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REVIEW

Variation in different agronomical characters of some carnation (*Dianthus caryophyllus*) cultivars

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ABSTRACT

Human has been always enthusiastic of gardening with flowers and ornamentals since ancient periods of time. The economic importance of ornamentals (floricultural plants) has been increasing and its world-wide international demand has rapidly expanded with the passage of time. Worldwide trends and production centres of floricultural crops are changing continually. A predictable trend in the international flower market is the increased emphasis on quality. Quality factors related to post-harvest keeping quality include environmental influences on flower longevity, as well as the influence of pathogenic microorganisms, including virus diseases. As competition in the world market is increasing, quality has become a more important factor. Increasing vase-life or flower-life on a pot plant is an important goal. A large number of floriculture units based on greenhouse technologies for the export of their produce have been set up. These developments had an effect on the flower cultivation in the open field condition and thus significant growth took place in the floriculture sector which is now experiencing a change in terms of technology of production, packaging and storage, varieties and qualities of product, quantum of production and the marketing mechanism. In this recent platform, Caryophyllacean dicot plant member *Dianthus caryophyllus* (Carnation) is an important, commercial season based floricultural crop. It grows well in temperate climate all over the world and popular as cut-flowers for its variegated petal's colour. So, it has terrific market demands in international trading. In this modern era, an agronomic demand of high yielding cultivar of this crop was noticed. Development of cultivars with more desirable floral characteristics and higher productivity are also very important in this crop. Various biometrical/agrometrical characters viz. growth parameters (mature plant height, number and length of shoots and internode, number of tillers, nodes, leaves, stem diameter, length-breadth of leaf etc.), flowering parameters (days to flowering, bud opening, flower development, flower longevity etc.), flower quality parameters (length, girth and diameter, weight of flower, petal number, calyx splitting etc.) and yield parameters (number of flower/plant and seeds/inflorescence, seed weight etc.) were varied greatly from cultivar to cultivar. These parameters serve as key traits for crop improvement programme in which mutation breeding plays a vital stage.

Key Words: Carnation, crop improvement, *Dianthus caryophyllus*, floriculture, metrical traits, mutation breeding.
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INTRODUCTION

Carnation (*Dianthus caryophyllus* L.) belongs to the family Caryophyllaceae having diploid chromosome number 2n=30. It is grown in several parts of the world and is believed to be the native of Mediterranean region. The generic name *Dianthus* comes from the writings of Theophratus who lived about 300 B.C. He proposed that the word "*Dianthus*" came from the greek words: '*dios*' means devine (God); '*anthos*' means flower, that is 'the flower of the Gods'. 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 likely derived from '*coronation'*, as the Greeks wove *Dianthus* flowers into crowns for their athletes. It is genetically a quantitative long-day plant (Blake 1955). The variety William Sim produced in 1938-39 by William Sim of North Berwick, Marine was the greatest contribution to the present Carnation industry. From that one red flowered plant, there have been mutations to several variegated forms like white, pink, orange, etc. Today the Sim Carnation strains are grown throughout the world. Years ago, Carnations were grown in local greenhouses near population centers. Increased production per unit of greenhouse area, along with high flower quality, could be achieved during winter months in the high light-intensity area, namely Colorado and California. The advent of plastic film also made it possible for southern California growers to produce Carnations in simple structures without winter heating. Carnation is an important flower crop having great commercial value as a cut flower due to its excellent keeping quality, wide array of colour and forms. Carnation, apart from producing cut flowers can also become useful in gardening for bedding, edging, borders, pots and rock gardens. From medicinal point of view, Carnation flowers are considered to be cardiotonic, diaphoretic and alexiteric (Shiragur *et al.* 2004b). In the world, area of 'natural climates' for Carnations, are generally occurs near 30^{o} N or S latitude and on the Western edges of the continents. The area under Carnation has more than doubled within one year from the preceding one. India has been identified as one of the major forces in the world floriculture scenario. With liberalization of Indian economy, floriculture has become a new rising industry in agribusiness. West Bengal has a prominent position on floriculture map of India. Carnations are grown commercially in India in places having mild climate in Solan, Shimla, Kalimpong, Kodaikanal, Mandi, Kullu, Srinagar, Ooty and Yercaud. In West Bengal, it is grown under controlled condition as the transitional belt parts/area seems to be very ideal for cultivation of flowers on account of favourable climate, soil and other factors (Shiragur 2004b).

Carnation plants are half hardy herbaceous perennial. The flowers are solitary, terminally formed; the petals are broad with frilled margins and the calyx cylindrical with bracts at the base. The hybrids involving many *Dianthus* species are of perpetual flowering types. The florist's Carnations are grouped into two major classes such as 'Standard' and 'Spray'. The standard type produces larger blooms on longer flower stalks. On the other hand the spray type produces many flowers of

smaller size with weaker stem. The commercial Carnation plant is capable of producing 10-20 flowers per year. Each flowering stem originates from a 'break' or shoot that emerges from one side of flower stem node. A typical flowering stem develops 15-18 nodes with two opposite leaves at each node. A long time goal of Carnation breeder is to develop varieties of standard Carnations which will not produce shoots at the upper nodes. Such varieties would make it possible to eliminate 'disbudding, 'the most costly labour operation in Carnation culture. Standard Carnation performs well under cool climate, whereas spray type grow better at higher temperature. Growth and flowering of Carnations are influenced by several factors. Carnation is long day plant. It forms flowers fasters during long day than in short day. It requires more than 21.5 Kilo Lux light intensity, cyclic lighting or continuous lighting from dusk to dawn hastens flowering. Temperature plays an important role in Carnation growing. Temperature fluctuations result in reduction of flower yield, stem strength, increased calyx splitting and shorter keeping quality. The optimum range of temperature during winter and spring is 10-12.7^{o}C and during summer 13.0-15.4^{o}C, respectively. Polyhouse fitted with fan and pad system can bring down the temperature by 8-10^{o}C. However, top ridge and side ventilation also gives good fresh air exchange and lowers the temperature. High humidity results into several fungal diseases. The crop must be protected from rain by covering the plants with polyethylene sheets. Carbon dioxide level affects both growth and quality. Low level of CO_2 100-150 ppm in greenhouse during the day inhibit the growth. The greenhouse CO_2 level should be maintained at 300-500 ppm on cloudy days and 750- 1500 ppm on sunny days. Carnations require sufficient amount of light and proper ventilation to produce high quality flowers and therefore design and orientation of greenhouse are of greater importance. The Carnation flowers are sold as cut flowers round the year throughout the world and it is one 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. Though there are different types of greenhouses, naturally ventilated polyhouses are preferred in mild climate in which temperature is reduced by ventilation (Ryagi *et al*. 2007). Cut flowers of Carnations are sensitive to ethylene and senescence is accomplished by sequential rise in ethylene production by different flower parts (Nichols *et al.* 1983). Silver Thiosulphate (STS) an inhibitor of ethylene action is known to increase vase life of Carnation and other ethylene sensitive flowers (Veen 1983, Singh *et al.* 2003). Since, STS contains Silver which is considered to be an environmental pollutant, its use has been restricted for treating the ethylene sensitive flowers (Serek and Reid 1993). Maintenance of turgidity is an important factor in prolonging vase- life of many flowers. The demand for Carnation cut flower is gaining momentum with increasing aesthetic sense and higher socio-economic standard of the people. In India, it is common practice to have the plants growing in greenhouses for the cut-flower production resulting in increased crop production. On the other hand, when the plants are grown in open condition especially plants in northern India, the planting after April has to pass through a great stress due to prevailing high temperature. Though such low temperature conditions exist in India during winter months but the shortage of light during winter months is the main barrier for its reduced and delayed flower production owing to its long day requirement. In addition to its long day, other operations are also known to affect its flowering but so far, there is no systematic report from India on its growth and flower regulation. The performance of Carnation varieties varies with region, season, genotypes and growing environment. In India, there is a wide fluctuation in temperature, light intensity and humidity which not only affect the yield and quality of flowers but also limit their availability for a particular period of a year. It is necessary to grow Carnation under polyhouse condition for obtaining good quality flowers. Testing of the available varieties for suitability and adaptability with respect to flowering, flower quality and yield parameters are of prime importance. Many varieties are grown in the world, however only few varieties are under commercial cultivation in India. A systematic study of vegetative characters would facilitate the breeders to select suitable genotypes for planned breeding programme. Further there is need of suitable varieties and production technologies suitable to our conditions. Selection of proper variety for producing the desired quantity and quality of flowers for domestic as well as export market is of greater importance. Carnation in the modern times has become one of the most important and highly remunerative flower crops grown under polyhouse, mainly for its cut-flowers. Some of its varieties are used for bedding, pots, rock gardens, window boxes and edging too. Now a days, not only standard Carnations, even spray type Carnations are popular in flower arrangements for decoration of homes. It is difficult to obtain higher yields of good quality flowers throughout the year under open conditions. However, the cultivation of Carnation is possible even during the off season under greenhouse condition. The varieties differ significantly in their performance with respect to yield, quality and vase life. This research review contains the past literatures pertaining to the performance of Carnation and the other related flowers under protected condition has been compiled to enable better understanding of the varieties and suitable growth conditions in flowering plants.

