DISCUSSION

Effect of Time of Sowing

The results presented in the foregoing pages indicate that the growth and flowering of carnation is influenced to an appreciable extent by the sowing time. When sown in different months of the year, the plants are exposed to the variation of environmental factors which are reflected in the growth and flowering of plants.

The growth of carnation seems to be dependent primarily on the prevailing temperature and light intensity. The June-sown plants were most stunted in growth, while the height of plants was maximum in October-sown plants. The growth period of June-sown plants ranging from June to September corresponds to high temperature, high humidity and less sunshine hours. On the other hand, plants raised from October, November and December sowings received most favourable temperature and sunshine during their growth period from October to February, as a result, plant growth was most rapid during this period. A number of workers reported variation in growth of carnation due to variation in temperature and light conditions (Hanon, 1959; Freeman and Langhans, 1965c; Harris and Harris, 1962). However, there is wide differences in the results obtained by different workers and it is difficult to simulate the results obtained in the present study with those of other workers, since the experimental conditions were quite different.

Further, the October to December-sown plants developed more branches than other sowings. The differences in the number of branches produced from different sowings could also be due to seasonal variation in temperature and sunshine hours prevailing during this period. It has been already mentioned
that October to December-sown plants received more sunshine hours and more favourable temperature for growth and development. Munoz and Holley (1972) found that a combination of low night (13.3°C) and high day (23.8°C) temperature increased the number and length of lateral branches. The day and night temperature prevailing during the experimental period from October to January were more or less similar to that of Munoz and Holley.

In the present study, the number of days taken to bud emergence varied from 106.92 to 121.83 days (in December and June, respectively), depending upon the time of sowing. That variation in temperature and light intensities causes earliness or delay in flowering has been reported by several workers (Harris and Harris, 1962; Freeman and Langhans, 1965a,c; Bunt, 1974). It appears that light intensities influenced bud initiation appreciably, as during the low light intensity period from June to September, flowering was considerably delayed. On the other hand, the plants raised during October, 1978 to January, 1979 received ample sunshine, and consequently the initiation of flower buds was advanced. Nevertheless, such flower buds took slightly longer time to reach anthesis. Shorter time-lag between bud emergence and opening of flowers in January sown plants indicate that flower development was most rapid with the increasing temperature. Bunt (1974) noted that a relatively low temperature delayed flower development.

A perusal of the available literature shows that temperatures within a reasonable limit do not have marked effect on production of carnation (Freeman and Langhans, 1965b; Langhans, 1968). In this study, the difference between the maximum and minimum yield was 5.1 flowers per plant, which was an increase of 37.22 per cent over the minimum. Increased yields were recorded in October...
to December-sown plants. The January-sown plants although received more light, produced less flowers, most probably due to high temperature prevailing at the time of flowering. Bunt (1974) observed that relatively low temperature brought about increase in flowering of carnation. About flower quality, Freeman and Langhans (1965b) as well as Munoz and Holley (1972) found that low night temperature was conducive to good quality flowers. The former workers further observed that night temperature above 18.3°C was detrimental to quality. Hanan (1959) found that variation in day temperature affected flower quality. Bunt (1974, 1978) reported that flower diameter was largely dependent on temperature, relatively high temperature producing small flowers and vice versa. In this experiment the best quality flowers (expressed in terms of diameter) were found in the November-sown plants. A comparison of the flower qualities (diameter) obtained here with those of the research findings discussed earlier will probably lead to the conclusion that the flower qualities obtained in the different seasons was influenced by the growing temperature. Generally, the flower size (diameter) from August to December sowing did not vary much. During this period the temperature also did not show much variation. The night temperatures during November, 1978 to March, 1979 were little cooler, and hence the flower diameters of October–December, 1978 sown plants were slightly more. The January sown plants produced flowers of smaller diameter, as these opened in April–May when the temperature (both day and night) rose abruptly. The reason for smaller diameter flowers in June and July-sown plants may be that these plants made comparatively poor vegetative growth. Bunt (1978) reported marked seasonal changes in flower diameter. He observed that the environmental conditions
required to produce good quality carnation flowers were high solar radiation integrals coupled with low ambient temperatures.

