops and is, therefore, a lucrative business. The Indian floriculture industry has been shifting from traditional flowers to cut flowers for export purposes.

Carnation (*Dianthus caryophyllus* L.) from dicotyledonous Caryophyllaceae family is one of the most popular commercial flowers all over the world. As an

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important floricultural crop, carnation is cultivated all-year-around in temperate areas. In addition, the lengthy vase life of carnations may have great implications for wholesale and retail markets (Aalifar *et al.* 2020). While carnation longevity is frequently used to evaluate flower quality, harvest quality is expected to be extended when flowers are stored inside (Naing and Kim, 2020).

Carnation belongs to the family Caryophyllaceae, commonly called as the pink family. The genus name 'Dianthus' is derived from the Greek words 'dios' meaning 'God' or 'divine' and 'anthos' meaning 'flower' and hence known as 'Divine Flower'. The species name 'caryophyllus' is derived from the Greek word 'caryan' meaning 'nut' and 'phyllon' meaning 'leaf'. Linnaeus chose the species name, *caryophyllus*, after the genus of clove, as the fragrance from carnation is reminiscent of clove. The common name carnation is as well derived from a Greek word coronation as it was earlier used for decoration of the crown of Greek athletes.

Origin and significance

Carnation (*Dianthus caryophyllus* L.) a native to Mediterranean region (Salehi, 2006) is an important flower crop having great commercial value as a cut flower due to its excellent keeping quality, wide array of colours and forms (Pralhad, 2009). The plant family includes 2200 species and 86 genera (The Angiosperm Phylogeny Group III, 2009). The genus Dianthus includes approximately 300 species grow in Europe, Asia, South Africa (Jürgens *et al.,* 2003). Carnation growing countries are Italy, Spain, Colombia, Kenya, Sri Lanka, France, Holland and Germany. In India, carnation productivity centres are Bangalore, Pune, New Delhi, Himachal Pradesh, Andhra Pradesh.

Carnations have a sweet fragrance and commercially utilized for extraction of oil in France and the Netherlands. The volatile oil of carnation contains 40% benzyl benzoate, 30% eugenol, 7% phenylethyl alcohol, 5% benzyl salicylate and 1% methyl salicylate. It is used only in sophisticated perfumes. Carnation essential oil is used to heal wounds, asthma, eye diseases, relieve dizziness and restoring memory as well as act as antiseptic (Ibrahim, 2016). Carnation is used in perfumes (Usher, 1974).

Carnation, apart from producing cut flowers has also become useful in gardening for bedding, edging, borders, pots and rock gardens (Biondo and Noland, 2000; Dole and Wilkins, 2005). From medicinal point of view, the carnation flowers are considered to be cardiotonic, diaphoretic and alexiteric (Shiragur *et al.,* 2004). Carnation flowers are sold as cut flowers round the year throughout the world and it is on the top three cut flowers traded in the international market. The flower quality is maintained in the long-distance transport as they have ability to rehydrate after transportation (Pralhad, 2009). The major importing countries were USA, Netherland, U Arab Emts, UK and Germany. There are more than 300 export-oriented units in India. More than 50% of the floriculture products are produced in Karnataka, Andhra Pradesh and Tamil Nadu and Madhya Pradesh. With the technical collaborations from foreign companies, the Indian floriculture industry is poised to increase its share in world trade.

Taxonomy

- Kingdom : Plantae
- Division : Magnoliophyta
- Class : Magnoliopsida
- Order : Caryophyllales
- Family : Caryophyllaceae
- Genus : *Dianthus*
- Species : *caryophyllus*

Botanical description

Carnation is a semi hardy herbaceous perennial with thick, narrow, linear and succulent leaves. Leaf blades are simple, entire, linear, glaucous, arranged in pairs, keeled and five nerved and their colour varies from green to grey-blue or purple. The stems are hardy, shiny and have one to three angles with tumid joints. Each stem produces a terminal flower and hence inflorescence is generally a terminal cyme, sometimes racemiform. Flowers are bisexual and occasionally unisexual. The flower colour varies from white to pink or purple in colour. When grown in gardens, flowers grow between 6 and 8.5 cm in diameter. Some disbudded greenhouse grown plants for exhibition have flowers of up to 10 cm diameter. Petals are broad with frilled margins and calyx is cylindrical with bracts at the base. The stamens can occur in one or two whorls, in equal number or twice the number of the petals. Based on the number of petals per flower, carnations are grouped into "single", "semi-double" and "double" flower types. Flowers of standard and spray varieties, which constitute the largest market share, are usually of the double and semi-double type, respectively.