VARIETAL EVALUATION

The new varieties of the Bulgarian Carnation race developed in recent years excel Sim varieties in decorative and commercial characteristics. They produce larger and fuller flowers with bigger and heavily serrated petals, improved shape, wider colour range and stronger fragrance combined with higher stability against calyx splitting and longer vase-life (Boikov 1983). The important characters for Carnation evaluation are keeping quality of the flowers, *Fusarium* tolerance and production (Gelder 1987). Atanassova (1988) recommended Carnation varieties *viz.*, Salmony, Mirna, Silvery Pink and White Lilliann for commercial cultivation under Bulgarian conditions for combined yield and quality. New Bulgarian Carnation varieties with a complex of most importation decorative and commercial advantages have been developed. Entirety new characters significantly improving the competitiveness and commercial efficiency of this culture have been attained, such as flower size over 12 cm in diameter, strong fragrance, development of stem branches from the adventitious buds at the root neck, tolerance to virus diseases, combined with high *Fusarium* resistance (Boikov 1992). Among the different types of Carnations, perpetual flowering types are the hybrids involving many *Dianthus* species. It flowers all the year round. The florist's Carnations are grouped into two major classes "Standard" and "Spray". The standard types produce larger blooms on longer flower stalks. The spray on the other hand produces many flowers of smaller size with weaker stem (Bhatt 1993). The cultivar William Sim produced during 1938 and 1939 by William Sim of the USA is the greatest contribution to the present Carnation industry. From this red flowering variety, there have been mutation to white, pink, orange and several variegated forms. Some important Carnation varieties *viz.*, Arthur Sim, William Sim, White Sim, Scania,

Laddie, Can Can, Shocking Pink, Tangerine, Harvest Moon and Clear Yellow grown under the open field conditions of sub-tropical environments which revealed that Sim Carnation can be successfully grown as a single crop and was not possible to extend up to second year. The yield of high quality flowers was obtained 328/m^2 from the plants established in the beds in the month of September. The varieties like Arthur Sim, Can Can and Clear Yellow exhibited high tolerance (Gill *et al.* 1988). Lal *et al.* (1998) studied the performance of fourteen varieties of Carnation; five standard varieties *viz.*, Scania, Dusty, White Sim, Shocking Pink and Arthur Sim found to behaving performed better in terms of their flower production and tolerance to various fungal diseases. Sahakar and Sable (2003) investigated on the performance of six varieties of Carnation grown in naturally ventilated greenhouse and reported that all were performed well with respect to growth, cut-flower yield and post-harvest life. Among them, cultivar Cobra, Gaudina and Super green were found to produce maximum number of flowers.

GROWTH PARAMETERS

Plant Height

Khanna *et al.* (1981) reported that 15 ×15 cm spacing was found to produce significantly taller plants than wider spacing that is 30 × 30 cm. He also recorded the plant height of the cultivar 'Marguerite Scarlet' was 62 cm. Singh *et al.* (1994) studied the effect of summer shading on the plant growth and flower production on standard Carnation cultivar 'Espana' under different shading treatment (0 or control, 25 and 50%) shading. The maximum (54.47 cm) plant height was recorded in 25% shade treatment. The minimum (49.42 cm) plant height was recorded in control check. Kaicker (1998) reported, plant height of important cultivars for spray type 'Chaubad Giants' and 'Enfant de Nice' were 50 cm tall, Carnation 'Fantasie' was 50-60 cm tall, Carnation 'Dwarf Frangrance' about 30 cm tall while plant height of 'Malmaison Giant' was 40 cm. Lal *et al.* (1998) reported that the variety 'Scania' attained maximum plant height (59.46 cm), followed by 'Shocking Pink' (59.51 cm). The varieties 'Tangerine' (52.67 cm), 'Harvest Moon' (53.06 cm) and 'Yellow Dusty' (53.3 cm) had smaller plants among the standard types. The maximum plant height (62.10 cm) was recorded under unpinched and the lowest one (39.27 cm) when the plants were pinched twice (Pathania *et al.* 2000). Patil (2001) observed maximum plant height in cultivar 'Alma' (116.86 cm), followed by cultivar 'Sugar Baby' (116.18 cm). It was minimum (76.76 cm) in cultivar 'Leon' under low cost polyhouse. Kumar and Singh (2003a, 2003b) studied Carnation cultivar 'Red Corso' under screen house for three planting seasons viz., early, mid and late and two day lengths conditions, viz., short and long day in all possible combinations. Plant height was maximum (86.65 cm) in autumn season. In interaction effect, autumn season and long day condition showed maximum plant of 93.36 cm. Among the six standard Carnation cultivar viz., Cobra, Gaudina , Montezuma, Niva, Salsa and Super Green under polyhouse condition, cultivar 'Gaudina' recorded maximum plant height (85.72 cm), followed by 'Montezuma', 'Super Green', 'Salsa', 'Niva' and 'Cobra'. Minimum plant height of 64.60 cm was recorded in 'Cobra' (Shahakar and Sable 2003). Dwivedi and Kareem (2004) evaluated 15 varieties of Carnation under cold arid region of India and revealed that average plant height varied from 47.65 cm and 57.66 cm in 'New Espana' and 'Arthur Sim', respectively. Under partially modified greenhouse condition, Gurav *et al*. (2004) standardized the package of practices for Carnation cultivar Sunrise and recorded maximum plant height (60.16 cm) at first harvest in treatment (soil + compost + sand at ratio 2:1:1 substrate and 40 KPa irrigation regime, basal dose as 200:200:100 NPK Kg/ha/year + 100 kg N/ha/year + 200 kg K/ha/year through fertilization. According to Reddy *et al*. (2004), cultivar 'Alma' recorded maximum plant height (110.55 cm), followed by 'Sugar Baby' (110.32 cm), 'Pirandello' (107.16 cm) and 'Candy' (102.50cm), whereas cultivar 'Leon' recorded minimum plant height of 83.74 cm. Height of plant was medium in varieties Denton, Desio and Madame Collette (98.83 cm, 96.91 cm and 94.15 cm, respectively) grown under low cost polyhouse conditions. Shiragur *et al.* (2004b) reported that out of nine varieties viz., Alma, Aicardi, Candy, Desio, Madame Collette, Pirandello, Sorisso, Sugar Baby and West Pretty cultivated under protected conditions for evaluating vegetative characters. Varieties Madame Collette, Candy and West Pretty were vigorous in their growth throughout the growing period in terms of plant height (115.86 cm, 115.67 cm and 105.66 cm, respectively); but finally 'Pirandello' recorded maximum plant height (118.22 cm), whereas cultivar 'Desio', 'Sorisso', 'Aicardi' and 'Sugar Baby' were moderate in terms of plant height (106.64 cm, 105.38 cm, 102.62 cm and 101.67 cm, respectively). Singh and Singh (2005) observed maximum (58.50 cm) plant height in single pinching. In interaction effect the maximum plant height of 69.10 cm was found in single pinching with 500 ppm nitrogen. Maximum plant height (90.67 cm) was observed when plants were treated with common basal dose + Vermicompost (500 g/m^2 twice a year) + 3% Manchurian mushroom tea + 3% Panchagavya, whereas plants treated with 50% required dose of fertilizers resulted in minimum plant height of 78.49 cm (Bhalla *et al*. 2006). Studies were conducted on the effect of supplementing the day length on growth and flower production in Carnation cultivar 'Tasman'. Such study revealed that, plants under 6 h additional light exhibited the maximum plant height (76.0 cm), followed by exposure to 4 h additional light of 73.9 cm (Singh *et al*. 2006). Eighteen standard *Chrysanthemum* varieties were evaluated to study their performance under polyhouse cum rain-shelter and open conditions. Among them, cultivar Temptation was found tallest (85.67 cm) under polyhouse cum rain shelter. However, under open condition, cultivar 'Snow Ball' exhibited maximum plant height of 84.00 cm (Talukdar *et al*. 2006). Bhalla *et al*. (2007) reported that, the maximum plant height was observed in cultivar 'Raggio - de – Sole' (69.84 cm) as compared to cultivar 'Murcia' (67.95 cm). Amongst different treatment combinations, maximum plant height (72.47 cm) was observed in the treatment (Sand + Soil + Vermicompost at ratio 1:1:1 + Inorganic water soluble fertilizers + biofertilizers), whereas minimum plant height (64.93 cm) was observed in this treatment supplemented with sand + soil + FYM (Control). Interaction data revealed that maximum plant height (73.20 cm) was observed in cultivar 'Raggio – de- Sole' when grown in media containing sand + soil + vermicompost at ratio 1:1:1 + inorganic fertilizers + biofertilizers. Ryagi *et al*. (2007) studied the effect of pinching on growth, yield and quality of flowers of Carnation varieties viz., Dover, Cherry Solar, Solar, Yellow Solar and Domingo under polyhouse. The maximum plant height was recorded in variety 'Solar' (78.55 cm) which was on par with variety 'Domingo' (78.12 cm) and the minimum plant height was recorded in variety 'Dover' (68.52 cm) grown under polyhouse.

Stem girth

Atanassova and Batchvrova (1995) observed maximum stem girth at base (6.0 mm) in cultivar 'Yanita', followed by cultivar 'Krassina' (5.6 mm) and cultivar 'Red Barbara' had minimum girth and stem of 4.5 mm. As per Patil (2001) Maximum stem girth (5.99 mm) found in cultivar 'Madame Collette', whereas minimum stem girth (3.83 mm) was recorded in cultivar 'Leon'. According to Shiragur *et al.* (2004b), among the varieties evaluated under polyhouse condition, cultivar Sugar Baby, Madame Collette, Alma and West Pretty had thicker and strong stem (7.14 mm, 6.88 mm, 5.98 mm and 5.16 mm, respectively), while cultivar 'Sorisso' had weak stem of 3.53 mm. Tejaswini and Murgod (2005) reported that stem thickness was significantly higher (5.42 mm) in module treatment with Sand + Soil + Compost.