The longevity of flowers on the plant was found to be significantly longer on October and November-sown plants compared to all other sowings. On the other hand, the longevity of flowers on the January-sown plants was significantly less than other sowing dates. Flowers under the other planting dates lasted more or less for same duration. The reason behind the flowers lasting longer in October and November sowing might be also the temperature prevailing at the time of flowering. The comparatively lower temperatures and greater plant vigour of these plants might have contributed towards greater longevity of flowers.

The results of the present investigation is important from horticultural point of view, because it clearly shows that the sowing of carnation can be started as early as September and continued upto December. Sowing during the period from February to May has been found hazardous and hence is not recommended to the growers.

Effect of Plant Spacing

Apparently, spacing had no appreciable effect on the height of plants. However, the results indicate that the branch number is a function of spacing in carnation. Thus, the number of branches increased with increasing spacing; the optimum being found to be 45 cm x 45 cm. That closer spacing results in the reduction of branch number has been reported by Schroder (1974):

It is also clear from this experiment that carnation flower production per plant increases with the increase in plant spacing and a spacing of 45 cm x 45 cm
Effect on flowering appeared to be the optimum one, which showed a 148.15 per cent increase in flower yield over closer spacing of 25 cm x 25 cm, producing minimum number of flowers per plant. Although Butters (1960) recommended as close a spacing as 15 cm x 17.5 cm, under the present experimental condition at Bangalore, where the climatic and soil conditions favour rank vegetative growth, spacings like 25 cm x 25 cm or 30 cm x 30 cm appeared to be quite low resulting in much congestion of plants. A large number of reports have accumulated to show that the yield of flowers per plant decreased as the plant density was increased, and the optimum plant spacing varied from place to place depending on soil and climatic conditions (Gugenhan, 1963; Durkin and Janick, 1966; Lisse, 1968; Schroder, 1974; Hanan and Heins, 1975; Heins, 1975; Mukhopadhyay et al., 1975; Hong et al., 1977).

As regards the effect of spacing on flower quality it has been found that the size of flowers increased gradually and steadily as the plant spacing was increased from 25 cm x 25 cm; and the maximum flower diameter was recorded at 45 cm x 45 cm spacing. This appeared to be the optimum spacing for flower size also, since further increase in spacing did not bring about any subsequent increase in flower diameter. The available literature on the effect of spacing on flower quality showed variable results. Thus while many workers (Durkin and Janick, 1966; Heins, 1975; Hanan and Heins, 1975) showed definite decline in flower quality with increased planting density, several other workers observed only slight difference (Holley and Lehman, 1961; Butters, 1974) or no difference (Seager, 1965; Schroder, 1974; Hong et al., 1977) in quality due to various spacings.

The longevity of flowers in the field under different spacings was also studied, and it was observed that, in general, flowers on the plants at wider
spacing lasted longer than those on closer spacing of 25 cm x 25 cm or 30 cm x 30 cm. The flower-life was extended by a maximum number of 2.74 days at a spacing of 45 cm x 45 cm, over that of the flowers which lasted minimum number of days at the lowest spacing of 25 cm x 25 cm. Bankar and Mukhopadhyay (1980) observed that flower spikes of gladiolus lasted slightly longer in wider spacing compared to closer spacing. Bhattacharjee et al. (1979) in tuberose and Cocozza (1971) in gladiolus also obtained similar results. One reason for this is the increased vigour of plants at wider spacing due to less competition for nutrients and light.

Thus, the optimum spacing for carnation under Bangalore condition, giving maximum yield of better quality flowers, seems to be 40 cm x 4.0 cm and hence recommended for commercial use.

