Review of Literature
II. REVIEW OF LITERATURE

Exotic roses are well suited to be grown under greenhouse conditions. While, hundreds of indigenous varieties of roses are being grown under open conditions. With the introduction and expansion of hi-tech greenhouse production technology, turnkey projects are implemented with particular reference to roses.

The growth, yield and quality of the flowers of roses in protected cultivation are influenced by application of growth regulators and fertigation. Fertigation is very important for plant growth, development and production of flowers. The levels of fertilizer application through fertigation significantly influence the flower yield.

Growth regulators find their extensive use in ornamental crops for modifying their developmental processes. In fact, they have become an integral component of agro-technological procedures of few cultivated ornamental crops, since, the regulation for usage of chemicals in ornamental crops is less stringent unlike those in food crops, their application in these crops extended to alter varying responses.

There is immense potential for floriculture trade. However, very limited work has been undertaken in floriculture crop and literature is seldom available. Hence, the present review includes the research work done on fertigation and growth regulator aspects with respect to rose cultivars under protected cultivation. The literature so reviewed under the following heads.

2.1 Influence of fertigation on production and quality of flowers

2.1.1 Influence of nutrients on growth, yield and quality of flower crops.

2.1.2 Influence of nutrients on vase life of flower crops.
2.1.3 Influence of nutrients (soil application/fertigation) on soil nutrients status.

2.1.4 Economics of fertigation.

2.2 Influence of growth regulator on production and quality of flowers

2.2.1 Influence of plant growth regulators on growth, yield and quality of flower crops.

2.2.2 Influence of plant growth regulators on vase life.

2.2.3 Economics of growth regulator application.

2.2.4 Influence of Humic acid on few crop species.

2.1 Influence of nutrients on growth, yield and quality of flower crops

2.1.1 Influence of normal fertilizers on growth, yield and quality

Bakly (1974) reported that, high dosage of nutrients (90:54:30g NPK/plant) delayed the flower opening but increased the stem length in 'Chrysler Imperial' roses, while Jayaprasad (1976) obtained maximum stem length in rose cv. 'Super Star' by applying 8 g of N and 16g of K per plant. Low amount of phosphorus (6.72 kg/ha) with a specified dose of nitrogen (15 g/plant) and potassium is reported to have vegetative growth in rose cv. 'Celebration'. It was associated with higher yield and anthocyanin pigmentation (Maharana and Pradhan, 1976).

Johanson (1978) recorded flower weight with lower dose of N in 'Parelvan Aalsmeer' roses grown under greenhouse condition. Fifty grams each of N, P and K per plant was the optimum dose which can meet the requirement of three years old 'Super Star' rose bushes (Saini et al., 1978). Irrulpan et al. (1980) observed that an application of 10 kg FYM per plant to Edward rose resulted in optimum rate of flower production with highest yield.
Uma and Gowda (1987) observed maximum shoot length as well as maximum fresh weight of 'Super Star' rose flowers with the application of 16 g of nitrogen alone and 16 g of each of nitrogen in combination with potassium respectively. Nitrogen and phosphorous at the rate of 75 g per 1.44 m² and 100 g per 1.44 m², respectively increased the stem length in rose cv. 'Happiness' significantly when compared to other treatments (Amitabha et al., 1989).

In combination of nitrogen along with phosphorous and potassium (25:20:15 g/plant) gave the best growth in rose in terms of plant height, plant spread, total leaf area and shoot diameter (Anamika and Lavania, 1990). Application of 60, 10 and 20 g NPK per m² respectively increased plant growth and yield of rose cv. 'Gladiator' (Bhujbal et al., 1992). While, a combination of 60:30:60 g NPK per m² in rose cv. 'Super Star' resulted in best growth in terms of plant height, number of shoots per plant and quality parameter like stem diameter (Sindhu and Yamdagni, 1992).

Eighty grams nitrogen with 30 g of potassium per plant was the superior dose for better growth and production of better quality blooms in roses as suggested by Arvind and Kale (1994). However, flowering characters like days taken for flower emergence, duration of flowering and size of flowers of rose cv. 'Super Star' were enhanced by application of 20 g nitrogen, 15 g phosphorous and 20 g potassium per plant per year (Prasad et al., 1994).

High density planting trial of rose cv. 'Happiness' was taken up by Sujatha et al. (1994). They found that application of 100 kg N, 200 kg P₂O₅ and 150 kg K₂O per acre was found to yield 5,45,000 flowers per acre per annum. Damke and Bhattacharjee (1997) observed a dose of 75 g N, 125 g P₂O₅ and 100 g K₂O per 1.44 m² produced the maximum flower yield of 'Super Star' rose.
The plants receiving 30 g N and 24 g K recorded significantly improved performance in terms of number and fresh weight of flowers, stem and bud length, bud diameter and also production of good quality flowers in 'Gladiator' rose (Nagaraju, 1997). Application of 75:150:50 g NPK per 1.44 m² produced more number of flowers with long stems in rose cv. 'Happiness' (Rajamani and Sundaram, 1997). Moradinejad and Malakooti (1998) found that increased rose cut flower yield with desirable floral traits were obtained with higher rates of nitrogen.

Anwar et al. (1999) studied the effect of nitrogen and potassium fertilizers in combination on vegetative and reproductive growth of rose (Rosa centifolia). The maximum spread of plants and higher number of flowers and leaves were obtained when plants were treated with potassium alone at 774 g per plot. However, nitrogen and potassium in combination (N-1680 g/plot + K - 516 g/plot) gave best height of plant and number of petals per flower and the best size of flowers. Most of the vegetative characters such as plant height, spread of plants and number of leaves were enhanced with higher doses of nitrogen. Interaction of nitrogen and potassium gave positive results for vegetative growth when dose of nitrogen was higher and that of potassium was lower. Number of flowers, flower size and quality was improved when dose of potassium was increased.

In rose cv. 'Arjun' at 400 kg N per ha resulted in maximum flower yield and improved quality as well as more number of primary and secondary shoots. However, longest vase life was recorded at 500 kg N per ha (Vidhya Sankar and Bhattacharjee, 2000). While, with the application of higher doses of nitrogen (60 g/plant) in rose, Viradia and Singh (2002) revealed that plant height, number of shoots per plant and plant spread were increased.
Application of full dose of NPK (50:40:30 g NPK/m²) significantly increased leaf area index (0.48) whereas, maximum plant height (137.86 cm) was recorded in treatment combination of 4 kg FYM, remaining recommended dose of chemical fertilizers and *Azotobacter* in rose cv. ‘Gruss-as-Teplitz’ (Anil and Yesh, 2003). Two split application of 60 g N per m² can be followed in rose cv. ‘Gruss-an-Teplitz’ cultivation under Tarai conditions of Uttranchal (Anil *et al*., 2004).

Khan *et al.* (2004) studied the effects of various levels of NPK supplied on plant growth and flowering characteristics of *Gladiolus hortulanus* L. cv. Wind Song. Plant height, number of leaves, leaf length and spike length were maximum with 10:10:5 g NPK per pot, whereas, emergence of spike, opening of first and last floret, flower diameter and flower weight were maximum with 5:5:5 g NPK per pot.