The fruit is in the form of a capsule and contains many small seeds. The fruit ripens within five weeks of pollination. The fruits contain an average of 40 seeds. On maturity the tubular capsule opens from top and releases the seeds.

Present day florist's carnations are the result of continuous genetic improvement and selection by many breeders throughout the world due to which most of them are fully double with their stamens transformed into petaloids.

The basic chromosome number in Dianthus is 15. Carnations are generally diploids (2n=30), though tetraploid forms (4n=60) have also been identified. Triploid carnations were produced for commercial purpose, but the resulting plants were mostly aneuploid. Most cultivable carnations are diploid.

Flower colour in carnation is attributed to the presence of two major pigments *viz*., carotenoids and flavonoids. The carotenoids are responsible for colour ranging from yellow to orange. However, many carnation plants do not have carotenoid pigments. Flavonoids are water soluble pigments such as anthocyanins. The major types of anthocyanins which contribute colour to carnation flowers are the cyanidins which are responsible for red or magenta colour and the pelargonidins which are responsible for orange, pink or brick red colour.

The fragrance in carnation flower is predominantly due to eugenol, α- caryophyllene and benzoic acid derivatives. The level of these compounds increases during flower development.

Types of carnation

Based on the availability of large number of varieties and diversified cultural requirements, carnations are classified as Chabaud or Marguerite, Border and Picotee, Malmaison and Perpetuals.

- **Chabaud or Marguerite:** These are annual carnations developed by crossing of *Dianthus chinensis* with *Dianthus caryophyllus*. Flowers are single or double, propagated by seeds. Flowers are large with fringed petals and have shorter post-harvest life. The various kinds of Chabaud are Giant Chabaud, Compact Dwarf Chabaud, Enfant de Nice, Fleur de Camelia and Margarita.

- **Border and Picotee:** The flowers of border type carnations are symmetrical and are the easiest to grow. The flower colour varies from single to blended colour with irregular markings. The petals are broad and smooth edged. The flowers are generally frilled with open centres. During first year plant produces single stem and in subsequent years become bushy. In Picotee type ground colour is without spot or bars. The edges are regular and of bright colour. Border carnations are further subdivided according to colour of flowers as Selfs, Flakes, Bizarres and Fancies. Selfs are of a single colour flower. In Flakes flowers have a ground colour striped with another shade. In Bizarres the flowers have a ground colour marked and flaked with two or three other tints. In Fancies, the flowers do not come into the above subdivisions.

- **Malmaison:** These are strong, sturdy and stiff plants with broad leaves. Flowers are large, double with well filled centres and are mainly pink coloured with good fragrance.

- **Perpetuals:** These are hybrids of different Dianthus species. The plants are not hardy and are generally treated as cool greenhouse plants. They bear flowers round the year with long stalks which make them suitable for cut flowers. They produce better quality flowers and withstand long distance transportation. These perpetuals are classified into two classes *viz*., standard and spray carnations.

a) Standard carnations: Standard carnations produce larger blooms with longer stems, usually a single large flower on an individual stem.

b) Spray carnations: Spray or miniature carnations produce smaller sized blooms with shorter stems in bunches. The flowers are borne on short branches of a single stalk.

Varieties of carnations classified in Table 1.

Soil

Soil plays an important role in cut flower production. Carnations grow in all soil types and withstand atmospheric pollution. However, sandy loam soils rich in organic matter with pH 6.0-6.5 are ideal as plants are susceptible to decay (Singh, 2006). Soils having higher slit or clay content should be amended by incorporating organic matter or compost.

As the crop is highly susceptible to wilt, soil must be well drained. Plenty of organic matter (8-10 kg/m^2) along with cocopeat should be applied to maintain soil structure, aeration and good drainage in the medium. Cultivated plants need regular watering and good soil drainage, to avoid excessive soil moisture conditions. Drip irrigation is applied (Whealy, 1992).