Number of nodes and internodal length

Hanzel *et al.* (1954) observed the number of internodes in Carnation. The variety 'Northland' had 24.2 stems originating from base, 23.2 in stems originating from middle portion and 17.2 in case of stems originating from top portion at the time of flowering. Cultivar improved 'White Sim' had 17.8 nodes on primary shoots at the time of flowering under normal day length condition (Heins *et al.* 1979). Bhautkar (1994) reported variation in nodes ranging from twelve in cultivar 'White Sim' to 23 in cultivar 'Eveline' grown under greenhouse. Mahesh (1996) studied the performance of ten Carnation varieties and revealed that internodal length ranged from 6.32 to 8.85 cm. The cultivar 'Starlight DOP' (spray) showed minimum internodal length, whereas cultivar 'Dusty Pink' (standard) showed maximum (8.85 cm) internodal length. Sawwan and Samawi (2000) observed that double pinch after six weeks of planting significantly reduced number of nodes per flowering stem. Maximum number of internodes per branch recorded in cultivar 'Desio' (18.86) and the minimum in cultivar 'Leon' (13.45). The internodal length was maximum in cultivar 'Pirandello' (6.89 cm) and was minimum (4.65 cm) in cultivar 'Desio' (Patil 2001). Shiragur *et al.* (2004b) reported that number of internodes per stem was maximum in cultivar 'Madame Collette', 'Alma', 'Sugar Baby' and 'Desio' (20.38, 19.54, 19.28 and 18.48, respectively). However, it was minimum (15.69) in cultivar 'West Pretty'. Cultivar 'Sorisso', 'Madame Collette', 'Pirandello' and 'Aicardi' had maximum internodal length (5.71 cm, 5.69 cm, 5.4 cm and 5.18 cm, respectively) while it was minimum in cultivar 'West Pretty' (4.75 cm). Ryagi *et al.* (2007) recorded maximum number internodes in variety 'Cherry Solar' (17.78), followed by 'Solar' (17.33) and it was minimum in variety 'Dover' (15.57). Among the pinching methods, more number of internodes recorded in double pinched plants and minimum was recorded in single and half pinched plants. Whereas, interaction effect were found significant with maximum number of internodes recorded in 'Cherry Solar' variety with single pinching (18.8).

Number of shoots

The performance of Bulgarian varieties was good with respect to number of branches per plant than Sim varieties (Boikov 1983).There was variation in average numbers of shoots from 4.3 in traditional group of varieties to 5.9 in *Dianthus* x *Doris* group of varieties (Sparnaaij *et al.* 1990 a). Sparnaaij *et al.* (1990 b) reported number of shoots per plant varied from 3.3 to 6.7 in Carnation genotypes. Sparnaaij and Putten (1990) studied the performance of different progenies of Carnation. The number of shoots varied from 3 in progenies of *Dianthus superbus* to 5.4 in progenies of cross between *Dianthus Knappi* x *Dianthus Caryophyllus.* Bhautkar (1994) reported variation in number of branches ranging from 10 (in varieties Lena, Scania and Arthur Sim) to 18 (in cultivar Eveline) under greenhouse. Singh *et al.* (1994) noted that number of shoots produced by the plant under shade was more than unshaded plants and there was no significant difference with two shading treatments (25% and 50% shading). Mahesh (1996) conducted study and revealed that variety 'Starlight DOP' (Spray) had maximum number of branches (4.2), whereas variety 'White with Red Edge' (Standard) had least number of branches (1.87). Sathisha (1997) conducted trail in a greenhouse and revealed that variety 'IAHS-7' had a highest number of branches (13.75), followed by 'IAHS-27' (10.25) whereas, variety 'IAHS-5' had minimum number branches (6.70).The number of branches per plant varied from 7.5 in cultivar 'Cabaret' to 8.0 in cultivar 'Red Corso' under polyhouse condition (Naveenkumar *et al.* 1999b). Patil (2001) noted that the variety 'Madame Collette' recorded maximum number of branches (4.52), followed by 'Desio' (4.35) and 'Alma' (4.22), whereas 'Leon' recorded minimum number of branches (2.85) at 180 days after plantation. Kumar and Singh (2003) reported relatively higher number of branches (8.58) in autumn planting in Carnation. Maximum number of shoots (9.3) per plant were recorded in treatment M_1 (Soil +Compost + Sand (2:1:1) substrate, 20 KPa irrigation regime, basal dose as 200:200:100 NPK kg/ha/year + 100 Kg N/ha/year and 200 kg K/ha/year through fertilization, followed by (9.17) in treatment M_4 (Same as M_1, except fertilization through straight fertilizers (Gurav *et al.* 2004). Under low cost polyhouse, cultivar 'Madame Collette' recorded maximum number of branches (4.80) per plant followed by 'Sugar Baby' (4.73), 'Pirandello' (4.40) and 'Alma' (4.1); whereas, minimum number of branches (2.97) were recorded in cultivar 'Leon' (Reddy *et al.* 2004). Shahakar *et al.* (2004) studied the growth, flower quality and yield a of Carnation varieties under polyhouse condition and revealed that 'Cobra' recorded significantly superior result in respect of number of shoots per plant (5.80) and it was followed by 'Gaudina', 'Super Green', 'Niva' and 'Salsa'. Minimum number of shoot was observed in 'Montezuma' (4.25). In a greenhouse trial on Carnation conducted by Shiragur *et al.* (2004b), more number of shoots were exhibited by the varieties 'West Pretty' (7.81), 'Desio' (7.14), 'Aicardi' (6.96) and 'Candy' (6.64); whereas the cultivar 'Sugar Baby' has its lowest value (5.25). Singh and Singh (2005) reported that, the maximum number of branches (9.5) were observed in Double pinching and 500 ppm nitrogen, followed by (9.1) in Double pinching and 200 ppm nitrogen. Singh *et al.* (2006) reported 7.4 side shorts per plant under natural day length, whereas, in 4 h and 6 h additional light the number of side shoots were 7.3 and 7.0 respectively. Ryagi *et al.* (2007) reported that the number of branches was found maximum in variety 'Domingo' (5.85) and minimum in 'Cherry Solar' (2.26).

Length of shoot

Patil (2001) showed that the maximum shoot length was observed in cultivar 'Alma' (114.45 cm), followed by cultivar 'Sugar Baby' (111.65 cm) and minimum shoot length was observed in 'Leon' (70.87 cm) at 180 days after planting under low cost polyhouse condition. Singh *et al.* (2006) reported that the long days enhanced internodal length shoots and

hence, produced longer flowering stems. The extended photoperiod resulted in longer flowering stem (69.9 cm and 67.8 cm under 4 h and 6 h additional light, respectively) over the control (50.2 cm).

Number of leaves

Sparnaaij *et al.* (1990a) noted that number of leaf pair per branch in Carnation ranged from 17.7 to 27.3. Kanamadi and Patil (1993) studied the performance of Chrysanthemum varieties in the transitional tract and reported that the maximum number of leaves was observed in cultivar 'Red Gold' (168.23) and minimum in the cultivar 'Co-1' (58.00). Naveenkumar *et al.* (1999b) studied the effect of growing environment on flowers of Carnation and the study revealed that cultivar 'Red Corso' and 'Cabaret' under polyhouse recorded 27 and 23 leaf pairs at flowering, respectively. Leaf production varied significantly in Gladiolus varieties at 60 days after planting and it ranged from 9.13 in cultivar 'Magic' to 21.27 in cultivar 'Vedanapali' (Kamble 2001). Patil (2001) reported that the number of leaves produced per plant was maximum in cultivar 'Madame Collette' (204.80), followed varieties 'Alma' (194.82) and 'Candy' (184.67) and was minimum in cultivar 'Leon' (129.54) at 180 days after planting plants under low cost polyhouse. Kumar and Singh (2003a, 2003b) reported relatively higher number of leaves (209.47) was observed in autumn planting. Plant grown under short days at winter recorded 215.03 leaves. However, in case of interaction effect, the maximum number of leaves (224.71) was recorded under autumn planting season with short day length. Under low cost polyhouse condition, cultivar 'Madame Collette' produced maximum number of leaves per plant (184.10), followed by 'Candy' (180.74) and 'Alma' (172.28), whereas minimum (110.29) was recorded in cultivar 'Leon' (Reddy *et al.* 2004). Among the six Carnation varieties evaluated under polyhouse, maximum number of leaves was recorded in cultivar 'Gaudina' (93.76), whereas minimum (67.10) was recorded in cultivar 'Niva' (Shahakar *et al.* 2004). Shiragur *et al.* (2004b) studied the performance of standard Carnation varieties under protected cultivation and study revealed that the number of leaves produced per plant was maximum in cultivar 'Madame Collette' (208.97), 'Aicardi' (204.03), 'Candy' (203.87) and 'Alma' (198.73), while 'Sorisso' produced lesser number 4 leaves (165.47). Talukdar *et al.* (2006) recorded maximum number of leaves in Chrysanthemum cultivar 'Cavelia' (128.33) under open condition while in polyhouse cum-rain shelter condition it was 64.67 in cultivar 'Stanly Gosling'.

Length of leaf

Lindgren and Uhlinger (1981) noted that the cultivar 'Smoky Carnation' had 5 cm long leaves. In another study Uhlinger and Lindgren (1984) noted leaves of 11 cm length in cultivar 'N-74133'. Kamble (2001) observed the carnation cultivar 'Trust' had recorded maximum leaf length (53.31 cm), while cultivar 'Melody' recorded minimum (42.67 cm) at 60 days after planting. The cultivar 'Madame Collette' recorded maximum leaf length (13.12 cm), whereas cultivar 'Leon' recorded minimum leaf-length (7.29 cm) grown under low cost poly house (Patil 2001). Kumar and Singh (2003a, 2003b) reported that the leaf length was lowest (15.18 cm) when the cuttings were planted in late winter. The maximum leaf length (17.84 cm) was recorded in the plants grown under short days of winter. In case of interaction effect, the maximum leaf length was recorded in autumn planting season of short days. Among the ten varieties grown under low cost poly house longest leaves were produced in cultivar 'Madame Collette' (11.27 cm), followed by 'Alma' (9.85 cm) and 'Denton' (9.71 cm), whereas leaves produced were shortest (6.03 cm) in cultivar 'Leon' (Reddy *et al.* 2004). Shiragur *et al.* (2004b) studied the performance of standard carnation varieties under protected cultivation and reported that leaf length was maximum in varieties 'Madame Collette', 'Pirandello', 'West Pretty' and 'Aicardi' (10.88 cm, 10.30 cm, 10.04 cm and 8.78 cm, respectively); while cultivar 'Sorisso' recorded the minimum leaf length of 6.03 cm.