Effect of Different levels of N, P and K

As regards the effects of fertilizers on growth and flowering of carnation, it has been found that the plants responded favourably to the doses of N, P and K used in this experiment. However, it is evident from the results presented in the foregoing pages that vegetative growth of plants is primarily determined by added nitrogen and phosphorus. High levels of nitrogen (20 g/m²) caused significant increase in plant height, number of branches and leaves produced per plant and size of leaves over other treatments. Conversely, plants (receiving no additional supply of nitrogen) were not only stunted in growth but also weak and thin, and produced fewer branches and leaves of smaller size. Although the effect of added phosphorus as reflected in significant increase in plant height, and number and size of
leaves, the response was less pronounced when compared with those of nitrogen. Potassium, at the levels used in this study, showed less direct effect on vegetative growth of plants than did either nitrogen or phosphorus. These results therefore confirm the earlier findings of Arora and Saini (1976) who reported relative ineffectiveness of added potassium and are in partial agreement with those of Eck et al. (1962), who demonstrated the importance of nitrogen and potassium in influencing plant height in carnation. Further, it was observed that growth in terms of dry weight increment of aerial portion of the plant was accelerated by increased levels of added nitrogen and phosphorus, while addition of potassium to the soil resulted in the reduction of dry weight of plants. This is in contrast to the findings of Winsor and Long (1962) who found reduction in dry weight due to high dose of nitrogen and increase in dry weight as a result of high potassium fertilization.

Although statistically significant, the effect of N, P or K fertilization on flower bud emergence or anthesis was only marginal and commercially valueless. The results, however, show that nitrogen and phosphorus fertilization stimulated blossom bud formation and significantly increased the number of flowers per plant over control. The effect of added K on flower number was not very pronounced. High nitrogen increased the number of flowers in two ways — (i) by increasing the number of primary branches and (ii) by increasing shoot growth and number of secondary branches and hence the ultimate size of the plant, thereby increasing the number of potential sites where flowers could develop. Similar results have been obtained by several workers (Holley et al., 1951; Chan et al., 1958; Belgraver et al., 1960; Winsor and Long, 1962; Arora and Saini, 1976; Blomme and Roels, 1977).
The application of N, P and K brought about improvement in the size of flowers compared to no supply of additional fertilizers. The diameter of flowers increased at both levels of N and P, but lower level (10 g/m²) of nitrogen excelled over the higher level, while no significant difference between two levels (20 and 40 g/m²) of P₂O₅ was noted. Potassium also tended to increase the diameter of flowers, but the effect was less pronounced compared to nitrogen or phosphorus. The deleterious effects of high nitrogen on quality of carnation flowers have been reported by many workers (Belgraver et al., 1960; 1961; Blanc, 1967; Winsor et al., 1970). The longevity of flowers also increased as a result of additional supply of N, P or K, however, in most cases the response was very small (varying from 0.38 to 1.39 days) and of not much practical value. Holley (1953) did not find any effect of potassium on keeping quality of carnation flowers.

**Effect of interactions**

A number of significant interactions of nitrogen, phosphorus and potassium at almost all levels were observed in this study.

**Nitrogen x Phosphorus**: Application of nitrogen together with phosphorus significantly improved the height of plant, number of branches and leaves per plant, breadth of leaves, length of flower stem, number of flowers per plant, diameter and longevity of flowers, and dry weight of plants. In general, the response was more pronounced when nitrogen was applied at higher levels. The results indicate that the efficacy of applied nitrogen is increased considerably by a simultaneous application of phosphorus. The present findings are in general agreement with those of Winsor et al. (1970) and Arora and Saini (1976).
Nitrogen x Potassium: Nitrogen and potassium also showed significant interaction almost in the same manner as in case of nitrogen and phosphorus. High dose of nitrogen (20 g/m²) together with moderate supply of potash (20 g/m²) caused maximum improvement in plant height, length of flower stem and number of flowers per plant, while high nitrogen along with high potash (40 g/m²) increased the number of branches and leaves to maximum extent.

A number of research workers reported significant interaction of N and K in carnation (Eck et al., 1962; Belgrever et al., 1960; Seagar, 1965; Blanc, 1967). Chan et al. (1958) reported that K-effects were most marked at higher N-levels, but N-effects were significant at each of the 3 K levels tested.