Plants can also be grown in a mixture of perlite and rock wool at 3:1 proportion. The media should be sterilized with formaldehyde solution at the rate of 25-30 g/m^2.

Climate

There are three climatic major factors essential for carnation growth.

- **Light:** Carnations perform best in relatively cool climate. It is genetically a quantitative long day plant (Blake, 1955) and requires approximately 21.5 K lux sunshine for at least 8 hours a day. High light intensity is detrimental to a young crop and may cause leaf burning and weak foliage. It leads to infection of parasites such as red spider mites. Harris and Ashford (1966). reported that light intensities delayed flower initiation and that this delay was associated with reduced rates of growth in terms of dry weight, reduced rates of leaf initiation and an increased number of leaves formed below the flower.

- **Temperature:** Holley and Baker (1963) reported that carnation is very sensitive to temperature. It is a major factor that influences the growth and flowering, colour, grade and the quality of cut flowers. Holley and Baker (1963)

Table 1: Varieties of carnations.

Flower Color	Standard varieties	Spray varieties
Red	Guapo, Leopardii, Domingo, Master, Gaudina, Taureg, Turbo	Red Eye, Red Fuego, Red Vital, Aveiro
White	Baltico, Madame Collette, Emotion, Angelica, White Dona	White Prestige, Milky Way, Elvis, T-587
Pink	Navona, Varna, Pink Dover, Dumas	Rosa Bebe, Spur, Suprema, D- 925, Celebration, Osiris
Yellow	Kiro, Salamanca, Soto, Diana, Hermis	Stella, Prestige, Mila, Sonia, Abril
Orange	Malaga, Florgore, Solar, Star, Orange Prestige	Sunshine, Autumn, Fancy Fuego, Disney, Eilat
Bicolor	Spencer, Swing, Madras, Giampi,Naxos, Guinea, Leila, Olympia,Wizard, Navidad, Happy Golem	Berry, Orbit Plus, Nadeja, Picaro

considered 50°F (10°C) the best growing temperature for the carnation. Hanan (1959) found, that the highest average quality of the flowers was obtained when the plants grown at a day temperature of 65°F and a night temperature of 52°F. Halliday and Watson (1953), Beisland and Kristoffersen (1968) found that low night temperature caused flower initiation to occur after fewer leaves had been formed and that, conversely, high night temperature delayed flower initiation and increased the number of leaves formed below the flower.

• **Humidity:** The optimum humidity for growing Carnation is between 50-65%. When humidity is higher; plants become susceptible to fungal diseases like Alternaria and Botrytis. Very low humidity is detrimental to a young crop and may cause leaf burning and weak foliage and infection of parasites such as red spider mites. So, at the initial stage the humidity should be maintained around 80-85%.

Propagation

Carnation can be propagated through different ways of propagations like seed, cutting and tissue culture.

• **Propagation by seed:** Commonly grown Chaubad and Marquerite carnation are propagated by seed. The nursery of these spray type carnations raised in well prepared 15 cm high raised bed of 2×10 ft. The 1 cm deep row of sterilized beds sown with seeds from 15th August to 15th September in the northern plains and August-October and March-April in the Hills. October-December has been found to be the best time for South India. Seedling usually gets ready for transplanting in the beds after 8 weeks of sowing. Normally it takes, 5-6 months to flower after transplanting.

• **Propagation by cuttings:** Generally carnation is multiplied through terminal cuttings. Maintaining mother plants of each variety in good vegetative condition is essential. To obtain good quality cutting mother plants can be established in cooler months of October to February. Cuttings are obtained from these mother plants for a period of four months. The cuttings, 10-15 cm long having 4-5 pair of leaves ate broken from the mother plant by hand and planted in sand bed or in cocopeat in mist chamber. There should not be over watering of cuttings. The cuttings must be treated with NAA 250-500 ppm before planting in sand bed for better rooting. The rooting beds should be drenched with 0.2% solution of Bavistin or Captan. The cuttings root in 46 weeks. Unrooted cuttings of carnation can be stored in unsealed plastic bags in carboard boxes in 1°C. The best time for planting of rooted cutting is August-September to get production of flower in the winter and spring.