Haripriya *et al.* (2004) conducted an experiment to study the effect of Vermi-compost (100 or 200 g per plant); 50, 75 or 100 per cent of the recommended fertilizer rates (RFR; 6:12:12 kg NPK/plant through urea, super phosphate and muriate of potash, respectively) and 50, 75 or 100 per cent RFR + Vermi-compost on the growth, yield and quality of rose (*Rosa centifolia*) cv. Andhra Red. They found significant influence of growth, yield and quality of rose over the untreated control, especially when applied in combination. The application of 75 per cent RFR + 200 g vermi-compost and 100 per cent RFR + 200 g vermi-compost per plant resulted in the greatest plant height (87.6 and 91.4 cm), leaf area (36.0 and 36.2 m²), shoot dry weight (17.98 and 18.70 g), root dry weight (5.13 and 5.20 g) and number of laterals per plant (8.1). The highest flower yield (300.2), number of flowers (48.6), fresh weight of flower (6.07 cm) and number of petals per flower (78.8) were obtained with 100 per cent RFR + 200 g vermi-compost per plant. The soil nutrient content was
analyzed at 150 days after treatment. The available N, P and K were higher in plots supplied with both vermi-compost and N: P: K fertilizers.

Singh (2006) conducted an experiment on rose cv. Gruss-an-Teplitz. Treatment consisted of three levels of nitrogen (20, 40, 60 g/m²), two levels of Azotobactor and three levels of nitrogen (20, 40, 60 g/m²). Maximum yield is obtained with FYM 5 kg per m² and nitrogen 60 g per m².

2.1.2 Influence of normal fertilizers through fertigation on growth, yield and quality

Yields were optimum with the application of 170, 34, 158, 120 and 12 ppm of N, P, K, Ca and Mg respectively in the nutrient solution during each irrigation in rose (Gowda, 1994). Ashok and Rangaswamy (1999) studied the effect of varying levels (50, 100, 150 ppm) and sources of N fertigation (Ammonium nitrate, Aqueous ammonia, Nitric acid and Urea) on the flowering of cut rose cv. First Red under protected cultivation. Ammonium nitrate at 150 ppm gave the highest values for bud circumference (6.09 cm), flower diameter (7.33 cm), petal length (4.01 cm) Petal breadth (3.84 cm) and flower yield (153/m³) compared to other treatments.

Larik et al. (1999) conducted an experiment to assess the effect of different rates of nitrogen and potassium on morphological traits of Zinnia. The fertilizer treatment comprised 20-10, 20-15, 40-10, 40-15, 60-10 and 60-15 g NK per m². The maximum plant height (74.5 cm), branches per plant (16.05), leaves per branch (17.75), blooming period (55 days), flowers per plant (15.05 and flower weight (13.25 m) were recorded with application of 60 N + 15 gm K per m². Mean squares attributable to treatments differed highly significantly for all the
quantitative traits showing importance of fertilizer treatment in influencing morphological characters.

Fertigation with 200:300 NK kg per ha per yr with straight fertilizers plus micronutrients (2 g/l) at monthly interval was found to be best for ‘Super Start’ rose cultivation under partially modified greenhouse conditions (Gurav et al., 2003). While, maximum number of flowers of grade 60-89 cm and 30-45 cm stem length was recorded with 150:200 ppm NK through straight fertilizers in growing media consisted of Soil: Farm Yard Manure: Sand (2:1:1).

Barbosa et al., (2005) carried out an experiment to evaluate the flower yield and quality of the rose cultivars ‘Sonia’ and ‘Red Success’ as affected by different potassium (K) rates supplied by drip irrigation. The K treatment was 0, 30, 60 and 90 g per m³ per year. Maximum yield of rose stems with superior quality (>69 cm in length) was obtained with a K application rate of 49.76 g per m³ per year. ‘Sonia’ yielded a higher number of normal, straight stems of 50.36 m³ per year.

Barman et al., (2006) conducted an experiment in partially modified greenhouse to standardize the cultural practices for sustainable production of rose cv. First Red. The plants grown in the growing medium consisting of two Soil : One compost and at 40 Kpa irrigation regime and supplied with 200 and 300 kg N and K₂O per ha per year respectively through fertigation. Maximum flower yield is obtained with medium combination soil: 1 compost: 1 cocopeat at 40 Kpa irrigation regime.

Pimple et al. (2006) carried out an experiment to study the yield and quality of Gerbera as influenced by nitrogen and phosphorous levels. The result indicated that, significantly maximum flowers per plant and per sq.m, flower stalk length, flower stalk thickness and number of
flowers of grade-1 were recorded under the higher levels of nitrogen and phosphorous (10 N + 15 g P₂O₅ g/m²). Maximum flower diameter was obtained under the application of 10 g N per m² along with 12.5 g P₂O₅ per m². Whereas, maximum flowers of grade-2 and more vase life were reported under lower level of nitrogen and higher level of phosphorous (5g N + 15 g P₂O₅ g/m²).

2.1.3 Influence of water soluble fertilizers on growth, yield and quality

Waters (1967) conducted an experiment to study the effect of N and K₂O₅ on production, keeping quality and chemical composition of field grown Tropicana roses. The weight, number of stems and the N content of the leaf increased linearly as the N fertilization rate increased from 16 to 48 lbs per three week period.

Number of flowers and stem length of rose cut flowers increased with increase in irrigation and nitrogen as observed by Borelli (1981) but beneficial effects were much greater when irrigation and N supplied were both combined together. Feigh et al. (1986) studied the different NH₄ per NO₃ ratio in different solutions on growth of greenhouse roses and reported that the presence of NH₄ - nitrogen in the nutrient solution increased the rose flower yield and dry matter production whereas, cumulative yields were highest with 1:4 (NH₄: NO₃) ratio.

In rose cv. 'Mercedes', greater stalk length and cumulative flower yield (1421 flowers/m²) were recorded, when they were grown in 5 cm thick rock wool and supplied with 180 ppm N through drip irrigation by Hazan et al. (1994). A basal application of fertilizers at the rate of 2 Kg super phosphate, 1 kg calcium ammonium nitrate and 0.5 Kg of muriate of potash per m² before planting and thereafter application of 200 ppm each of nitrogen and potash through the irrigation system for roses
grown under greenhouse conditions has been recommended for optimum flower production (Anon., 1996).

Hydroponic system for rose was tried in the form of NH$_4$ or NO$_3$ and found no significant effect on flower yield and quality (Cabrera et al., 1996). Similarly, the growth of roses grown in hydroponics was not influenced by the application of K and Ca (Tereda et al., 1997). Increased number of rose cut flower stems and shoots breaks and longer shoots were produced at higher nitrogen rates (Pertusier et al., 1996).