It is clearly evident from the results of this study that high N along with high K gives maximum yield. Winsor et al. (1970) observed that the response of K was less when the supply of N was less. Chan et al. (1958) also reported significant interaction of N x K on flower yield. They found that K effects were most marked at higher N levels, but N effects were significant at each of the 3 K levels tested. In this study, K showed no appreciable influence on production without N application and the highest production was observed at N₂K₂O. Although Arora and Saini (1976) observed significant N x K interaction on flower size, in this study N x K interaction had no significant effect on flower quality.

Phosphorus and Potassium: P x K interaction did not show any significant effect on plant height and number of branches produced per plant. However, high levels of P₂O₅ (40 g/m²) along with moderate dose of K₂O (20 g/m²) resulted in the maximum improvement in leaf number, leaf length, flower number and dry weight of plants, while high level of phosphorus along with high level of potassium showed maximum improvement in breadth of leaves and length of flower.
stem. Thus, treatments like P2K1 and P2K2 were proved most beneficial. Similar interaction effect of P and K was noted by Winsor (1970).

**Nitrogen x Phosphorus x Potassium**: The second order interaction (N x P x K) also showed significant effects on a number of parameters. In general, the treatments lacking nitrogen produced the lowest values. However, there was wide variability in the treatments giving best results. Thus, while N1P2K0, N1P2K2, N2P2K2, N2P0K1, and N2P1K2 gave significantly higher yield of flowers, the flower size showed appreciable improvement under N2P2K2, N1P1K1, and N1P1K2.

Such widely varying combinations producing similar results are difficult to explain. But most of the results show the relative importance of nitrogen compared to other fertilizers. Bik (1962) also noticed relative importance of N for carnations and the relative unimportance of other nutrient elements.

Winsor et al. (1970) also found the beneficial effects of N, P, K and lime on the production of carnation flowers. Freeman and Bing (1968), on the other hand, recorded that N, P, K combinations at higher rates were not tolerated well by carnations and such plants had less growth and flowering. Mantrova (1976) stressed the need of correct nutrient balance in carnation which promoted carbohydrate synthesis and translocation into the flowering parts.

**Effect on leaf composition**

The leaf analysis results for N, P and K content indicate that the leaf N content was significantly affected by the nitrogen fertilization both at vegetative and flowering stage; the leaf N level increased linearly and significantly with the increasing levels of N fertilization. Eck et al. (1962) observed that nitrogen fertilization only up to certain levels affect the
content of leaf N. Waters (1964-65), on the other hand, reported that the N content of leaves increased linearly with the increased levels of nitrogen.

The P content of the leaf also increased with increasing dose of P\textsubscript{2}O\textsubscript{5} but the increase was not as pronounced as in case of nitrogen. These are in broad agreement with the findings of Puccini (1956), Miura et al. (1969), Parker and Holley (1972).

The foliar K level increased only up to 20 g/m\textsuperscript{2} of added K\textsubscript{2}O and further increase in supply of K was not reflected in the composition of the leaf. This is in contrast to the findings of Eck et al. (1962). Further, it has been noted that high N application was associated with low concentration of K in the foliage. Decrease in K-content of leaves as a result of increase in N supply was also reported by Winsor et al. (1970).

There was considerable reduction in leaf N content in the flowering stage compared to vegetative stage. This might be due to utilization of N during flowering. According to Bik (1962) there is a close relationship between the leaf N content and the condition of the crop. Like N, the P and K content of the leaf also decreased at the flowering stage compared to vegetative stage, but the reduction in K value was not as appreciable as N or K. Winsor et al. (1970) reported that percentage of nutrients in leaves always decreased from the first to the second date of sampling.

It appears that the effect of different levels of fertilizers are well reflected in the composition of the leaf and data can be useful for diagnosis of deficiency. However, more tests are required before recommending the critical levels of nutrient elements to the growers.
Effect of Pinching (stopping)

Two experiments on pinching were carried out in successive years at the same season. A comparative study of both the experiments revealed that the effect on plant heights were not affected to an appreciable extent by vegetative pinching at different stages of growth. It was noticed that the stopped plants had better look, sturdier stems, while the unstopped plants were wiry, weak and lanky. Scott (1972) reported that stopping resulted in the improvement of plant shape. Seager (1965) observed that stem length of unstopped plants was satisfactory. In another trial Seager (1969) found that unstopped carnation plants had weak stem but good stem length.