Mortality percent

According to Blanc (1983) varieties 'Pallas' and 'Elsy' were found very resistant to mortality (0.5%) and varieties 'Tanga', 'Lonseva', 'Vanessa' and 'Danillo' were fairly tolerant with 30 to 60% mortality and cultivar 'Scania' was highly susceptible that is 100% death of plants. Boikov (1983) noted that some of the Bulgarian varieties had higher resistance to *Fusarium* wilt (*Fusarium oxysporum* F. sp. *dianthi)*, race 20 than 'Sim' varieties. The percentage of symptomless plants in the trial under conditions of artificial infection in the cultivar 'Plam' was 92.5%; while in the 'Scania' (control) cultivar it was 17.5%. Garibaldi (1983) reported that for all the pathotypes of *Fusarium oxysporum* F. sp. *dianthi* cultivar Duca was resistant. Tramier *et al.* (1983) evaluated 27 Carnation varieties to study the *Fusarium* wilt incidence and noted that varieties 'Diano' (0.3%), 'Elsy' (1%), 'Duca' (3%), 'Lanakino' (3%), 'Clair' (4%) and 'Pallas' (8%) were resistant and varieties 'Embed' (86%), 'Lonzelou' (84%), 'Vanessa' (68%) and 'Tangra' (57%) were susceptible ones. Tramier *et al.* (1987) found variety 'Elsy' and 'Pallas' were tolerant with 14% and 17% of diseased plants, respectively and varieties 'Aril Diana' and 'Sacha' as moderately tolerant, but cultivar 'Ember' was highly susceptible (100% diseased plants). Boikov (1992) stated the advantages of Bulgarian complex Carnation varieties and noted that over 80% of the Bulgarian varieties showed high *Fusarium* resistance, both in laboratory and in commercial condition. About 15% of them registered moderate were medium resistance to this disease and 5% were tolerant to it. Schoffelmeer *et al*. (1992) evaluated the Carnation varieties against *Fusarium* wilt resistance and stated that cultivar Novada was most resistant (95%) and varieties 'Lena' and 'Early Sam' were most susceptible (100%). Ben-Yephet *et al.* (1993) studied the comparison of the effect of inoculation in the greenhouse and at field in the *Fusarium* wilt development in six Carnation varieties. The study revealed that variety 'Galit', 'Pallas' and 'Eveline' were free from disease, whereas cultivar 'Fantasia' recorded maximum disease incidence (100%) in 1st and 3rd year followed by Raggiodi-sole 95% in 1st year and 100% in 3rd year. In another study of 11 varieties evaluated, the study revealed that variety 'Aviv', 'Golden Queen', 'Mark Queen' and 'Pink Tween' were free (0%) from any disease symptoms under greenhouse, whereas variety Libnatl, Alpinia, Oriliand Spring Tween recorded 100% disease incidence under greenhouse. Atanassova and Batchvarova (1995) observed that varieties 'Regina', 'Nicki', 'Krassina', 'Yanita' and 'Biliana' were high yielding than 'Red Barbara' and were highly resistant to *Fusarium oxysporum* F. *sp. dianthi* race (95% resistance) whereas varieties 'Red Barbara' was found to be tolerant (31.9% resistance). Ben-Yephet *et al.* (1996) evaluated five Carnation varieties to study *Fusarium* wilt resistance and reported that cultivar 'Galit', 'Eveline' and 'Candy' had no disease incidence, whereas cultivar 'Hermon' showed 40% disease incidence. In Carnation varieties, 'IAHS-27' had

minimum mortality (13.57%) whereas cultivar 'IAHS-7' had the highest mortality of 25% (Sathisha 1997). Lal *et al.* (1998) studied the performance of fourteen Carnation varieties for their susceptibility to various fungal diseases and reported that the varieties 'Scania', 'Dusty', 'Whitesim', 'Shocking Pink', 'Arthur Sim' and 'Sam's Pride' were moderately to highly susceptible. While, the variety 'Alec's Red', 'William Sim', 'Harvest Moon', 'Lena', 'Yellow Dusty', 'Tangerine', 'Laddie' and 'Scarlet Elegance' were highly susceptible. Patil *et al.* (2001) studied the performance of Carnation varieties against *Fusarium* wilt resistance and found that varieties 'Sugar Baby' and 'Aicardi' recorded minimum plant mortality (5.86%) due to *Fusarium* wilt, whereas cultivar 'Leon' recorded maximum mortality (16.67%). Shiragur (2002) stated that the mortality of plants due to *Fusarium* wilt was minimum (9.6%) in cultivar 'Madame Collette' followed by varieties 'Pirandello' (10.44%), 'Alma' (10.73%) and 'Aicardi' (11.22%); whereas it was maximum (25.98%) in cultivar 'Sorisso'.

FLOWERING PARAMETERS

Number of days taken to bud initiation

Naveenkumar *et al.* (1990b) observed that cultivar 'Red Corso' was early in flowering (138 days after planting) when compared to 'Cabaret' (162 days after planting). Bhautkar (1994) studied the performance of 10 varieties under greenhouse and reported that cultivar 'Barbara' was the earliest to initiate following 10th days after planting. However, cultivar 'Eveline' was late which required 119 days for the bud initiation. In another study, cultivar 'Sterile DOP' (spray) was earliest (122.06 days), whereas cultivar 'Pink' (Standard) was late (166.77 days) in flowering (Mahesh 1996). Satisha (1997) reported that early flower bud initiate was recorded in cultivar 'IAHS -22' (95.75 days), followed by cultivar 'IAHS-23' (96.30 days). Patil (2001) studied 10 Carnation varieties under low cost polyhouse and reported that cultivar 'Leon' was earliest to initiate flowering (55 days), whereas cultivar 'Aicardi' was too late that took 128.67 days for flower bud initiation. Kumar and Singh (2003a, 2003b) reported that the maximum number of days (102.94) for flower bud emergence was taken by autumn planting whereas further delay in planting led to early emergence of flower bud. The earliest bud emergence (85.65 days) was observed in the late winter season. The plants exposed to long day condition took the least number of days for their bud emergence (78.5%). In case of interaction effect the earliest bud emergence (71.61 days) was observed in late winter season with long days. Among six cultivar evaluated under naturally ventilated greenhouse, cultivar 'Salsa' was earliest to initiate flowers (74.8 days after planting), whereas cultivar 'Cobra' was late which took 87.55 days for flower bud initiation (Sahakar and Sable 2003). An experiment was carried out to study the performance of 10 Carnation varieties by Reddy *et al.* (2004). According to them, the flower bud initiation was earlier in cultivar 'Leon' (55 days), followed by 'Sorisso' (71 days) and 'Desio' (72 days). Late flowers were observed in varieties 'Aicardi', 'Pirandello' and 'Candy' (128, 120.67, 114.66 days respectively). Sahakar *et al.* (2004) studied the growth, flower quality and yield of six Carnation varieties under polyhouse and reported that cultivar 'Salsa' recorded the shortest period (99.55 days) for flower bud initiation while cultivar 'Gaudina' recorded maximum (122.20) days for bud initiation. Sarkarand Gimiray (2004) studied the performance of 'Gerbera' under protected condition and reported that it took 109.72 to 141.12 days to visibility of flower bud. Among the nine Carnation varieties evaluated under law cost ploy house, cultivar 'Desio' was earliest to initiate bud (63.83 days), followed by cultivar 'Sorrisso' (67.50 days), while cultivar 'Pirandello' was late which took 119.50 days for flower bud initiation (Shiragur *et al.* 2004a).

Number of days taken for flower bud opening

Cultivar 'Espana' took 82 days to reach stage of harvesting from planting (Sing *et al.*, 1994). Sparnaaij *et al.* (1990a) reported that first flowering ranged from 103 days from pinching in *Dianthus* x *Doris* hybrid (80910-4) to 17 days in *Dianthus knappi* hybrid (79127-2). Varieties differed significantly for number of days taken for bud opening under low cost greenhouse. Cultivar 'Master' took maximum number of days (6.38) for bud opening, while cultivar 'Vienna' took minimum number of days (6.06) for bud opening (Krishnappa *et al.* 2000). Under low cost polyhouse, Patil (2001) evaluated 10 varieties; among them 'Leon' was earliest for flower bud opening (84.67 days), followed by cultivar 'Sorisso' (97.33 days); whereas cultivar 'Aicardi' was late in flower bud opening (151.67 days). Shiragur *et al.* (2004a) evaluated the 10 standard Carnation varieties under protected cultivation and reported that the cultivar 'Sorisso' and 'Desio' showed early flower bud opening (91.50 and 93.33 days, respectively); whereas in cultivar 'Aicardi' flower bud initiation was late hence, there was delay in flower bud opening (137 days). Sarkar and Ghimiray (2004) studied the performance of 'Gerbera' under protected condition and reported that Gerbera varieties 'Red Explosion' and 'Kalimpong Red' requires 118.43 days and 15.18 days to flower bud opening, respectively. Among the varieties studied under polyhouse condition by Sahakar *et al.* (2004), cultivar 'Salsa' recorded the minimum number of days (20.60 days) for flower opening, while cultivar 'Super Green' recorded maximum days for flower opening. Tejaswini and Murgod (2005) reported that module M_4 (Sand: Soil: Compost + 6 liter irrigation regime per m^2 per day + straight fertilization) exhibited slow opening (5.33 days), followed by those from module M_3 (Saw dust: Soil: Compost + 6 liter irrigation regime per m^2 per day + water soluble fertilizers (94.67 days). On the contrary, flower from M_7 (Saw dust: Soil: compost + Irrigation regime 3 liter per day + water soluble fertilization) opened quickly within 93.45 days.