• **Micropropagation:** Micropropagation is a modern system for production of healthy and virus free stock plants and supports breeding activities in agriculture and forestry. Producing of plants through *in vitro* technique is labour intensive and expensive. Surface sterilization of explants with mercuric chloride (0.1%) for four minutes has been found successful for shoot tips and nodal segments. Establishment was achieved on Murashige and Skoog basic medium containing NAA (1 mM), kinetin 20 mM, 15 g/litre sucrose and 6 g/litre agar for shoot multiplication. The rooting media contains NAA (1 mM) and BA (3 mM), with IBA (5 mM). The plantlets produced are transplanted to a potting medium containing soil and manure in equal proportion.

Land preparation

The soil should be ploughed thoroughly up to 80-100 cm deep and organic manure is to be mixed with soil properly. Soil sterilization should be done prior to planting. Soils should be thoroughly irrigated to remove chemical residues. A maximum length of 35 m should however be considered and beds should not exceed 1.2 m in width. Raised bed of 15-20 cm height and paths of 40 cm width in between beds are essential to carry out all cultural operations, efficiently.

Planting

Rooted cuttings of standard carnations are planted on raised beds with a spacing of 20×20 cm. Plant spacing of 30x30 cm is ideal for spray carnations. However, the lateral shoot development is best at a density of 50 plants/m². In high density, 15×15 cm spacing is adopted under protected conditions. Planting date is fundamental management information, which is typically required by crop models (Waha *et al*., 2012). Timing of sowing has a considerable effect on the yields (Kucharik, 2008) due to the variability of weather. In Northern plains of India planting is done during mid September-November, which produces flower during February-April. In hilly areas where there is no snowfall, October-February planting is suitable to obtain flowers during mid-April to mid July and in hilly areas having seasonal snowfall, planting is done during February-April to get flowers from August-October. In protected conditions, Carnations can be planted round the year.

Manure and fertilizers

Proper nutrition is very essential for carnation. Apart from major nutrients like N, P and K, Ca, Mg, B and Fe also play a crucial role in carnation nutrition. At the time of land preparation 5-10 kg farmyard manure per m^2 must be added. Costa *et al*. (1991) observed that addition of manure increases the soil water holding capacity and this means that nutrients would be made more available to crops where manures have been added to the soil. In the first three weeks after planting, no chemical fertilizers are applied. Excess potassium causes magnesium and boron deficiency. Carnations are very sensitive to boron deficiency. It may cause excessive calyx splitting and abnormal opening of flower buds. 30 g N, 20 g P_2O_5 and 10 g K per m^2 is applied for standard carnation while same dose is applied for spray carnation except N at 40 g per m^2. Half of the nitrogen should be applied as basal

dose and the rest of the nitrogen should be applied one month after planting.

Spray of 0.1% urea and potassium nitrate (KNO_3) and 1 ppm Boron at 10 days interval till flowering produces good quality flowers. Some micronutrients like Fe, Zn, Mn, Mo and B may also be required depending upon the soil type, mineral content of irrigation water and leaf analysis of plant.

Irrigation

Watering is done immediately after planting. The sprinklers are not used as they encourage fungal diseases. Therefore, drip irrigation is adopted for regular irrigation (Whealy, 1992). After establishment of plants, they must be regularly watered during warm sunny days. During this period plants may require as much as 5-7 mm water each day. Water requirement during cool and humid conditions may be as low as 1 mm/day.

Cultural practices

These special cultural practices help to build a proper structure of plant, improve growth, increases branching, quality flower production and ultimately increase the production of flowers (Raghatate, 2021).

Weed control

Weeding of beds needs to be done regularly. Application of fluchloralin herbicide at 0.96 kg/ha or pendimethalin (30% EC) at 0.90 kg a.i./ ha were found very effective to control the weeds of carnation. These herbicides are to be incorporated in the moist beds a day before transplanting. Application of herbicides followed by light hoeing after two weeks is found effective to keep the beds absolutely weed free for eight weeks. Other herbicides *i.e.* chloroxuron (at 8.0 kg a.i./ha), trifluralin (at 3.0 kg a.i./ha) and oxadiazon (at 2.0 kg a.i./ha) as pre-emergence application were found effective to control the weeds of carnation.