The number of primary and secondary branches increased significantly as a result of pinching. However, pinching as early as 40 days after transplanting did not encourage branching as appreciably as pinching at 50 or 60 days after transplantation. Further delay in pinching (70 days after transplantation) also resulted in decreased branching. It was also noted that pinching stimulated branching more appreciably in the first year than in the second year.

The probable cause of this difference may be explained from the findings of Munoz and Holley (1972) and a look through the weather charts of 1977-78 and 1978-79 during November to February, the period corresponding to the most active vegetative growth of carnation under the two experiments. Munoz and Holley observed that a combination of high day and low night temperature greatly increased the number of lateral branches. In the present experimental condition, the night temperatures for the months of December, 1977 (14.7°C), January (14.8°C) and February, 1978 (17.3°C) were 2.2, 0.8 and 1.1°C less, respectively, compared to the temperatures in the corresponding months in
1973-79, when the plants were passing through their vegetative stage. This favourable night temperatures during 1977-78 might be instrumental for the increased number of branches per plant in the first experiment.

The beneficial effects of stopping on the production of more axillary branches have been observed by a number of workers (Scott, 1972; Mukhopadhyay et al. 1975; Bunt, 1979). Vonk-Noordegraaf (1971) observed that earliest pinching in carnation resulted in heaviest yield and latest gave lowest yield. In the present study also it was observed that pinching at later stages was comparatively less effective.

In both experiments, the yield and quality of flowers increased significantly in the stopped plants compared to the unstopped plants. In the first experiment, however, the late pinching (70 days after transplantation) was not found beneficial in terms of yield or quality (diameter) of flowers, whereas in the second year all stages of pinching were effective. The yield effect on flowering in the first experiment increased by 44.14 to 66.48 per cent and in the second year by 34.69 to 63.26 per cent. The increased flower yield due to pinching is attributed to increased branch number as a result of removal of the apical bud. The usefulness of pinching as a technique in enhancing flower yield had been demonstrated in carnation by a number of research workers (Seager, 1965; 1969; Vonk-Noordegraaf, 1971; Levonen, 1971; Mukhopadhyay et al., 1975; Hillard and Hannon, 1976). The present investigation also revealed that if pinching was delayed beyond 60 days after transplantation, the yield started declining and the quality of flowers (diameter) started deteriorating, but was still better than control (unpinched) plants. Maximum increase in diameter of flowers was recorded in plants pinched at 60 days after transplantation.
In both years it was observed that flowers on the pinched plants lasted significantly longer than those on the unpinched control plants. Pinching extended the longevity of flowers on the plant by 1.27 to 2.42 days in the first year and by 2.14 to 3.87 days in the second year, depending on the stages of pinching. Pinching at 40 or 50 days after transplantation was found most beneficial in this respect. This was an important finding since in India carnations are grown in pots or in beds mostly for display on the plant itself rather than as cut flowers. The reason for increased longevity of flowers in pinched plants may be that the growth of pinched plants were better, and consequently the plants were sturdier than the unstopped plants (Seager, 1969).

The present investigation therefore clearly showed the beneficial effects of pinching in producing better shaped and sturdier plants with more shoots giving higher yield of better quality of flowers. The experimental results suggest a possible optimum pinching date between 50 to 60 days from transplanting date, i.e. 80 to 90 days from germination. Pinching earlier or later than these dates may not be very effective in improving the yield or quality of flowers.

Effect of Disbudding

The disbudding or removal of axillary buds is a common practice in carnation growing and has two main purposes: (i) to increase flower size, and (ii) to obtain long flower stem (Randhawa and Mukhopadhyay, 1981). However, the time of disbudding is very important in order to get desirable effects and is different under different agro-climatic conditions. The results of the initial experiment show that axillary bud removal 21 days after emergence was not very effective because the treatment marginally increased the size of
flowers. In the second experiment disbudding was advanced and the buds were removed as soon as they appeared or 5 or 10 days after their emergence. The results show that early disbudding resulted in taller plants. The height of plants disbudded at 0 day (soon after emergence of axillary buds) showed 20.66 per cent increase, compared to control plants. Likewise, removal of axillary buds 5 or 10 days after their emergence caused increase in plant height by 13.13 or 11.55 per cent, respectively over control. It is therefore evident that the later the disbudding was done, the less effective it was in influencing plant height. This is in contrast to the findings of Kohl (1970) who did not find any increase in stem length as a result of deheading in carnation.