The effect of varying levels of N (50, 100, and 150 ppm) and sources of N fertigation (ammonium nitrate, aqueous ammonia, nitric acid, and urea) on the flowering of cut rose cv. First Red was investigated under protected conditions. Ammonium nitrate at 150 ppm gave the highest values for bud circumference (6.09 cm), flower diameter (7.33 cm), petal length (4.01 cm), petal breadth (3.84 cm), and flower yield (153/m$^3$) compared with the other treatments (Ashok et al., 1999).

The fertigation treatment comprising 150 ppm each of nitrogen and potassium with basal application of 50 ppm phosphorous per plant per day produced the maximum number of flowers (16) per plant in rose cv. First Red (Gurav et al., 2001). Increasing the amount of fertigation had a more positive influence on cut flower fresh weight, stem weight and leaf area. However, it had a little influence on the flower yield of 'Rote' rose (Mikio et al., 2001).

The water utilization and nutrient uptake of rooted rose [Rosa hybrida] cv. Madelon plants grown in pots containing coco-soil or pumice in a recirculating system was investigated. Each pot had 2 or 3 plants (6 or 9 plants/m$^2$) cultivated with the arching system on benches with circulation of the nutrient solution. The amount of fertigation daily was 800 and 1000 ml approximately per plant for coco-soil and pumice,
respectively. More flowers were harvested from plants grown on coco-soil than on pumice, irrespective of the planting density. On the other hand, stem length and weight were the same in rose flowers produced on both substrates (Syros et al., 2001).

Recycling systems based on electrical conductivity (EC) control were tested and compared to systems without recycling. Fertigation effluents were recovered in storage tanks. A water complement was added to the drainage to decrease the EC. The irrigation nutrient solution was obtained by adding a complement nutrient solution to obtain the desired EC. Losses by drainage and savings by recycling were measured. Losses were about 44 per cent for leachate solution and 56 per cent for nutrients. Savings by recycling were about 42 per cent for leachate solution and 55 per cent for nutrients. Flower yield, quality and vase life of *R. hybrida* were not affected by recycling. Management of recycling using EC measurement proved to be reliable (Brun et al., 2001).

Gurav et al. (2001) studied an experiment in a polyhouse to determine the effect of K and N fertilizer rates on rose yield. N and K were supplied at 150, 175 and 200 ppm per plant per day, while P was supplied at a constant rate of 50 ppm. N at 150 and 175 ppm produced higher flower numbers than N at 200 ppm. K at 150 ppm produced the highest number of flowers among the K treatments. Combination of 175 ppm of K and N, and P at 50 ppm produced the maximum number of flowers and length of flower buds.

An experimental trial at Mazara del Vallo, Sicily, Italy, is described for the continuous production of cut flowers by the red rose cultivars Red France, Dallas and First Red. The soilless system involves growing plants on *Rosa indica* major rootstocks in 30 cm diameter pots in double rows 1.5 m apart (12 plants/linear metre). Plants are inclined at 45 degrees and pruned to encourage the successive formation of flowering stems. A
micro delivery fertigation system delivers 4 liters per hour per pot. Harvest starts 3 months after transplanting and continues regularly with no vegetative break. All 3 cultivars adapted well to the system, with Red France adapting best, producing 160 flower stems per linear metre, compared to 121 and 122 for Dallas and First Red, respectively. The total production of cut flowers per plant for the 3 respective cultivars was 14.1, 10.1 and 10.2 (Favia, 2002).

Nutritional doses of 300:300:200 ppm and 400:300:200 ppm NPK per plant per week were found to be optimum for vegetative growth viz., plant height, spread of plant and yield in rose cv. 'Montezuma' respectively (Palai and Mishra, 2002). However, maximum flower yield in rose cv. First Red was obtained by Barman et al., (2003) when plants were grown in 2:1:1 soil, compost and cocopeat fertigated with 150:200 ppm NK at soil moisture of 40 Kpa during the month of June - September.

The average nutrient concentration for active flowering season in roses was found to be 67:14:80 ppm NPK per plant per irrigated interval (Hasan et al., 2003). In rose cv. 'First Red' maximum flowers (5.58/m²/month) were produced when plants were fertilized with 150:200 NH through water soluble fertilizers in the media of the ratio 2:1:1 of Soil: Farm Yard Manure: Saw Dust (Thakur et al., 2003).

A study of rose (cv. Red Corvette) in a soilless recirculating system with oxifertigation and nightly oxygen supply was conducted to determine whether there is a cause-effect relationship between the production and growth increase in soilless culture systems supplied with oxygen and the plant metabolism optimization due to the absorption of different nutrients. One- and two-year-old cv. Red Corvette plants were planted in containers with two substrates (perlite B6 and A13). They were grown with or without diurnal oxifertigation and with or without
night oxygenation. A robot automatically controlled fertigation and watering. The nutrient solution was continuously held with oxygen over saturation. Night oxygen supply was done directly into the substrate by sequent pulsations. The nutrient content on leaves and petioles were determined using ion-sensitive electrode (nitrogen), Bray-Kurtz colorimetric method followed by Spectrophotometry (lambda = 660 nm) (phosphorus), flame photometry (potassium), and atomic spectroscopy analysis (iron, calcium and magnesium). Differences in foliar mineral contents were observed between two produced fluxes. Moreover, calcium and magnesium leaf content was higher in plants grown in A13 perlite substrate. The foliar nutrient content in oxifertigation treatments were only different in potassium and calcium. They were highly significant in diurnal oxifertigation plants (Carazo et al., 2005).

A field experiment was conducted in Tamil Nadu, during 2003 to study the effects of boron fertigation on the incidence of *S. dorsalis* on rose. The population of *S. dorsalis* in the buds of rose plant was reduced by 29.8-47.4 per cent (7.0-9.3 Thrips/bud) after the third fertigation (13.3 individuals/bud in the control). The population of *S. dorsalis* in rose leaves also decreased in response to different rates of boron fertigation (0.18, 0.36 and 0.54 ppm). The thrips population was reduced to 0.2 individuals per leaflet with fertigation at 0.54 ppm boron (Saravanan et al., 2006).

The effects of (i) biophysical processes such as crop water uptake, and elements absorption and (ii) chemical processes such as fertilizers dissolution and pH changes, on Ca\(^{2+}\), Mg\(^{2+}\) and K\(^{+}\) concentration in a recirculated nutrient solution of a greenhouse soilless rose crop (*Rosa hybrida 'First Red'*), were studied. Measurements of greenhouse microclimate variables, crop water uptake as well as pH, EC and Ca\(^{2+}\), Mg\(^{2+}\) and K\(^{+}\) concentration in nutrient solutions kept in storage tank or
applied for crop fertigation, were carried out. The results showed that variations of Ca\textsuperscript{2+} concentration in the nutrient solution were highly correlated to crop water uptake, crop Ca\textsuperscript{2+} absorption, fertilizer dissolution and pH variation of the nutrient solution. The concentration of Mg\textsuperscript{2+} in the nutrient solution was correlated to EC of the solution. Equations for Ca\textsuperscript{2+}, Mg\textsuperscript{2+} and K\textsuperscript{+} concentrations prediction in the recycled nutrient solution were developed and calibrated. Validation gave satisfactory results (Lykas et al., 2006).