Netting

The plants should be supported by a network. The plastic nets having a mesh of 7.5-10 cm supported by stakes of metal fixed at the corner of beds is an ideal method. Make 3-4 layers of mesh laid together on the soil surface; lower is made 15 cm above the soil and upper layers are separated 20 cm apart. As the plants grow, the stems must be constantly stalled or caged within the respective mesh opening to maintain straight stems. A modern supporting method either of wire or nets comprises 2 vertical posts at both ends, with cross bars at intervals. Lighter grade ladder, preferably of metal can also be s*et al*ong the length of the bed 3.5-4 m apart. It is convenient if the end ports are fitted into sockets so that they can be easily removed and replanted and strengthened by a stake taken down to the side of a bed. The first layer is laid after pinching of plants and others as the plants grow (Sindhu and Choudhary, 2001).

Pinching

For successful production of top quality Carnations, pinching is an important operation. During pinching, the tip of the stem is removed to encourage the growth of the standard or Sim Carnations. Only 4-6 well grown lateral shoots will be allowed to grow. Pinching is done after 30-35 days of planting leaving only 6 pairs of basal leaves. If too many leaf pairs remain, stem and flower quality may be reduced considerably. Similarly, production will decrease if few leaf pairs will be left. There are three types of pinching methods generally followed (Fig 1).

Dalal *et al.* (2006) studied the effect of pinching on carnation cv. Yellow Solar under polyhouse condition at Akola and found that shortest plant height was observed under double pinched treatment in carnation.

- **Single pinching:** In single pinch, apical portion measuring 5-7 cm is pinched off to give about 4-5 lateral shoots, which produces flower. This is done for early crop.
- **Pinch and-a-half:** This method involves single pinching of the main stem to give 4-5 side shoots. Only half of total numbers of lateral shoots are pinched when they are about 5cm long. This method reduces the load of first crop and provides a steady supply of flowers throughout the year.

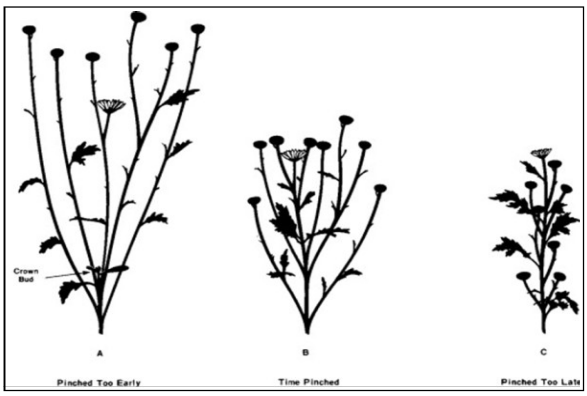

Fig 1: Effect of pinching on carnation flowering illustrated by C. Anne_Whealy (C. Anne Whealy, 1992).

• **Double pinch:** In this method all the lateral shoots arising from the first pinch are again pinched when they are 8-10 cm in length at 2-3 nodes. It is done approximately 5-6 weeks after first pinch. This is generally done for late harvesting or delaying the flowering period. Approximately 8-10 shoots are retained. This method produces large number of flowers bearing shoots and poor quality flowers hence not preferred.

Disbudding: Disbudding is the removal of unwanted buds. It is practiced in Carnation to obtain good quality flowers. Buds are taken away before they get too big, as they will considerably reduce the flower size. In case of standard Carnation, the lateral flower buds are removed leaving only the terminal or main flower bud. In spray or miniature Carnation, the terminal or main flower buds are removed, to encourage lateral flower buds. Disbudding help to produce quality bloom in standard carnation.

The unwanted buds should not be removed when very small as this is apt to damage the stem, nor should the lateral buds be left until nearly fully developed, for this takes food from the central bud and reduces the size of the ultimate flower (AM Abou Dahab, 1967).

Insec-pests

The most common insects attacking the Carnation are:

Aphids (*Myzus persicae*)

Aphids suck the sap from new shoots and leaves. They leave sticky substances on leaves and flower buds. Foliar spray of Rogor (2 ml/litre) or 0.25 % Demeton-methyl found to be effective.