Further, the production of branches was not affected by disbudding, neither the number of leaves per plant.

It has been also noted that early disbudding (0 or 5 days after emergence) reduced the time taken to reach anthesis. Further delay in disbudding showed no significant effect in this respect. Hieke (1963) observed that in Pelargonium zonale, the more flowers were there in an inflorescence, the later did the first flower open. The result in this experiment was similar in nature.

The number of flowers per plant were naturally more in control plants (no disbudding) than the plants disbudded at different stages, however, there was no significant difference in flower yield amongst the various disbudding treatments, thus confirming the earlier report of Mukhopadhyay et al. (1975).

The diameter of flowers increased appreciably as a result of disbudding. However, magnitude of increase tended to decrease as deblossoming was delayed
from 0 to 21 days after bud emergence; later the bud removal, the less was the increase in diameter of flowers.

Coste and Gagnard (1951) also recommended disbudding as a practice to improve flower quality. Kohl (1970) reported 12 per cent increase in flower size as a result of deshooting. Mukhopadhyay et al. (1975) on the other hand, did not find any appreciable increase in flower size, most probably because disbudding was done considerably late. While Patterson and Holley (1973) observed few distortion of the flower stem in some cases of early disbudding, no such distortions were observed in the present investigation.

The longevity of flowers in plant under field conditions improved significantly as a result of disbudding at all stages except 21 days after bud emergence, where the flowers lasted almost as long as in control plants. Hieke (1963) noted that in Pelargonium zonale the life of individual flowers became shorter if there were more flowers in an inflorescence.

The experiments therefore clearly show the utility of disbudding, especially at an early stage, in increasing plant height and improving flower quality in terms of diameter of flowers and their longevity under field condition.

**Effect of Growth Regulators**

**NAA**: In contrast to the well known growth-promoting effect of auxins, it has been found in this study that NAA at all the concentrations ranging from 100-500 ppm caused substantial inhibition in linear growth of plants; the higher concentrations being found more effective than lower ones. Similar growth inhibition due to treatment with NAA at the same concentration range used in the experiment was recorded by Tsukamoto and Harada (1957) in chrysanthemum. On the other hand, Shoushan
et al. (1971) reported promotion of stem growth in carnation at comparatively lower concentrations of NAA (25-50 ppm).

Significant inhibition in plant height due to NAA at 500 ppm was accompanied by appreciable increase in the number of branches and leaves. However, the size of leaves was not affected. Similar promotive effect of NAA was recorded by Tsukamoto and Harada (1957) and Tsukamoto et al. (1968).

It is further evident from the results that the bud emergence was delayed for several days by NAA, but the subsequent development of the bud was accelerated, consequently the opening of flower buds was advanced by nearly 2 days in plants treated with 500 ppm of NAA. The results indicate that NAA possibly interferes with the processes that occur during floral initiation and differentiation, but not the development of the flower bud.

Although statistically insignificant, NAA tended to increase the number of flowers per plant, mostly owing to increased number of branches per plant following sprays with NAA; the effectiveness of the chemical was found to be dependent on concentration. NAA did not affect the size of flowers neither their longevity to an appreciable extent. The results of the present experiment therefore show only slight benefit from NAA sprays.

**GIBBERELLIC ACID** : As regards the effect of gibberellic acid (GA$_3$), it has been found that the plants sprayed with 100 ppm GA$_3$ were significantly taller and lankier, compared to control; lower concentrations of GA$_3$ was mostly ineffective. Ebben (1957-59) demonstrated that young carnation plants watered with 20 ml solution of gibberellic acid (1%) showed a definite acceleration of shoot growth. However, although Ebben noted 40-43 per cent increase in plant height, in this study the
plants increased in height by only 18.03 per cent. That gibberellic acid stimulated the height of plants has been demonstrated in several species of plants by many workers (Tamberg, 1963; Singh, 1966; Misra and Singh, 1977; Heist and Hey, 1976).