Rose plants, 'Bridal Pink' budded on Rosa manetti, were grown in 15-liter pots filled with a peat: vermiculite: perlite medium (3:2:1 v/v). They were fertilized with either a complete nutrient solution adjusted to provide 112, 16 and 117 mg per Liter N, P and K, respectively. No significant differences in flower yield, plant biomass (fresh weight yield/plant) and average flower shoot length were observed between the two fertilization methods after five flushes of growth and flowering (8 months). (Cabrera, 2007).

Field experiment was conducted to study the distribution pattern of moisture, P and K under drip fertigation at Coimbatore in rose crop. Soil samples were collected at 0, 15, 45 and 75 cm distance horizontally away from the emitting point and at 0-15 and 15-30 cm depth using core sampler. These samples were analysed for moisture, available P and K content. From the results it was inferred that drip fertigation provides the most effective way of supplying water to the plant roots. Drip fertigation can also be used to supply any water soluble fertilizer in precise amounts, as and when required to match the plant needs or any other agronomic management thereby enhancing the nutrient use efficiency. Thus, fertigation proved a promising technique for increasing the water and nutrient use efficiency in the crop production (Suganya et al., 2007).
To examine the most suitable concentration of nitrogen in recirculating nutrient solution, the growth and total nitrogen uptake of potted miniature rose was compared under nutrient solution with 60, 75 or 90 mg dm\(^{-3}\) of total nitrogen. The ratio of nitrate- to ammonium-N in recirculating solution was 2:1. Under cultivation using a nutrient solution with 60 mg dm\(^{-3}\) of total nitrogen, low nitrogen content per dry weight of plants was caused by the nitrogen supply deficiency, and plant growth was retarded. Under cultivation using a nutrient solution with 90 mg dm\(^{-3}\) of total nitrogen, the high concentration of nitrogen in the recirculating solution disrupted the balance of evapotranspiration and nitrogen uptake, increased the nitrate nitrogen in soil solution and inhibited water uptake due to the high osmotic potential. These results may lead to both low efficiency and low amounts of nitrogen uptake per dry weight of plant. However, under cultivation using a nutrient solution with 75 mg dm\(^{-3}\) of total nitrogen, plant growth was normal, and both the efficiency of nitrogen uptake and amount of nitrogen content per plant were high. (Imaida et al., 2007).

Experiment was carried out to evaluate the flower yield and quality of the rose cultivars 'Sonia' and 'Red Success' as affected by different potassium (K) rates supplied by drip irrigation. The K treatments were 0, 30, 60 and 90 g per m\(^2\) per year. The cultivar 'Sonia' produced higher number of stems for the commercial (length) grades <30, 30-40 and 40-50 cm. The cultivar 'Red Success' had higher production of 60-70, 70-80 and >80 cm stems. Maximal yield of rose stems with superior quality (>69 cm in length) was obtained with a K application at a rate of 49.76 g per m\(^2\) per year. 'Sonia' yielded a higher number of normal, straight stems, with maximal production at K application rates of 50.36 g per m\(^2\) per year. The cultivar 'Red Success' was more susceptible to Oidium (powdery mildew) infection, but increases in K applications produced a reduction of the disease infection (Barbosa et al., 2007).
In order to evaluate rose leaf nutrient content as affected by potassium (K) rates applied through drip irrigation, Sonia and Red Success cut roses were grown under a plastic greenhouse. The treatments comprised 4 K rates (0, 30, 60 and 90 g/m/year). Foliar analysis was done in order to determine plant nutrient uptake curves during the plant growth and production cycles. In the absence of K (control), the leaf K contents decreased from 2.46 and 2.41 to 1.47 and 1.46 da g per Kg after 60 and 635 days for Red Success and Sonia plants, respectively. With K application, leaf K contents decreased from 2.41 and 2.34 to 1.80 and 1.54 da g per kg after 60 and 635 days for Red Success and Sonia, respectively, suggesting that the existing soil K was enough to provide satisfactory rose leaf K content, once the exhibited leaf K contents were in the optimal range for most commercial cut rose cultivars (Santos et al., 2007).

Hydroponically grown rose plants, Rosa hybrida 'Kardinal', were exposed to different oxygen concentrations and the water and nitrate absorption rates of each plant were measured. No noticeable correlation between water and nitrate absorption rates and root zone oxygen concentration were observed. These results were contrary to the past research and have led to the conclusion that, the data at lower concentrations of oxygen must be gathered to demonstrate a critical oxygen concentration for water and nitrate absorption. Data from lower oxygen concentrations may demonstrate the point at which the root zone oxygen concentration becomes a limiting factor on cellular respiration (Flannery and Lieth, 2008).

The effects of two levels (500 and 250 ml) of NPK applied through fertigation at 2, 4 and 6-day intervals on the growth and flowering of 2 rose (R. hybrida) cultivars (Amalia and Anjleeq) were studied. Plant height, number of branches, number of leaves, number of flowers per
plant, number of petals per flower, and leaf N, P and K contents were highest with NPK at 500 ml applied at 2-day intervals. A higher number of days to the emergence of the first flower was recorded for NPK at 250 ml applied at 6-day intervals. All the treatments improved growth and yield in both cultivars compared to the control; however, NPK at 500 ml applied at 2-day intervals was the most effective, particularly in improving vegetative and reproductive growth (Qasim et al., 2008).

2.2 Influence of nutrients on vase life of flower crops

2.2.1 Influence of normal fertilizers on vase life

Keeping quality of rose cv. ‘Celebration’ in vase was highest with application of K (8 g/plant) alone or K in combination with P but was reduced in the treatment N as examined by Maharana and Pradhan (1976). Similar results were observed in ‘Super Star’ roses (7.79 days) by the application of potassium at the rate of 8 g per plant (Uma, 1985). Vase life of roses (7.33 days) were longest with application of KNO₃, P₂O₅ and K₂O at 703, 100 and 100 Kg per ha, respectively (Sutrapradja, 1989). Maximum vase life of 7 days was recorded in ‘Gladiator’ rose flowers from the plants that received 30:24 g N/K per plant per year (Nagaraju, 1997).

Longest post harvest life (7.80 days) of cut rose cv. ‘Arjun’ was recorded by Vidhya Sankar and Bhattacharjee (2000) with nitrogen treatment at 500 Kg per ha per year. Manisha and Syamal (2002) opined that longevity of flowers in the field and keeping quality ‘Super Star’ rose in vase were reduced with increasing the doses of urea (1.5 per cent).

2.2.2 Influence of normal fertilizers through fertigation of vase life

Vase life of rose cv. ‘Celebration’ was highest with K alone or K in combination with P as examined by Maharana and Pradhan (1976).
Maximum vase life of 7 days was recorded in ‘Gladiator’ rose flowers from the plants that received 30:24 g N, K per plant per year (Nagaraju, 1997).