Number of days taken for flower development

Mahesh (1996) reported the cultivar 'Pink' (Standard) took very less time for flower bud development (26.20 days); whereas cultivar 'Sterile DOP' (Spray) took more time for flowering (41.06 days) in Carnation. The time taken for bud development from flower initiation was very less in case of cultivar 'IAHS-22' (20.35 days) as compared to cultivar 'IAHS-7' (36.3 days) under low cost greenhouse (Sathisha 1997). Patil (2001) evaluated 10 varieties under low cost polyhouse and reported that cultivar 'Alma' took very less time for bud development (18.00 days), whereas cultivar 'Sorisso' took more time (26.33 days) for development of flower bud. Shiragur *et al.* (2004a) observed that cultivar 'West Pretty' took less time for bud development (17.67 days), followed by 'Sugar Baby' (18.00 days); whereas cultivar 'Sorisso' was late in bud development (29.33 days) when cultivars were evaluated under low cost polyhouse. Singh and Singh (2005)

reported that earliest flowering (170.90 days) was observed in single pinching and 500 ppm Nitrogen while double pinching and 200 ppm Nitrogen combination took maximum days (196.93) for flowering.

Duration of Flowering

Gill and Arora (1988) reported that duration of flowering in cultivar 'Scania' was 33.81 days. Lal *et al.* (1998) studied the performance of different variation of Carnation and noted that the longest duration of flowering (31.5 days) was observed in the variety 'Sims Pride' which is a spray type, followed by the standard type 'Scania' (31.03 days). The duration of flower was maximum (48.77 cm) when no pinching was performed and minimum (21.10 cm) was with double pinched plants (Pathania *et al.* 2000). Patil (2001) reported that the flowering period was maximum in cultivar 'Desio' (188.67days) and was minimum in cultivar 'Aicardi' (143.33 days). Dwivedi and Kareem (2004) evaluated the fifteen Carnation varieties and noted that the longest duration (34.3 days) was observed in the variety 'Flair', followed by 33.0 days in 'Etora'. 'Red Carnation' variety had shortest duration of flowering (26.65 days). Shiragur *et al.* (2004a) evaluated the standard Carnation cultivar under protected cultivation and reported that as far as flower duration is concerned; cultivar 'Aicardi' (235.0) recorded maximum duration, followed the 'Alma' (229.67), 'West Pretty' (222.67), 'Candy' (222.0) and 'Sugar Baby' (218.67), whereas varieties 'Pirandello' (184.67), 'Desio' (184.67) and 'Sorisso' (193.33) recorded minimum duration.

FLOWER QUALITY PARAMETERS

Length of flower Stalk

Boikov (1983) observed that the average flower stalk length of Bulgarian Carnation varieties was higher (101.11 cm) than Sim Carnation varieties (89.0 cm). Gill and Arora (1988) observed the average flower stalk length ranged from 44.8 cm in cultivar 'Scania' and 48.5 cm in cultivar 'Can Can'. Bhautkar (1994) revealed that flower stalk length ranged from 65-87 cm where cultivar 'Lena' recorded maximum flower stalk length (87 cm) 'White Sim' recorded minimum (65 cm) of this parameter. Singh *et al.* (1994) observed that stem length (59.05 cm) was found higher in 25% shading, whereas it was minimum (58.78) under no shade condition for second flush in Carnation crop. Mahesh (1996) evaluated Carnation varieties under low cost polyhouse and found that flower stalk length varied from 99.35 cm to 115.10 cm in varieties 'Arthur Sim' and 'Starlight DOP', respectively. Cultivar 'IAHS-23' had the longest flower stalk length (80 cm) at harvest, followed by cultivar 'IAHS-22' (79.40 cm), whereas varieties 'IAHS-7' had the shortest flower stalk length of 66.75 cm. (Sathisha 1997). Lal *et al.* (1998) studied the performance of different varieties of Carnation in and noted that longest flowering stalk (28.85 cm) was found in the variety 'Scania', followed by 'Shocking Pink' (27.28 cm). The minimum flowers stalk length was found in variety 'Scarlet Elegance' (20.05 cm). The maximum flower stem length (54.08 cm) was observed in cultivar 'Red Corso' under polyhouse as compared to open (42.00 cm) in cultivar 'Cabaret', where it was 38.00 cm under polyhouse condition (Naveenkumar *et al.* 1999b). Pathania *et al.* (2000) noted that the stem length was maximum (48.77 cm) when no pinching was followed. The stem length was minimum (21.10 cm) when double pinching was followed. The stem length of 34.50 cm recorded in pinch and half for second flush. Patil (2001) studied the 10 Carnation varieties under low cost polyhouse and revealed that cultivar 'Sugar Baby' recorded maximum stalk length (106.77 cm) followed by cultivar 'Alma' (103.83 cm); whereas minimum stalk length was recorded in cultivar 'Leon' (67.04 cm). Kumar and Singh (2003a, 2003b) observed that stem length was maximum (37.41 cm) in autumn season. In case of interaction effect, autumn season with long day condition showed maximum stem length (39.86 cm). Singh and Sangama (2003) noticed that significant variation was observed in flower stalk length at different Carnation varieties under pad cooling system greenhouse condition. Cultivar 'Navajo' had longest stalk length of 70.06 cm followed by cultivar 'Sunrise' (67.63 cm). The minimum stalk length of 39.26 cm was recorded in cultivar 'Isaq'. Dwivedi and Kareem (2004) published that cultivar 'Dusty Pink' showed maximum flower stalk length of 27.00 cm whereas it was more in cultivar 'Cabaret' (19.65 cm). An experiment was carried out by Reddy *et al.* (2004) to study the vegetative growth, flower yield and quality of ten standard Carnation varieties under law cost polyhouse condition. The study revealed that the length of flower stalk was longest in 'Alma', 'Sugar Baby', 'Aicardi' and 'Pirandello' (95.92, 93.63, 89.85 and 89.15 cm. respectively). Moderate flower stalk length was recorded in 'Desio', 'Candy' and 'Madame Collette' (88.68, 87.54 and 85.76 cm, respectively); whereas shortest stalk length was recorded in cultivar 'Leon' (67.70 cm). Six Carnation varieties were evaluated under polyhouse by Sahakar *et al.* (2004). The study revealed that maximum stem length was observed in cultivar 'Gaudina' (93.94 cm) and it was minimum in cultivar 'Niva' (68.26 cm). Study conducted under low cost polyhouse by Shiragur *et al.* (2004a) found that, maximum stalk length was recorded in cultivar 'Pirandello' (91.02 cm) followed by cultivar 'Candy' (87.74 cm); whereas minimum stalk length was recorded in cultivar 'Desio' (67.88 cm). The maximum flower stem length (52.10 cm) was found under single pinching and minimum (39.5 cm) under double pinching. In case of interaction effect the maximum flower stalk length (58.4) was recorded in single pinching and 500 ppm nitrogen (Singh and Singh 2005). Singh *et al.* (2006) noted that the extended photoperiods resulted in longer flower stem (69.9 cm and 67.8 cm under 4 hour and 6 hour additional light, respectively) over the control (50.2 cm). Maximum stem length (64.38 cm) was observed in cultivar 'Raggio-de-sole' as compared to cultivar 'Murcia'. Amongst different treatment combinations, maximum stem length (67.47 cm) was recorded under treat T_6 (Sand + Soil + Vermicompost (1:1:1) + Inorganic water soluble fertilizers + Bio fertilizers) and minimum under T_1 or control check (Bhalla *et al.* 2007). Ryagi *et al.* (2007) studied the effect of pinching on growth, yield and quality of Carnation varieties under greenhouse and the study revealed that maximum stem girth was recorded in 'Yellow Solar' (88.6 cm), minimum in 'Domingo' (86.3 cm). In case of interaction effect between cultivar and pinching method, the maximum stalk length was observed in 'Cherry Solar' with single pinching (93.2 cm), whereas it was lowest in 'Domingo' with double pinching.

Girth of Flower Stalk

Girth of flower stalk of Bulgarian varieties was higher (3.8 mm) when compared to Sim varieties (3.7 mm), stem thickness at third mode was highest in case of genotype 'Pink' (0.31 cm) and was lowest (0.20 cm) in case of genotype 'Deep Pink' (Mahesh 1996). The maximum girth of flow stalk was observed in cultivar 'IAHS-5' (0.49 cm), whereas the

lowest flower stalk girth (0.36 mm) was recorded in cultivar 'IAHS-7' grown under low cost polyhouse (Satisha 1997). Patil (2001) observed maximum girth of flower stalk (15.60 mm) in cultivar 'Madame Collette' followed by cultivar 'Sugar Baby' (5.60 mm) and minimum flower stalk girth was recorded in cultivar 'Leon' (3.50 mm) grown under low cost polyhouse. An experiment was carried out by Reddy *et al.* (2004) to study the vegetative growth, flower yield and quality of 10 standard Carnation varieties under low cost polyhouse condition. The study revealed that girth of flower stalk was maximum in cultivar 'Madame Collette' (0.56 cm), 'Sugar Baby' (0.55 cm) and 'Alma' (0.53 cm), whereas cultivar 'Leon' recorded minimum. Six Carnation varieties were evaluated under polyhouse by Shahakar *et al.* (2004). The study revealed that the maximum girth of stem was recorded in 'Super Green' (0.49 cm) followed by 'Niva' (0.48 cm), 'Cobra' (0.45 cm) and 'Gaudina' (0.43 cm). Under low cost polyhouse, maximum girth of flower stalk (6.94 mm) was recorded in 'Sugar Baby' followed by 'Madame Collette' (6.70 mm), whereas minimum (3.27 mm) girth of flower stalk was recorded in 'Sorisso' (Shiragur *et al.* 2004a). According to Tejaswini and Murgod (2005), the stem thickness was significantly higher (5.42 mm) in cultivar 'Sunrise' in M_5 (Sand: Soil: Compost (1:2:1) + 3lit/m^2/day irrigation regimes + water soluble fertilizers). Ryagi *et al.* (2007) studied the effect of pinching on growth, yield and quality of Carnation varieties under greenhouse. The study revealed that maximum stalk girth (5.12 cm) was observed in 'Domingo', whereas it was minimum in 'Dover' (3.73 mm). In case of interaction effect between variety and pinching methods the maximum stalk girth was recorded in 'Domingo' with double pinching (5.35 mm). It was recorded minimum (3.54 cm) in 'Dover' with single pinching and 'Cherry Solar' with single and half pinching.