It is reported that gibberellie acid enhances apical dominance in certain species (Scott et al., 1967), but can stimulate the growth of laterals in others (Kato, 1953). In the present experiment GA$_3$ at a concentration of 100 ppm induced more axillary branching. Similar results have been reported by Tamberg (1963) and Singh (1966) in a number of annuals. The axillary shoots in snapdragon became elongated and feathery, when treated with 100 ppm spray of GA$_3$ (Mastalerz, 1959-60). In the present study also the shoots became lanky with 100 ppm spray of GA$_3$.

A substantial and significant increase (21.50 per cent) in leaf numbers was observed following treatment with GA$_3$ at 100 ppm. The increase in leaf number is partly attributed to the increase in branch numbers.

Flowering was neither hastened nor delayed by GA$_3$ at the concentrations used in this experiment. However, the number of flowers tended to increase with GA$_3$; the effectiveness being more pronounced with increasing concentrations. The size (diameter) of flowers also increased at all levels of GA$_3$. The increase in diameter varied between 12.18 to 31.68 per cent depending on concentrations; 50 ppm GA$_3$ being found most effective. Mukhopadhyay et al. (1975) observed that early GA$_3$ treatment produced the largest sized flowers in carnation compared to GA$_3$ sprayed at later stages of growth. Jeffcoat et al. (1969) found that application of GA$_3$ to the developing bud of carnation increased the petal size of the resulting flowers.
The gibberellin may have a direct role in inducing flowering by causing the synthesis of florigen, under appropriate conditions (Lang, 1965); but its role in improving yield or quality may be through the process of translocation of metabolites to the bud itself or to the site of bud development.

The elongation effect of GA$_3$ at 100 ppm observed in this investigation could not be considered as desirable, since such plants are lanky and spindly. A spray with 50 ppm GA$_3$ might be of more practical value, as the treatment results in increased number of flowers of larger size without causing any adverse effect on growth.

**ETHREL**: Ethrels at the concentrations of 500 and 1000 ppm appreciably reduced the height of plants compared to control; 1000 ppm being found more effective than 500 ppm, when initial measurements were made 30 days after the treatment. However, the marked dwarfing effect of Cycocel at 1000 ppm did not last long, which decreased with the passage of time, and consequently, the plants recovered to a great extent by the time of flowering. Retardation in stem length due to exposure to ethylene has been reported by Piersol (1973, 1974, 1974a). Shanks (1969) also did not notice any long lasting effect of ethrel in a number of ornamental plants. The linear growth reduction due to ethrel treatment may be attributed to the hypothesis proposed by Michener (1935, 1938) that application of ethylene might affect auxin transport or its metabolism. The more recent interpretation given by Morgan and Gausman (1966) indicates that ethylene inhibits polar transport of auxin.
Further, the linear growth reduction was accompanied by marked increase in production of axillary branches. The number of branches increased by 41.42 and 67.61 per cent over control due to application of 500 and 1000 ppm of ethrel, respectively. The number of leaves also increased following the above two treatments; the increase is mostly due to increased number of branches. The leaves of ethrel-treated plants were appreciably smaller in size than the control. These results are in general agreement with those of Piersol (1973, 1974, 1974a), and Smith and Johanson (1977).

In contrast to the earlier observations by Johnson, 1973; Piersol, 1973, 1974 that ethylene or ethrel accelerated anthesis in carnation, in this study high concentration of ethrel (1000 ppm) delayed bud emergence by 24.83 days compared to control, while lower concentrations were mostly ineffective. Delayed flowering following application of ethrel has been reported by Kher (1973) in chrysanthemum and Tijia and Buxton (1977) in hybrid petunia.