Vase life of ‘Super Star’ roses increased with the application of potassium at the rate of 8 g per plant (Uma, 1985). Applying potassium at higher concentrations prolonged the vase life of chrysanthemum cut flowers grown under greenhouse (Ajoy, 1999). Maximum vase life of gerbera flowers (14.34 days) was obtained by Sekar et al. (2003) when plants are supplied with normal fertilizers through fertigation at the rate of 300:200 mg per NK per week per plant.

### 2.2.3 Influence of water soluble fertilizers on vase life

A tendency to slightly increase the keeping quality of the ‘Carol’ rose flowers was noticed with application of N while increasing K had no significant but slight effect on the keeping quality as reported by Bik (1972).

Greater longevity of cut flowers in rose cv. ‘Royalty’ was noticed by Menard et al. (1996) when plants were fed with low N. While, Ajoy Gopal (1999) reported that vase life of chrysanthemum flowers was significantly extended to 15.10 days in T4 fertigation (1.6 g each of N and K2O, 2.5 g P2O5/m2/split) and lowest (10.40 days) in T2 fertigation (1g each of N and K2O, 1.5g P2O5/m2/split). Whereas, application of 120 per cent more than the recommended dose of fertilizer resulted in longer vase life (10.82 days) of carnation flowers (Krishna, 1999).

Application of 300 ppm per week each of nitrogen and phosphorus and 200 ppm per week of potash was found to be best for obtaining longer vase life of roses (Anon., 2000). The application of graded levels of N influenced the water loss and water uptake of rose flower stalk significantly under greenhouse conditions. The water uptake ratio
decreased with increased levels of N indicated a shorter vase life of ‘First Red’ rose flowers (Ashok et al., 2000).

Longer vase life (5.66 days) of carnation flowers was obtained by the application of water soluble fertilizers through fertigation (Gopinath, 2001). However, vase life was not affected among different levels of fertigation. Higher vase life (14 days) to ‘First Red’ rose cut flower was noticed by Barman et al. (2003) when plants were fertigated with 150 ppm N plus 200 ppm K as well as spraying with polyfeed and micronutrients.

2.3 Influence of nutrients (soil application/fertigation) on soil nutrients status.

Carlson and Bergman (1966) recorded less soil P and Ca and more soil N and K content when higher doses of fertilizer were used but soil Mg was not affected. In most of the soils, phosphorus is generally fixed when fertilizers are broadcasted, high concentration of phosphates are found in the surface soil layers while with fertigation a more uniform phosphate gradient is observed (Rolston et al., 1974).

Increased organic carbon, phosphorus and potash content in soil were observed by Damke and Bhattacharjee (1995) with the application of N, P and K fertilization respectively in ‘Super Star’ roses. Similarly, available calcium and magnesium content in soil was influenced by nitrogen, phosphorus and potash fertilization of ‘Super Star’ roses (Damke and Bhattacharjee, 1997). The soil N, K, Zn and Cu were significantly increased, by the application of N, K and multiplex respectively (Nagaraju et al., 2003) in rose cv. ‘Gladiator’. 
2.4 Economic of fertigation

Generally the investment on the cultivation of flower crops under greenhouse is higher when compared to traditional methods. But the returns from greenhouse cultivation are also higher. Hence, Cost: Benefit analysis is useful. Cost of cultivation of rose had risen with the time, hence profitability declined greatly (Rijssel and Oprel, 1979).

The investment on roses found to be economically viable as it gave a Benefit: Cost ratio of 1.7 to 1.8 with hardly 2-3 years payback period depending upon the channel of sale (Subramanyam, 1989). As fertigation studies in rose are limited, the study of Cost: Benefit analysis of other flower crops under greenhouse is useful.

Cost and returns of the five major greenhouse cut flower crops viz., carnation, chrysanthemum, freesia, gerbera and roses in Netherlands over a ten year period was studied by Zawaneberg (1990). It proved that chrysanthemum production showed lowest increase in labour cost. Also rapid growing cycle and closer planting resulted in higher productivity.

Maximum revenue and net profits were obtained by Bhagyalakshamamma (1998) in gerbera plants treated with multiplex and cv. ‘Ibiza’ merged as the most profitable one when compared to others.

Robert et al. (1998) examined the economics of an innovative long stem rose production system as a specialized perpetual production system as well as an enterprise integrated with other typical green house crops. Commercial quality cut roses can be grown in a single stem system from cuttings. Single stem roses grown in 6 to 10 cm containers can be grown on mobile trays with a ebb and flood sub irrigation to greatly reduced irrigation runoff. Marketable yields for the greenhouse space are significantly increased over conventional production systems,
although capital cost and management intensity are increased. This system allows the use of pot handling robots to reduce labour cost and the movement of the roses to specific controlled environments that are appropriate for each stage of rose growth.

Data from seven sequential crops of ‘Lady Diana’ cuttings grown from February to May 1995, showed that rooting required a mean of 16 days, flower buds were visible in 39 days, flower harvest required a mean of 55 days and mean stem length was 54 cm. Production costs within several enterprise schemes were determined for cut rose stems that met these mean characteristics as well as high quality stems (66 to 75 cm long). Economic consideration integrated seasonal market prices, seasonal energy costs, special capital and labour cost etc. These variations led to break even costs ranging from $0.20 to $0.25 per stem. Estimated internal rate of returns were 77 per cent for rose year around rose production and 175 per cent for rose production specially targeted to Valentine’s Day market while integrated with other greenhouse products over the rest of the year.

Studies carried out by Ajoy (1999) in chrysanthemum indicated that 100 per cent water soluble fertilizers resulted in maximum profit of Rs. 25,70,718/- per 100 m². The economics of fertigation revealed that fertigation with 80 per cent straight or water soluble fertilizers was most effective in gerbera cv. ‘Ilbiza’ with Benefit:Cost ratio of 2.48 to obtain higher returns (Sujatha, 1999).

Application of 80 per cent recommended dose in the form of water soluble fertilizers resulted in the maximum revenue (Rs. 1,06,748/m²/annum), net profit (Rs. 72,213/100 m²p/annum) and Benefit:Cost ratio (2.09) in carnation (Gopinath, 2001).
2.5 Influence of plant growth regulators on growth, quality and yield

The investigation was conducted to study the effect of plant growth regulators on growth characters of Floribunda roses cv. Iceberg by using gibberellic acid (100 and 200 ppm GA$_3$), Benzyl Adenine (100 and 200 ppm BA), salicylic acid (150 and 200 ppm SA) and Cycocel (Chlormequat) (1500 and 3000 ppm) applied at three intervals after pruning. The foliar applications of growth regulators showed significant results on many growth parameters, GA$_3$ at 200 ppm increased the shoot length (20.66 cm) and internodal length (4.42 cm), while number of laterals (4.62) and leaf area (133.12 cm$^2$) were recorded maximum with cycocel at 1500 ppm. More number of leaves per new shoot (56.13) was observed in BA at 200 ppm and maximum shoot thickness (1.39 cm) in plants sprayed with Cycocel at 300 ppm. The plants treated with cycocel were compact with more shoot diameter, laterals and leaf area whereas, the plants sprayed with GA$_3$ showed elongated shoots with reduced shoot diameter and number of laterals (Prashanth et al, 2006).