Flower Diameter

Flower diameter of Bulgarian race was found significantly higher (8.9 cm) compared to flower diameter of Sim Carnations (7.7 cm) at the peak of flowering stage (Boikov 1983). Pawliczuk and Orlikowski (1987) noted that cultivar 'Kmic' had maximum flower diameter (7.9 cm), whereas cultivar 'Pallas' had minimum (6.8 cm). Singh *et al.* (1994) observed maximum bloom size (8.4 cm) in cultivar 'Scania', whereas it was minimum (96.7) cm in cultivar 'Can Can'. According to Atanassova and Batchvarova (1995), the diameter of flower was maximum in 'Biliand' and 'Red Barbariz' (4.5 cm), whereas it was minimum (4.3) in 'Yanita'. Naveenkumar *et al.* (1999a) reported that flower diameter ranged between 6.83 cm in cultivar 'Red Corso' to 5.40 cm in 'Cabaret'. The maximum flower diameter (7.20 cm) was noted in cultivar 'Cabaret' under polyhouse as compared to open condition (4.80 cm) (Naveenkumar *et al.* 1999b). Mahesh (1996) studied the Carnation varieties under low cost polyhouse and observed that diameter varied from 4.66 cm in cultivar 'White' to 7.11 cm in cultivar 'Arthur Sim'. In another study conducted by Satisha (1997), it was found that, cultivar 'IAHS-23' had larger sized flower (7.58 cm diameter) when compared with 'IAHS-7' (5.10 cm diameter). Patil (2001) noticed that cultivar 'Madame Collette' had maximum flower diameter (6.63 cm) followed by cultivar 'Alma' (6.31 cm), whereas cultivar 'Leon' had minimum flower diameter of 4.13 cm. Flower diameter was maximum (6.98 cm) in no pinched plants. However, it was minimum 5.60 cm in case of double pinched plants (Pathania *et al.* 2000). Singh and Sangama (2003) noted that there was significant variation among the varieties evaluated. The maximum flower diameter of 6.08 cm was recorded in cultivar 'Aicardi' followed by 'Sunrise' (5.61 cm). The flower diameter was minimum in 'Lilac Torres' (4.25 cm). Dwivedi and Kareem (2004) reported that diameter of flower showed no significant variation and it ranged from 5.0 cm in 'White Candy' to 5.9 cm in 'Shocking Pink', 'Atora' and 'Carpalmor'. Gurav *et al.* (2004) reported that the maximum flower diameter (6.98 cm) was recorded in modulus M_1 (Soil + compost + Sand (2:1:1) substrate, 20 kPa irrigation regime, basal dose at 200:200:100 NPK kg/ha/year + 100 and 20 kg N and K /ha/year) through fertilization; whereas it was minimum of 5.47 cm in modulus M_9 (same as M_1, except rationing after one year). An experiment was carried out by Reddy *et al.* (2004) to study the ten standard Carnation varieties under low cost polyhouse condition. The study revealed that the cultivar 'Madame Collette' recorded maximum flower diameter (6.65 cm) followed by 'Desio' (5.44 cm); whereas diameter of flower bud was minimum in cultivar 'Leon' (4.66 cm). Six Carnations cultivars were evaluated under polyhouse by Shahakar *et al.* (2004). The results revealed that the maximum flower diameter (7.45 cm) was in cultivar 'Gaudina'; whereas it was minimum (6.00 cm) in variety 'Salsa'. Among nine varieties grown under low cost polyhouse, cultivar 'Candy' recorded maximum flower diameter (6.63 cm) followed by 'Madame Collette' (6.41 cm), whereas cultivar 'Sorisso' recorded minimum flower diameter of 5.63 cm (Shiragur *et al.* 2004a). The maximum flower diameter (5.7 cm) was obtained in single pinching and was least (5.2 cm) in double pinching, whereas in case of interaction effect it was maximum in (5.8 cm) in single pinching with 200 ppm nitrogen and single pinching with 500 ppm nitrogen (Singh and Singh 2005). Singh *et al.* (2006) noted that maximum flower diameter (6.61 cm) was noticed under 4 h additional light, whereas it was minimum (5.76 cm) under natural day length.

Length of Flower

Bhautkar (1994) reported that the maximum length of flower (7 cm) was recorded in varieties 'White Sim', 'Lena' and 'Arthur Sim', whereas minimum (4.5 cm) was recorded in 'Starlight' under glasshouse. Gurav *et al.* (2004) evaluated Carnation cultivar 'Sunrise' under partially modified greenhouse and revealed that the flower length was found to be maximum (5.36 cm) in treatment M_4 (Soil + compost + Sand (2:1:1) substrate, 20 KPa irrigation fertilization + basal dose at 200: 200:100 NPK kg/ha/yr + fertilization through straight fertilizers), whereas it was recorded minimum of 4.45 cm.

Number of Petals

Halliday and Watson (1953) reported that variety 'Northland' had more number of petals per flower (57.5) as compared to variety 'William Sim' (47.7). Boikov (1983) noticed that mean number of petals in Bulgarian Carnation varieties was significantly higher (66.1) when compared with mean number of petals in sim Carnation varieties 63.8. Boikov (1992) noted that in new Bulgarian Carnation varieties, number of petals per flower ranged between 100 and 200, which was much more than that of Mediterranean and Sim varieties. Lindgren and Uhlinger (1996) observed 29 petals per flower in cultivar 'Prairie Pink'. Atanassova and Batchvarova (1995) recorded maximum number of petals in variety 'Regina' and 'Krassina' (48.5 and 97.5, respectively); whereas variety 'Nicki' had minimum of 29.6 petals. According to Mahesh (1996),

number of petals ranged from 44.88 in cultivar 'Pink' to 66.75 in cultivar 'Arthur Sim'. Naveenkumar *et al.* (1999b) noted that cultivar 'Cabaret' had maximum number of petals per flower (87), whereas cultivar 'Red Corso' had minimum of 42. Naveenkumar *et al*. (1999a) noted that cultivar 'Carbaret' had maximum number of petals per flower (85.5) under polyhouse condition as compared to 49.0 under open condition. Patil (2001) Evaluated 10 Carnation cultivars under low cost polyhouse and reported that maximum number of petals per flower were recorded in cultivar 'Madame Collette' (68.33) followed by cultivar 'Desio' (60.67); whereas cultivar 'Leon' recorded minimum (38.33) number of petals per flower. Evaluation of Carnation varieties under protected cultivation revealed that number of petals ranged from 42.32 in cultivar 'Sugar Baby' to 69.16 in cultivar 'Alma' (Shiragur *et al.* 2004a).

Flower Weight

The fresh weight of Bulgarian race (10.6 g) was higher than Sim varieties (8.24 g) as reported by Boikov (1983). Singh *et al.* (1994) observed no significant difference in final cut-flower weight. It was maximum (28.82 g) in no shade whereas minimum (28.02 g) in 50% shade treatment for second flush. Krishnappa *et al.* (2000) reported significant differences in cumulative fresh weight of flowers. Significantly highest cumulative fresh weight (148.28 g) was recorded in cultivar 'Aleda'; whereas minimum cumulative fresh weight of flower was recorded in cultivar 'Vienna' (104.96 g). Singh *et al.* (2001) studied different varieties and noticed that cultivar 'Forca' recorded higher fresh weight (28.73 g) followed by 'Tasman' (20.16 g) and 'Aicardi' (19.53 g) and lowest weight was observed in 'Lillac Torres' (10.10 g). Cultivar 'Pentara' and 'Sunrise' recorded better fresh weight with the incorporation of silver nitrate + Sucrose + 8- Hydroxyquinoline as reported by Chikkasubbanna and Sharada (2002). Shiragur (2002) studied the performance of Carnation varieties under polyhouse condition and reported that 'Madame Collette', 'Sugar Baby', 'Aicardi', 'Alma' and 'Pirandello' recorded higher flower weight (16.42, 15.83, 13.92, 13.43, and 13.83 g, respectively), while cultivar 'Sorisso' recorded minimum flower weight of 8.42 g. Singh and Sangama (2003) reported that 'Forca' had highest fresh weight of flower stalk (28.13 g) followed by cultivar 'Tasman' (18.33 g). The minimum fresh weight of 11.96 g was obtained in 'Lilac Torres'. Among the difference Carnation varieties studied, cultivar 'Madame Collette' recorded higher fresh weight (16.42 g) followed by 'Sugar Baby' (15.83 g) and 'Aicardi' (13.92 g) and lowest (8.42 g) in cultivar 'Sorisso' (Shiragur *et al.* 2004a). According to Tejaswini and Murgod (2005) fresh weight of flower was significantly higher (14.45 g) in M_7 as Sawdust: Soil: Compost at 1:2:10 + 3 liter /m^2/day irrigation + water soluble fertilizers. Fresh weight was recorded least in M_1 as Sand: Soil: Compost (1:2:1) + 6 liter/m^2/day irrigation + water soluble fertilizers.