Ethrel tended to increase the number of flowers per plant over control without affecting the size of flowers. Ethrel at 1000 ppm was found most effective in increasing flower yield. This increased intensity of flowering is attributed to increased number of branches per plant. Increase in flower buds as a result of ethrel spray was also reported in rhododendrons (Ticknor, 1968). The study also reveals that the longevity of flowers was not affected to an appreciable extent by ethrel.
The results of the present study show that Cycocel at the concentrations of 2500 and 5000 ppm was effective in suppressing plant height, when initial measurements were made 30 days after the spray of the chemical. However, the effect was not long lasting, as by the time of commencement of flowering the plants at lower concentrations almost recovered from the dwarfing effect, but at higher concentration the plant height still remained suppressed. The research findings on the dwarfing action of Cycocel on carnation showed variable results. Thus, while several research workers (Kofranek et al., 1962; Smith, 1968 and Scott, 1970) were optimistic about the dwarfing action of Cycocel on potted carnations, some others obtained a slight dwarfing effect (Liepinya and Yakobsone, 1976) or no dwarfing effect (Johnson, 1973) at all. One of the reasons for ineffectiveness of the chemical is that sometimes the concentrations used were too low to induce any dwarfing effect (Johnson, 1973). A review of the literature coupled with the findings of the present investigation reveals that the most effective concentration of Cycocel would be around 5000 ppm as foliar spray, although under such a high concentration the plants initially developed chlorosis, from which they, however, recovered later. These observations are in full agreement with the report of Stuart and Cathey (1961). Knypl showed that Cycocel strongly inhibited chlorophyll synthesis. The efficacy of Cycocel in suppressing the linear growth can be explained in the light of Luckwill's hypothesis that Cycocel brings about a reduction in gibberellin production in young leaves which in turn results in a reduced output of auxin in the apical meristem and consequent weakening of the auxin promoted transport mechanism which draws nutrient to the apex (Luckwill, 1968).
The number of branches increased by 40.00 per cent and the number of leaves by 47.71 per cent over the control, as a result of treatment with Cycocel at 5000 ppm. The branch promoting effects of Cycocel were observed in various ornamental plants like geranium (Semeniuk and Taylor, 1970), Pelargonium (Kneissl, 1972), Salvia (Jasa et al., 1971), Jasminum grandiflorum L. (Pappiah and Muthuswamy, 1977). The number of leaves increased in Jasminum grandiflorum (Pappiah and Muthuswamy, 1977) and Primula obconica (Abou-Zied and Bakry, 1978) as a result of Cycocel treatment.

Although Brorson (1969) found that Cycocel at a concentration of 0.2-0.25 per cent increased leaf size in carnation, in the present study, the length of leaves was reduced by Cycocel at all the concentrations used. It may be possible that carnation cultivars react differently to Cycocel.

Cycocel at the concentrations used in this experiment neither delayed nor enhanced the time of first flower bud emergence. However, the flower yield increased by 48.18 per cent at the highest concentration of Cycocel, but there was no marked effect of Cycocel on the size of flowers. The research findings on these aspects of carnation showed a wide variability. El-Fouly et al. (1977) observed that spraying carnation plants thrice with Cycocel at concentrations between 10-100 ppm increased flower yield considerably. The findings of Johnson (1973) in carnation revealed that Cycocel (1250 mg/l) greatly improved flower production without affecting quality or flower size. Brorson (1969) found that Cycocel treatment (0.2-0.25%) in August-planted carnation increased production slightly, but the production increased greatly in January planting when the application was made after the long day treatment. Other results of Cycocel on carnation
showed that flower production was not much affected (Petoyan and Stolova, 1974; Beisland, 1969).

Further, the length of peduncle increased significantly with Cycocel spray at all concentrations, a result which might be helpful to those who use carnation flowers for lei making. This is in contrast to the observation of Johnson (1973) who found that Cycocel made the flower stem neck shorter in *Chrysanthemum frutescens* hybrid.

The longevity of flowers on the plant treated with 5000 ppm Cycocel under field conditions was enhanced by 2.87 days compared to control. The beneficial effects of Cycocel on flower life were reported by few other research workers (Halevy and Wittwer, 1965; Johanson, 1973).