2.5.1 Effect of GA on plant height and internodal length

Mastalerz (1960) stated that 3 to 13 weekly application of GA$_3$ at concentration upto 100 ppm may result in marked increase in stem length in various plants such as rose, dwarf dahlia, chrysanthemum, snap dragon and datura.

Internodal length was significantly increased due to GA sprays. Maximum length of internode in rose was recorded at GA 500 ppm (4.83 cm). Whereas, control recorded least (2.50 cm) (Nanjan and Muthuswamy, 1975).

Gowda (1980) noticed increased stem length in rose cultivar Super Star with GA$_3$ at 100 to 250 ppm when applied in rose cultivar Queen
Elizabeth, all the applications increased stem length and internodal length.

Maharana and Pani (1982) reported increased plant height in rose cultivar. Celebration when the plants were sprayed with GA$_3$ at 200 ppm one month after pruning. Banker and Mukhopadhya (1982) reported that applying GA at 250 ppm recorded maximum intermodal length (6.16 m) compared to control (3.49 cm) in rose cv. ‘Queen Elizabeth’.

Venkatesh and Nagarajaiah (1986) reported that GA at 50 ppm produced maximum intermodal length (4.10 cm) in rose cv. ‘Queen Elizabeth’ whereas; least was recorded by control (2.53 cm).

Gowda (1988) observed increased stem length and neck length in rose cv. American Heritage with GA$_3$ spray at 300 and 350 ppm.. The length and diameter of shoot were also increased with the application of GA$_3$ at 45 ppm in rose cv. Super Star.

Sadanand et al. (2000) reported increased plant height, shoot length and maximum number of leaves per plant were recorded with the application of GA$_3$ at 200 ppm in rose cv. First Red.

**Number of stems**

Trader et al. (1980) reported that, the combination of pinching and treating with cytokinin (BAP) increased branching and the number of flowering shoots in rose cv. Meillandina.

Gowda (1985) reported increase number of primary and secondary shoots with GA$_3$ at 100 and 200 ppm in rose plant with the spray of GA$_3$ at 45 ppm compared to control (10.50) in rose cv. Super Star.

There was a marked increase in lateral branching by spraying of NAA at 500 ppm or GA$_3$ at 100 ppm in carnation cv. Margherite Crimson
(Mukhopadhyay, 1990). Geetha et al. (2000) reported that in China aster GA and IAA were responsible for more number of branches per plant.

Singh (2002) reported that drenching the soil with 20 mg Paclobutrazol per plant increased the number of primary and secondary shoots per plant in case of rose. Similar results were recorded per bush in rose cv. Super Star with 125 ppm NAA treatment (Singh et al., 2003).

The effect of plant growth regulators on vegetative growth and flower earliness of damask rose (Rosa damascena) was investigated. Treatments comprised 3 levels of gibberellic acid (GA₃; 50, 100 and 200 ppm), CCC (Chlormequat) (500, 1000 and 2000 ppm), and Ethrel (Ethephon) (0.02, 0.04 and 0.06 per cent), and distilled water spray as control. Plants sprayed with GA₃ at 200 ppm recorded the maximum vegetative growth and earliness flowering. CCC and Ethrel application reduced plant height but increased number of shoots per plant and plant spread. CCC hastened flowering whereas, Ethrel application delayed it (Porwal et al., 2002). While, application of GA₃ at 200 ppm resulted in the maximum number of branches in China aster cv. Shashank (Prabhat et al., 2003).

**Days taken for flower bud emergence and flower harvesting**

Shaul et al. (1995) proposed a hypothesis of a dual effect of GA₃ in suppression of Botrytis in rose cut flowers. Firstly, it may inhibit senescence related malfunction of cell membranes. Secondly, GA₃ may stimulate formation of endogenous compounds inhibiting Botrytis blight development in the petals. Nanjan and Muthuswamy (1978) reported that GA at 200 ppm significantly minimized the days for flower bud emergence and flower harvesting in Edward rose (Rosa bourboniana).

Hassan and El-Quesni (1990) reported that application of cytokinin on flower buds (1.5 to 1.7 cm length) advanced flowering in carnation by
4 days and significantly increased the number of flowers per plant. Parwal et al. (1994) reported that application of GA$_3$ at 200 ppm recorded early flowering in Damask rose. While, CCC hastened the flowering whereas,, ethrel delayed flowering. Bhattacharjee and Singh (1995) observed Daminozide (500 ppm) and Chloremquat (1000 ppm) enhanced early flower bud appearance, while ethrel (1000 ppm) delayed flowering in rose.

Roberts et al. (1999) reported that in rose cv. Felicite Perpetue, floral initiation occurred when concentrations of GA$_3$ were low and was inhibited when concentrations of GA$_3$ were high.

All paclobutrazol treated plants exhibited delayed flowering in rose cv. Gruss-an-Teplitz (Singh and Bist, 2003). Padmapriya and Chezhilyan (2003) reported that in chrysanthemum GA$_3$ was found to increase the IAA oxidase activity which is responsible for early flowering.

2.5.2 Influence of plant growth regulators on quality attributes

Pruning at first week of March significantly affected plant height and flower yield but not oil content in rose plants. The longest flowering period was associated with pruning at first week of April, although this treatment significantly lowered flower yield and shortened plant height. Alar, kinetin, NAA and Cycocel increased while GA$_3$ decreased flower oil content compared to the control and also showed the shortest flowering period among treatments (Saffari et al., 2004)

The highest values of chlorophyll- A, chlorophyll- B content and total Carotenoids content were obtained in rose plants which treated by (40 ppm Ki+15 ppm BRs) at the 1st and 3rd spray in both seasons: (40 ppm Ki+15 ppm BRs) at the 1st spray and (50 ppm GA$_3$+15 ppm BRs+40 ppm Ki) at the 3rd spray, respectively. Moreover, spraying rose plants
with (50 ppm GA₃ + 40 ppm Ki + 15 ppm BRs) resulted an increase in total carbohydrates and soluble sugars contents (Kandil et al., 2007).

Senescence is one of the most puzzling events in plant life. From seed germination to maturation, the plant undergoes several changes. Senescence shows accumulation of hazardous substance. Growth promoters delay the deteriorative process as well as accumulation of hazardous substance. Studies were carried out to determine the effect of plant growth regulators (Kinetin (KN) at 10, 20, 50 and 100 ppm, gibberellic acid (GA₃) at 10, 20, 50 and 100 ppm, and IAA at 100, 200, 300 and 400 ppm) on abscission and senescence of leaves of (Rosa indica) and (Rosa chinensis). Kinetin was the most effective growth regulator compared to GA₃ and IAA (Sharma and Tomar, 2008).