Calyx Splitting

Halliday and Watson (1953) noticed that calyx splitting varied from 1.04% in cultivar 'Northland' to 3.97% in cultivar 'Millers Yellow' grown under greenhouse. Boikov (1983) observed less incidence of calyx splitting in Bulgarian varieties (0.9%) when compared to Sim varieties (14.3%). Skalska (1983) studied the influence of fertilization on flower calyx splitting in pink Carnation variety 'Lena' and noticed that the number of flowers with split calyx/m^2 was not influence significantly by the fertilization of the plants to the required level of nutrients in soil. He further reported that, the greatest number of flower with split calyx was obtained in spring, in the period from mid-February to mid-May. Mitteau (1987) observed no calyx splitting in 'Vanya' and 'Carola'. The maximum calyx splitting was recorded in 'Ember' (27%) whereas it was minimum (1%) in 'Tanga' and 'Virginie'. Varieties 'Srebrina' and 'Cana' were free from calyx splitting. Bulgarian Carnation varieties were considerably free from calyx splitting, which ranged between 0.1 and 0.5 per cent according to Boikov (1992). Cultivar 'IAHS-27' had minimum calyx splitting (3.64%) followed by cultivar 'IAHS-7' (5.37%), whereas maximum calyx splitting (10.24%) was observed in cultivar 'IAHS-5' (Satisha 1997). Calyx splitting was found minimum in 'Clear Yellow' (10.30%) where it was maximum (15.7%) in cultivar 'Scania' (Gill and Arora 1998). Lal *et al.* (1998) recorded the lowest calyx splitting percentage (27.7%) in the variety 'Alec's Red' followed by 'Yellow Dusty' (28.76%) among the standard Carnations. Pathania *et al*. (2000) reported that when no pinching was followed, the percentage of calyx splitting was maximum (38.07%) because of more vigour in petals, whereas it was minimum (19%) in double pinched plants having 16 laterals. Among varieties studied, Patil (2001) noted no calyx splitting in 'Sugar Baby' and 'Desio' and low calyx splitting in cultivar 'Madame Collette' (0.83%); whereas cultivar 'Leon' recorded maximum calyx splitting (12.50%). Shiragur (2002) reported that the calyx splitting varied among the varieties. It was minimum in 'West Pretty' (0.09%) followed by 'Sugar Baby' (0.25%), 'Desio' (0.44%), 'Madame Collette' (0.98 %) and it was maximum in 'Pirandello' (13.46%). Singh *et al.* (2006) noted that calyx splitting was not observed in any of the treatment. This was apparently due to prevailing warmer temperature conditions in March-April when bud development took place.

Vase- Life

Among ten varieties evaluated by Bhautkar (1994), varieties 'Thalassa' and 'Bianca' recorded maximum vase life (8 day each). However, 'Arthur Sim' recorded minimum vase-life of 3 days. Singh *et al.* (1994) observed longer vase-life under unshaded plants for second flush. Mahesh (1996) reported that cultivar 'Deep Pink' and 'Dusty Pink' had maximum flower longevity of 16.0 days and 15.53 days, respectively; whereas cultivar 'White Sim' with red edge had minimum (10.45 days) longevity. Satisha (1997) reported that cultivar 'IAHS-7' had maximum vase-life of 11.48 days, followed by cultivar 'IAHS-27' (10.80 days) and 'IAHS-23' (10.10 days); whereas minimum vase-life (7.50 days) was recorded in 'IAHS-5'. Naveenkumar *et al.* (1999a) observed maximum vase-life (10.0) in cultivar 'Cabaret', whereas it was minimum (8.67 days) in cultivar 'Red Corso' under polyhouse when treated with 8-HQC 200 ppm. The maximum vase-life of 11.0 days was recorded in cultivar 'Master', followed by cultivar 'Kristina' (10.63 days); whereas cultivar 'Vienna' recorded significantly shortest (9.74 days) vase-life (Krishnappa *et al.* 2000). Pathania *et al.* (2000) reported that the keeping quality of cut Carnations was higher (13.13 days) in case of un-pinched plants because of better availability of nutrition and accumulation of carbohydrates. Patil (2001) evaluated 10 Carnation varieties under polyhouse and noted significant difference in vase-life. The maximum vase-life was recorded in cultivar 'Sugar Baby' (12.33 days) and it was minimum in cultivar 'Leon' (5.33 days). Chikkasubbanna and Sharada (2002) observed that maximum vase-life of 10.80 days was recorded in cultivar

'Pentara' in 0.4 mM STS + 6.1% Sucrose + 400 ppm 8-Hydroxyquinoline as against the control (4.80 days). In case of different combinations of chemicals vase-life was maximum in cultivar 'Sunrise' (15.80 days) in 100 ppm silver nitrate + 4% sucrose + 200 ppm 8-HQ compared to 7.4 days in control. According to Sumanbhatia *et al.* (2002) the maximum vase-life was recorded in cultivar 'Impala' (13.5 days) and 'Purple Choppin' (9.67 days) with holding solution of 100 ppm STS + 2% sucrose. Singh et al. (2006) observed that durability of flower was maximum (9.15 days) in autumn planting season, whereas maximum vase-life was observed in long day condition (8.33 days). In case of interaction effect, the maximum durability of flower was recorded in autumn season with long day condition (10.93 days). Among the 10 varieties of Carnation evaluated for post harvest quality under greenhouse (Singh and Sangama 2003), cultivar 'Sunrise' recorded maximum vase-life of 12.60 days, followed by variety 'Forca' (12.40 days). Cultivar 'Lilac Torres' had shortest vase-life of 8.40 days. According to Shiragur *et al.* (2004a), cultivar 'Alma' recorded maximum vase-life of 16.33 days, followed by 'Desio' (16.17 days), 'Sugar Baby' (15 days), 'West Pretty' (15 Days); whereas cultivar 'Sorisso' had recorded minimum vase-life of 6.67 days. Six Carnation varieties were evaluated under polyhouse by Shahakar *et al.* (2004). The study revealed that the maximum vase-life was observed in cultivar 'Super Green' (9.50 days), followed by 'Niva' (9.0 days), 'Salsa' (8.0 days), 'Montezuma' (7.0 days), 'Cobra' (6.0 days) and 'Gaudina' (5.80 days). Singh *et al.* (2006) noted that additional lighting did not affect vase life of the flowers. Ryagi *et al.* (2007) studied the effect at pinching on growth, yield and quality of Carnation varieties under greenhouse and the study revealed that maximum vase-life of 8.52 days was recorded in 'Yellow Solar' whereas it was minimum in 'Dover' (7.97 days). In case of interaction effect between cultivars and pinching method, the maximum vase-life of 8.81 days was in cultivar 'Yellow Solar' with single pinching; whereas it was minimum in cultivar 'Dover' with single pinching (7.53 days). Singh *et al.* (2007) studied the effect of vase and pulsing solutions on keeping quality of standard Carnation cut flowers and reported that the vase-life of cut-flowers was maximum (11.45 days) in solution containing sucrose (5%) + aluminum sulphate (200 ppm). Among different combinations comprising of sucrose, biocides and ethylene antagonists, the maximum vase-life (13.44 days) was observed when the stems were pre-treated with STS, 1 mM under cool conditions for 24 h, followed by placing the stems in vase solution containing sucrose (5%) + aluminum sulphate (200 ppm). Among the pulsing treatments, maximum vase-life (11.89 day) was obtained with solution containing sucrose (10%) + aluminum sulphate (200 ppm) + STS (0.2 mM). According to Tejaswini and Murgod (2005) the vase-life was found to be highest (8.89 days) in case of flowers produced in molecule M_4 (Sand: Soil: Compost as 1:2:1 + 6 lit/m^2/day irrigation regimes + Straight fertilizers) and was least (7.33 days) in M_1 (Sand: soil: compost 1:2:1 + 6 liter/m^2/ day irrigation + water soluble fertilizers) in Carnation cultivar 'Sunrise'.

YIELD PARAMETERS

Number of flower per plant

Khanna *et al.* (1981) reported that production of flowers per plant was significantly more (14.2 flowers) in widest spacing of 30 x 30 cm^2. Pinching the plants either twice or thrice enhanced the number of flowers per plant significantly over control. Most productive varieties of Bulgarian type had 70-80% higher yield than the Sim varieties and 30-40% than Mediterranean type (Boikov 1992). Bhautkar (1994) observed maximum number of flowers in cultivar 'Eveline' (18) followed by cultivar 'Furore' (17) and the cultivar 'Starligtht' (16), whereas minimum number of flowers was recorded in cultivar 'Lena' (10). Singh *et al.* (1994) noted that better flower yield was observed during the second lush that is in winter months. The maximum number of flowers per plant was harvested from 25% shade treatment (13.27 flowers). Atanassova and Batchvarova (1995) observed maximum number of flower per plant in cultivar 'Nicki' (6.2), followed by cultivar 'Yanita' (6.0) and minimum in cultivar 'Red Barbara'. Gill and Arora (1998) recorded maximum number of flowers per plant in cultivar 'Can Can' (6.7 flowers). Lal *et al.* (1998) studied the performance of fourteen varieties of Carnation and reported that higher numbers of flowers per plant were observed in spray variety 'Sam's Pride' (11.2). However, among the standard varieties maximum numbers of flowers (5.1) were produced by the variety 'Scania', followed by 'Arthur Sim' (4.97) and 'White Sim' (4.7). The variety 'Tangerine' (4.13) produced lesser number of flowers per plant. Naveenkumar *et al.* (1999b) recorded highest number of flowers per plant (7.75) in cultivar 'Red Corso' under polyhouse as compared to lesser (4.5) flowers per plant under the open cultivation. Cultivar 'Cabaret' recorded 6.25 flowers per plant under polyhouse as compared to 3.00 flowers per plant under open condition. Under low cost polyhouse, Patil (2001) evaluated 10 varieties of Carnation and recorded maximum number of flowers in cultivar 'Madame Collette' (4.29), followed by cultivar 'Desio' (4.13), while minimum number of flowers was recorded in cultivar 'Leon' (2.71). Kumar and Singh (2003a, 2003b) observed maximum number of flowers per plant in autumn season of planting, whereas in case of interaction of effect of planting season and day length, the maximum number of flowers per plant was observed in autumn season of planting with long day length. Dwivedi and Kareem (2004) reported that the number of flowers per plant were maximum (6.3) in cultivar 'Red Corso' whereas, it was recorded minimum in cultivar 'New Espana' (4.3). Gurav *et al.* (2004) standardized the package of practices for Carnation under partially modified greenhouse and reported that, treatment M_4 (Soil + Compost + Sand (2:1:1) 20 KPa irrigation + basal dose at 200: 200: 100 NPK kg/ha/year + 100 and 200 kg N and K/ha/year fertilization (straight fertilizers) was found to be superior in producing maximum number (154.2) of 'A' grade flower (Stem length is 55 cm or above), flowers/plant/year (5.88). The treatment M_7 (Soil + Compost + Sawdust 2:1:1) + 40 KPa irrigation + basal dose at 200: 100: 100 NPK kg/ha/year + 100 and 200 kg N and K/ha/year through fertilization (water soluble fertilizers) recorded minimum number of flowers per plant (3.59). An experiment was carried out by Reddy *et al.* (2004) to evaluate the 10 Carnation varieties and the study revealed that cultivar 'Madame Collette' recorded maximum yield (4.56 flowers per plant), followed by 'Alma' and 'Sugar Baby' (4.18 and 4.12 flower per plant, respectively). Varieties 'Pirandello', 'Desio' and 'Aicardi' recorded moderate flower yield; however, cultivar 'Leon' recorded minimum flower yield, of 2.82 flowers per plant. Shiragur *et al.* (2004a) evaluated nine standard Carnation varieties under protected cultivation and reported that yield of flower in terms of number of flowers per plant was highest in varieties 'West Pretty' (7.81 flowers), followed by 'Desio', 'Aicardi' and 'Madame Collette' (7.14, 6.97 and 6.69 respectively); while cultivar 'Sugar Baby' produced the lowest number of flowers per plant (5.25 flowers). Shahakar *et al.* (2004) investigated the performance of six standard varieties of Carnations under polyhouse and reported that yield of flowers per plant (5.80) was maximum in cultivar 'Cobra' which was