Thrips (*Thrips tabaci*)

Thrips also suck the sap of leaves and turn them yellow and patchy. Under severe attack they also cause streaks and spots on flowers and stems. Pink and red cultivars are more susceptible. Malathion or Rogor (dimethoate) or Dichlorovos, all at 0.1-0.2 % gave the best control of Carnation thrips.

Red spider mite (*Tetranychus urticae*)

Red spider mite is the most serious pest of carnation. They are very small red coloured insects mostly feeding on the lower sides of leaf and suck the sap. Leaves become yellow with dusty coating and fine webs on their surface. The most effective chemical against mite is Vertimec (0.4 ml/l) or Thiovat (2 g/l), which is effective against adults, eggs and larvae.

Caterpillars

The oblique-banded leaf roller and the greenhouse leaf tier also infest carnations. These are easily controlled by early applications of *Bacillus thuringiensis* or Sevin. Regular spray of Ripcorb (0.1%), Endosulfan (0.05%) or Polyfrin (0.1%) at fortnightly interval are also recommended for control of caterpillars.

Diseases

Carnations are attacked by a number of diseases like Fusarium, Alternaria and Bacterial wilt.

Fusarium wilt

It is caused by *Fusarium oxysporum f. Sp. dianthi*, also known as vascular wilt, is one of the most serious diseases of Carnation. It is soil born, invades the plant through roots. During certain occasions, a portion of the plant wilts and subsequently spread to all portions of the plant (Sohi, 1992). The wilted plants are stunted, yellow and dry often with hollow stem (Hood and Stewart, 1957; Baayen and Matt, 1987). Soil fumigation and treating the beds with Bavistin (0.1%) and Dithane M-45 (0.1%) at regular interval is effective.

Leaf spot

It is caused by *Alternaria dianthi* is another serious air-born disease. It is characterized by greyish-brown spots on leaf and stem. High temperature and humidity favours the disease spread. Lesions spread from leaf to the stems and lead to girdling of the stem (Arbelaez, 1987). Removal of infected leaves and foliar spray of Mancozeb (Dithane M-45) @ 0.2% or Bavistin 0.1% controls this disease.

Bacterial wilt (*Pseudomonas caryophylli*)

It is prevalent at high temperatures. It is soil born disease attacking older plants. Production of greyish green foliage, rotting of roots and deep longitudinal cracks on internodes are the major symptoms. Soil sterilization, treating the plant material with 0.01 % Streptocycline and using disease free plants helps in reducing the incidence.

Physiological disorder

Calyx splitting

Splitting carnation flower calyces; is one of major limiting factor that affect both pre and post-harvest quality of carnation flowers (Thompson, 2010). As the flower bud opens and petals reach to their full size, the calyx may split down either half or completely. A number of factors like genetic, environmental, nutritional and other cultural practices are responsible. The cultivars with short and broad calyx are more susceptible than the ones with long and narrow calyx. Irregular or fluctuating temperature during flowering also induces calyx splitting. Low temperature below 10°C leads to the development of an extra whorl of petals inside the calyx. The calyx unable to hold these extra growing petals splits up. Besides these, low nitrate, high ammoniacal nitrogen or low boron levels also enhance calyx splitting. The problem of calyx splitting can be controlled by regulating temperature. Higher nitrate to ammoniacal nitrogen ratio during low light periods are recommended to reduce splitting. It can be reduced by placing a rubber band or 6 mm wide clear plastic tape around the calyx of the flower bud when they have just started opening and this process is called as calyx banding. Cultivars like Espana, Carboret, Red Corso, Pamir, Raggio-di-sole are less prone to this problem. Application of 0.1 per cent borax one month after planting till bud initiation

and weekly intervals thereafter up to harvesting proved to be beneficial to produce higher yield of standard quality flowers. It is reported that boron treatment reduced the incidence of calyx splitting to 85% with increase in flower numbers and stalk length (Khalaj *et al.* 2007; Karthikeyan *et al*. 2009).

Slab side

This disorder refers to uneven opening of flower buds resulting in the petals protruding on one side only, giving an asymmetrical and lopsided shape to the flower. It is common during cooler periods. This can be overcome by gradually increasing the temperature to optimum level.