Bio-chemical contents of leaf viz. chlorophyll a, chlorophyll b, reducing & non reducing sugar and protein reduced during the course of development. Exogenous application of Indole Acetic Acid (IAA), Gibberellic Acid (GA₃), Cytokinens (KN) reduced the reduction of this content in attached and deattached condition while Abscisic Acid (ABA) and Etheophon (ETH) enhance the reduction. Out of GA₃, IAA & KN, kinetin is the most effective retardant, while ETH, is highest promoter of applied regulator during the development, the reduction is either due to mobilization of these content to younger ones, reproductive parts or degradation by hydrolytic enzyme. Perhaps, KN, GA₃ and IAA delay the production of hydrolytic enzyme, where as ABA and ETH not only promote the production of hydrolytic enzyme but also reduced the production of growth promoter (Sharma and Tomar, 2009).

Senescence is considered as a genetically programmed process with culminates the development and differentiations of plant structure and which serve to specific function in the plant. Physiological senescence is definitely followed by death while non-physiological not be
followed. It is due to definenecy of any essential mineral. The senescence process allows for the termination of cells, tissues, organs or even organisms in a controlled process. Senescence is age dependent and under the control by hormonal, molecular, and genetical processes. It is controlled by several factor, harmones are one of them. The hormonal regulation is an important aspect of the mechanism of the senescence but not an isolated aspect. Hormones act by controlling the development of the senescence programme. Gibberellins delay the senescence. Gibberellin is a powerful retardant (Sharma et al., 2011).

**Length of stalk**

In celebration Rose, GA$_3$ sprayed at 200 ppm accelerated the stem length (Maharana and Pani, 1982). Foliar application of GA$_3$ at 200 ppm twice (20 and 30 days after pruning) on ‘Queen Elizabeth’ cut roses, increased internode and shoot length (Nagarajaiah and Reddy, 1986). Spraying with gibersol (GA$_3$) every two weeks throughout the season increased flower stem length when flowers were harvested either continuously or in the autumn (Wisniewska and Treder, 1989).

BA, NAA, GA$_3$ and IAA were sprayed at 100 and 200 ppm concentration of each on *Rosa hybridra* cv. Super Star three week after pruning. All treatments with growth regulators accelerated shoot length except with BA (Anon, 1993).

Foliar spray of GA$_3$ at 50 to 500 ppm in field increased plant growth in Gladiolus (Bhattacharjee, 1984).In the rose cv. Super Star shoot length was maximum (37.71 cm) when compared to control (25.25) by applying GA at 45 ppm Goyal and Gupta (1994).

Sharma *et al.*, (1995) conducted an experiment in Raipur (M.P.) to investigate the effect of foliar application of NAA (25, 50, 75 and 100
ppm) one month after transplanting and found that plant height was directly proportional to NAA concentrations.

Patel and Patil (1998) reported that application of 300 ppm GA increases the length of cut flower stalk in rose. Arun et al. (2000) observed that rose cut flower stalk length was greatest by applying GA$_3$ (300 ppm). Maximum increase in stem length (55.22 cm) compared to control (32.79 cm) was found in rose cv. Queen Elizabeth by spraying GA (250 ppm) (Banker and Mukhopadhyya, 1982).

The effect of gibberellic acid at 100 ppm showed improved plant heights (70.50 cm) as compared to untreated ones (62.33 cm) in carnation cv. Improved Margherite (Jana and Jahangir, 1987). Application of N at 100 ppm per week and GA$_3$ applied twice in carnation significantly increased plant height (65.94 cm) and stem length (58.25 cm) (Verma et al., 2000).

Maximum stalk length (74.60 cm) was produced in rose cv. First Red by applying GA$_3$ at 300 ppm. Whereas, control recorded least (45.92 cm) (Dhekney et al., 2000). Highest flower stalk length (57.60 cm) was recorded by application of GA$_3$ (200 ppm) along with water soluble fertilizer @ 75 per cent of RDF in chinaster (Kore et al., 2003). Application of 200 ppm of GA$_3$ in carnation significantly increased plant height (88.24 cm) (Ramesh and Singh, 2003).

**Stalk girth**

In Edward rose maximum stalk girth was registered by phosfon at 500 ppm compared to control TIBA 500 ppm registered the least thickness. The shoot thickness was in general low in GA treated plants Nanjan and Muthuswamy (1978).
**Flower length and diameter**

Garrod and Harris (1974) reported that additional petals could be promoted by application of GA\(_3\) or IAA or kinetin to the shoot tip during flower initiation. Banker and Mukhopadhyay (1982) stated that GA\(_3\) at 100 ppm produced good diameter of bud in rose cv. Queen Elizabeth. Gowda (1988) noted more number of petals per flower with GA spray at 250 to 350 ppm in rose cv. American Heritage.

Bud diameter improved with all the concentrations of GA\(_3\) spray used in carnation (Amitabha, 1990). The maximum size of flower (6.4 cm) associated with longer stalk length (14.84 cm) was produced by applying GA at 150 ppm. The minimum size was recorded in MH-1000 ppm (4.13 cm) whereas, control recorded 4.85 cm in case of chrysanthemum (Jyoti, et al., 1995).

Goyal and Gupta (1996) recorded the highest flower diameter (9.55 cm) and weight of flower (13.91 g) with the foliar spray of GA\(_3\) at 45 ppm compared with control (9.05 cm and 10.15 g, respectively) in rose cv. Super Star. Sadanand et al. (2000) recorded that increased bud length and bud diameter was reported with GA\(_3\) application and the highest length and diameter were obtained in case of bud with GA\(_3\) at 200 ppm in rose cv. First Red.

Dhekney et al., (2000) reported that GA at 200 ppm resulted in increase in bud length, bud circumference and flower diameter. Verma et al. (2000) stated that applying Nitrogen (500 ppm) and GA\(_3\) (50 ppm) per week were found to be effective in increasing the flower diameter and flower length in carnation.

Thamarai Selvi et al. (2002) reported that applying calcium acetate 0.5 per cent + Panchakaya 5 per cent significantly improved the floral characters such as flower weight, flower length, flower thickness and
petal number in Edward rose. Chakradhar (2002) reported that the flower quality attributes such as length and diameter of flower bud, number of petals per flower, flower longevity and weight of flower improved with the application of GA$_3$ 60 ppm in rose cv. Gladiator.

Chakradhar et al. (2003) reported that flower bud length and diameter were maximum with application of GA$_3$ at 60 ppm and minimum with BA at 100 ppm in rose cv. Gladiator. Significantly maximum flower diameter (7.09 cm) was recorded at GA$_3$ 100 ppm with DSF @75 per cent of RDF in China aster as compared to control (4.87 cm) (Kore et al., 2003).

**Neck length**

The length of the pedicle (neck) was increased markedly by GA while phosfon and TIBA recorded least values than control (6.37 cm). The least pedicle length was noted under phosfon at 1000 ppm per 4.2 cm (Nanjan and Muthuswamy, 1978). Banker and Mukhopadhya (1982) reported that applying GA at 250 ppm produced maximum neck length (14.93 cm) compared to control (9.00 cm) in rose cv. Queen Elizabeth.