at par with 'Gaudina'. Next in order were 'Super green' (5.20), 'Niva' (5.13), 'Salsa' (4.46) and 'Montezuma' (4.25). Singh and Singh (2005) reported number of flowers per plant was maximum (5.80) in double pinching method, while in case of interaction effect of pinching method and nitrogen application, the maximum number of flowers per plant was recorded under double pinching and 500 ppm nitrogen (7.40 flowers). Bhalla *et al.* (2007) concluded that the treatment combinations T_6 (sand + soil + vermicompost (1:1:1) + inorganic water soluble fertilizers + bio-fertilizers) produced maximum number of flowers per plant (5.66), while minimum number of flowers per plant (4.53) were observed in control (sand + Soil +FYM, at 1:1:1).

Number of flowers per square meter

Naveenkumar *et al.* (1999) reported that maximum number of flowers per plant (8.0 and 6.7 in 'Red Corso' and 'Cabaret' varieties, respectively) were obtained in treatment T_5 (6-7 leaf pair and 15 days). Pathania *et al*. (2000) observed that double pinched plants with 16 laterals yielded the maximum number of flowers/m^2 (177.77) of poor quality. However, pinch and a half method staggered the flowers production in two flushes, yielding about 66.66 flowers per/m^2 of good quality. Gurav *et al*. (2004) standardized the package of practices for Carnation under partially modified greenhouse and reported that treatment M_4 (Soil + Compost + Sand (2: 1:1) + 20 KPa irrigation + Basal dose as 200: 200: 100 NPK kg/ha/yr +100 and 200 kg N and K/ha/year respectively, through fertilization (Straight fertilizer) was found to be superior in producing maximum number of flowers/m^2 per year (168.00). The same treatment, i.e. M_4 produced maximum number (154.2) of 'A' grade flowers (Stem length is 55 cm and above). The treatment M_7 (Soil +compost + Sawdust (2: 1:1) + 40 KPa irrigation + Basal dose as 200:200:100 NPK kg/ha/yr +100 and 200 kg N and K /ha/year through fertilization (water soluble) recorded minimum number of flowers/m^2 (102.24). Shahakar *et al*. (2004) investigated the performance of six standard Carnation varieties under polyhouse condition and revealed that highest yield of flowers/m^2 (171.80) was recorded in cultivar 'Cobra' which was at par with 'Gaudina'. Next in order were 'Sugar Baby' (162.40), 'Niva' (143.64), 'Salsa' (124.88) and 'Montezuma' (119.00). Shiragur *et al.* (2004a) evaluated nine standard Carnation varieties and reported that maximum flowers per square meter were found in cultivar 'West Pretty' (346.93 flowers), followed by 'Desio', 'Aicardi' and 'Madame Collette' (3.17, 309.75 and 297.45 flowers, respectively) while, cultivar 'Sugar Baby' produced the lowest number of flowers per square meter (233.31). An experiment was conducted by Ryagi *et al*. (2007) to study the effect of pinching on different varieties of Carnation grown under polyhouse and study revealed that among varieties the significantly more number of total flowers were recorded in variety 'Domingo' (112.54 per m^2), followed by 'Dover' (75.23 per m^2) and minimum flower yield was recorded in variety 'Cherry Solar' (44.89 per m^2). In case of interaction effect of cultivar and pinching method the maximum flowers per m^2 was recorded in cultivar 'Domingo' with single pinching method (117.05 per m^2).

AGROMETRIC TRAITS AND MUTATION BREEDING

Mutation breeding has been widely used for the improvement of vital plant characters in various crops. It is a powerful and effective tool in the hands of plant breeders especially for autogamous crops having narrow genetic base (Micke 1988). The prime strategy in mutation breeding has been to upgrade the well-adapted plant varieties by altering major characteristics which limit their productivity or enhance their quality, especially in *Dianthus* (Roychowdhury *et al.* 2012). Mutation can produce the development of *Dianthus* cultivars with more desirable floral characteristics and higher productivity (Roychowdhury 2011, Roychowdhury *et al.* 2011b, 2011d). For this purpose, inducible mutation is a suitable source of producing variation through mutation breeding procedure (Domingo *et al.* 2007) which can produce several improved mutant varieties with high demanding economic values (Din *et al.* 2004). First initiativeness was showed in first mutant (M_1) and second mutant (M_2) generations after Roychowdhury (2011); Roychowdhury and Tah (2011a); Roychowdhury et al. (2011c). Roychowdhury et al. (2011c) used chemical mutagenic (colchicine, ethyl methane sulphonate and maleic hydrazide) induction for M_1 generation production and new codes were given to each mutagenic treatment as: Control = ST1, 0.1% Colchicine = ST2, 0.4% Colchicine = ST3, 0.7% Colchicine = ST4, 0.1% EMS = ST5, 0.4% EMS = ST6, 0.7% EMS = ST7, 0.1%, MH = ST8, 0.4% MH = ST9. Days to seed germination ranged between 4.03 (ST3) - 5.82 (ST9), where control (ST1) showed 4.67. Plant height (cm) at 50% flowering phase and days to branching have a range between 45.87 (ST9) - 54.8 (ST3) and 15 (ST9) - 21 (ST2), respectively; whereas control plant showed the value 48.73 and 16.67 for respective traits. The ranges 3.33 (ST6) - 6.32 (ST4), 36.2 (ST6) - 84.2 (ST3) and 27.2 (ST2) - 42.3 (ST3) were for number of branches per plant, total leaves per plant and number of flower per plant, respectively. Leaf area ranging from 3.25 (ST4) to 4.5 (ST3) in which control (ST1) and ST9 share the same value 3.35. In case of flower diameter and seeds/inflorescence, the range were 3.87 (ST7) - 4.4 (control and ST3) and 22.6 (ST7) - 33.3 (ST3), respectively. Control has a value 28.6 for the later. Weight of 1000 seeds ranged from 1.35 (ST3) to 1.63 (ST5 and ST6), where control showed 1.59, i.e., very much close to the highest range. M_2 generation study of Roychowdhury and Tah (2011a) revealed highly significant differences among mutagenic treatment of Dianthus cultivar for all the characters studied. The value of variance ratio was as calculated significant at 1% level in case of number of tillering per plant, total number of flowers per plant and length of petals (foliar treatment) & length of flowers, length of petals (seed treatment) and at 5% level in total number of flowers per plant and weight of 1000 seeds (in foliar treatment) & number of tillering per plant and total number of flowers per plant (in seed treatment).

PRESENT FLORICULTURAL STATUS

Totth (1984) reported that, cultivation of Carnation for cut-flowers is no longer profitable due to enormous increase in production costs. However, profitability can be improved by adopting improved cultural methods and also by the introduction of highly productive good quality varieties. Subramanyam (1986) studied the economics of production and marketing of *Chrysanthemum* flowers. He concluded that labour cost accounted for the major portion of input and there was a huge difference in returns when the cut-flowers were sold through channel I (sale through commission) and channel II (sale to pre-harvest contractors). In rose cultivation, the major item of input cost was planting and plant material. The investment

in roses was found to be economically viable as it gave a benefit-cost ratio of 1.7 to 1.8 with hardly 2 to 3 years payback period depending upon the channel of sale (Subramanyan 1989). In an economic analysis made at Taiwan production in Gypsophilla, Carnation, Gerbera and Lilies under protected structure indicated that although the production costs were higher for Lilies, the returns were also higher. The revenues obtained from Gypsophylla although were lower, production costs were also low and thereby the profit margin was higher in Gypsophylla as compared to Carnation and Lilies. However, gerbera production costs and revenues were similar (Lin and Chin 1990). Zawaneberg (1990) compared the cost and returns of the five major greenhouse cut-flower crops viz., Carnation, Chrysanthemum, Freesia, Gerbera and Roses in Netherlands over a period of ten years. According to him, Chrysanthemum production has showed lowest increase in labour cost. Rapid growing cycle and closer planting resulted in higher productivity. Ferretto and Bendetto (1994) studied the economics of Carnation cut-flower production during winter by promoting supplementary light and concluded that the utilization of supplementary light can increase yields. They were of the opinion that for positive economics 30% increases in the yield and prices are essential. Ambad *et al*. (2001) reported that Gerbera has become a crop of choice in polyhouse cultivation. Construction of polyhouse needs high investments. MPKV, Rahuri has developed handy wooden structure affordable to all categories of growers with reasonably low cost. Mysore *et al*. (2005) studied the economic feasibility and profitability of Carnation cultivation under polyhouse condition and indicated it to be highly profitable and economically viable in the cultivated regions. Use of cost effective methods appear to cut down the erection cost by 50%. Similarly cut in cost was seen in other items such as the inner net, drip irrigation system and bed preparation, thereby reducing the overall cost of establishment.

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