Grassiness

Grassiness refers to failure of plants to produce flowers. This is a genetic disorder which varies from variety to variety. Removal and destruction of affected plants is the only way of correcting this disorder.

Sleepiness

Sleepiness causes huge post-harvest losses in cut carnation. It occurs due to exposure of flowers to ethylene or water stress. Also, the incidence of sleepiness has been found to be higher when the flowers are stored for a longer period or when they are exposed to high temperature. Spraying of STS 0.4 mM before harvesting the flowers will correct this disorder (Takashi Onozaki, 2018).

Harvesting

Harvesting stage depends on types of carnation and market. The optimum stage of standard carnation for distant market is paint brush stage when petals have started to elongate outside the calyx. The spray varieties are harvested with 2 open flowers on each stem. The best time for harvesting is in the morning. The flowers are harvested by either snapping the stem of at a node or cutting off with a sharp knife or small shears. The cut flower should be immediately placed in clean water or preservative solution for about 4-6 hours and then placed in cold storage at 4-6°C.

Post-harvest management

• Grading

Just after harvesting, the flowers must be graded and bunched properly. Various standardized grades based on stem length, flower diameter and physical condition of flower like stem sturdiness, free from diseases and insects, sleepiness, stem cracks, slab side, bullhead and calyx splitting should be considered while grading carnations. Grading in India is adopted as per the guidelines of the Society of American Florists. Each grade is bunched in a lot of 25 stems.

• Conditioning of flowers

Flowers are climacteric which makes them defenseless for huge post-harvest losses. Senescence is a process that follows physiological maturity and leads to death of the whole plant, organ, tissue or a cell. It is one of the imperative factors determining the longevity of the flower (Verma and Singh, 2021). The vase life of cut flowers is one of the most important characteristics that determine their quality and their ability to satisfy consumers' preference, thus stimulating repeated purchase. The most common consumer request for cut flowers is long vase life (Shimizu-Yumoto and Ichimura, 2013). Carnation flowers are highly sensitive to ethylene (Woltering and van Doorn, 1988). Exposure of fully open carnation flowers to ethylene induces autocatalytic ethylene production and wilting in petals (Thompson *et al*., 1982). Hence, ethylene is an important determinant of vase life of Carnation. The flowers after harvesting and grading should be pulsed with 10% sucrose+1 mm silver thiosulfate (STS) for 8-10 hr before transportation to increase storability and vase-life of cut carnations. After pulsing, the flowers should be stored at 2-4°C temperature and 95% relative humidity in water with a nutritive solution. This is necessary to prevent sleepiness in cut carnations (Ahmad *et al*., 2014).

• Packaging and transportation

Carnations are packed in corrugated cardboard boxes. About 800 carnations are packed in a standard-sized carton (122 cm × 50 cm × 30 cm). The boxes should be well-insulated. Bunches of 25 flowers are then packed in these boxes with one half of the total number of bundles oriented on each end of the container. Newspaper layers are placed between the layers to maintain high humidity and then when the container is filled, an insulated layer of paper is put across the box to cover the flowers completely. Transportation should be done in a refrigerated van at 2°-4°C temperature to maintain the cool chain up to cargo. However, for local markets it should be done by trams, buses and trucks during night hours.

Yield

Yield of carnation flowers mainly depends on variety, pinching and on the period, the crop is harvested. In general, sprays produce more flowers than standards. Generally, 200 flowers/m² can be obtained from standard type, while 250 flowers/m² can be taken from spray type.

CONCLUSION

The scientific cultivation practise and cultural management in Carnation is to maximise the yield and quality of the flowers keeping in view about environment sustainability. As this occupies a promising position in the cut flower market both in national and inter-national market, the vase life of cut flowers is one of the most important characteristics that determine their quality and their ability to satisfy consumers' preference, thus stimulating repeated purchase. The production technology discussed in this paper can be used commercially to increase the production and productivity by the farmers. Forming marketing co-operatives of flower growers may facilitate direct marketing

to fill the demand and supply gap. Along with this, further research can be taken up in form of organic trial aiming at the good production pace and environment health.

Conflict of interest

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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