Maximum flower neck length (9.073 cm) was produced in rose cv. First Red by applying GA$_3$ at 300 ppm while control recorded 6.43 cm (Dhekney et al., 2000). Thamarai et al. (2002) reported that calcium acetate 0.5 per cent + Panchakaya 5 per cent significantly improved pedicle length in Edward rose.

**2.5.3 Influence of plant growth regulators on yield attributes**

GA at 200 ppm recorded maximum yield per plant per m$^2$ per annum (205 flowers) in Edward rose compared to control (168 flowers) (Nanjan and Muthuswamy, 1975). El-Shafie et al. (1980) obtained highest
number of flowers with GA$_3$ at 250 ppm in Queen Elizabeth and Baccara rose varieties.

Application of GA$_3$ (10-100 ppm) twice after pruning in ‘Queen Elizabeth’ rose cultivar increased number of flowers (Bankar and Mukhopadhyay, 1982). In ‘Celebration’ rose, GA$_3$ spray (200 ppm) advanced flowering and accelerated stem (Maharana and Pani, 1982). Foliar spray of GA$_3$ at 50 to 500 ppm in field grown ‘Raktgandha’ roses increased number of flowers per plant and petals per flower (Bhattacharjee, 1983).

Gowda (1985) enhanced the flower yield in rose cv. Super Star with the foliar spray of GA at 200 ppm. Nagarajaiah and Reddy (1986) obtained similar results in rose cv. Queen Elizabeth with GA$_3$ at 10 to 100 ppm applied twice after pruning.

Dhekney et al. (2000) reported that applying GA$_3$ at 200 ppm produced maximum number of flowers (38.610) per m$^2$ compared to control (18.22). Kewte (1991) obtained highest number of flowers per plant with GA at 300 and 200 ppm (28.75 and 25.25, respectively) compared to control (14.50) in rose cv. Paradise.

Goyal and Gupta (1996) recorded 19.50 flowers per plant with GA at 30 ppm compared to 16.00 flowers per plant with control in Rose cv. Super Star. Kewte and Sable (1997) recorded highest number of A and B grade cut flowers from plants treated with GA$_3$ at 300 ppm compared with control in rose cv. Paradise.

Gowda (1998) reported that the numbers of marketable flowers were increased in rose cv. American Heritage with GA$_3$ at 300 and 350 ppm. Sadanand et al. (2000) recorded more number of flowers per meter
square with GA$_3$ at 200 ppm as compared with other treatments in rose cv. First Red.

Arun et al. (2000) reported that applying GA$_3$ at 200 ppm recorded more number of flowers per m$^2$ in rose cv. First Red. *Rosa hybrida* cv. Sntrix plants grown under greenhouse conditions were sprayed with 250 ppm gibberellic acid (GA$_3$) alone or combined with foliar fertilizer Sangral at the rates of 0.10, 0.20, 0.40 and 0.80 per cent. The control plants were sprayed with distilled water. The results showed that spraying the plants with GA$_3$ alone or in combination with the different rates of foliar fertilizer stimulated the growth and flowering of the plants, compared to the control. The highest values of vegetative and flowering parameters were obtained with spraying the plants with 0.40 per cent foliar fertilizer and 250 ppm GA$_3$. Moreover, the total carbohydrate and mineral contents in the leaves were increased as a result of spraying the plants with GA$_3$ and foliar fertilizer at different rates, compared to the control (Al-Humaid, 2001).

The number of flowers and yield (67.33, 192.59 g) per plant per m$^2$ per annum were highest with GA at 200 ppm while lowest with control (26.00 flowers and 76.8 g yield of flowers) in China aster cv. Kamini (Prabhat Kumar et al., 2003). Maximum yield (49.60 q ha$^{-1}$) was recorded by application of GA$_3$ (200 ppm) along with water soluble fertilizer at 75 per cent of RDF in China aster (Kore et al., 2003).

### 2.6 Influence of plant growth regulators on vase life

Post harvest pulsing for 20 h with solutions containing 20 to 40 mg GA$_3$ per litre extended the vase life and promoted bud opening of unstored and stored flowers of the rose cv. Mercedes. While continuous treatment with GA$_3$ was detrimental (Goszczynska et al., 1990). GA$_3$
stimulates active sucrose uptake in GA₃-persucrose-dependent rose petals (Kuiper et al., 1991).

Barthe et al., (1991) reported foliar spraying with ABA or cytokinin delayed wilting and senescence, increased the vase life in greenhouse grown Rosa hybrida cv. Royalty.

The petal area progressively increased with increased dose of GA₃. BA, NAA, GA₃ and IAA were sprayed at 100 and 200 ppm concentration of each on Rosa hybrid cv. Super Star three weeks after pruning treatment. Flowering was delayed to a greater extent by the spray of NAA, 100 and 200 ppm pronounced beneficial effect on flower size, number of petals, flower yield and longevity were recorded with NAA, 200 ppm (Anon, 1993).

Goyal and Gupta (1994) observed increased vase life of 141.62 hours with GA₃ at 45 ppm compared to 125.25 hours with control in rose cv. Super Star. Lee and Kim (1995) reported that flowers kept in distilled water with GA and BA showed high chlorophyll contents (Rosa hybrida L. cv. Red Sandra). Foliar application of GA₃ (300 ppm) and NAA (10 ppm) on the rose cv. Paradise gave highest number of A and B grade cut flowers and longest vase life (Kewete and Sable, 1997).

In chrysanthemum, flower longevity was increased by the increase in concentration of paclobutrazol i.e., 10, 20 and 40 ppm but 60 ppm concentration lowered flower longevity (Singh et al., 1999).

An investigation was carried out on "Eiffel Tower" cut roses to determine the most effective growth regulating chemical and its concentration in the holding solution for improving postharvest life and quality. Growth regulators like IAA, BA [Benzyl Adenine] and kinetin in 1, 2.5, 5, 10 and 25 ppm of each and GA [Gibberellic Acid], at 50, 100, 150,
200 and 250 ppm were used in the vase solution individually. All the above growth regulating chemicals showed beneficial effects on vase life, flower diameter, water uptake and fresh weight. Among the chemicals, kinetin at 2.5 ppm was the best in terms of effectiveness in increasing postharvest life, followed by GA3 at 150 ppm, BA at 5 ppm and IAA at 2.5 ppm (Bhattacharjee, 2000).

The longevity of harvested rose (Rosa hybrida) flowers of cv. Mercedes, has been promoted by application of GA3. The leakage of electrolytes from the GA treated petals of was lower in comparison with untreated ones (Agbaria et al., 2001). Chakradhar (2002) recorded that maximum vase life of cut flowers (8.90 days) was recorded with GA3 at 60 ppm compared to other treatments in rose cv. Gladiator. Paclobutrozol (10 ppm) gave the highest fresh weight on the third day (5.71 g) and the longest vase life (14.7 days) (Tiwari et al., 2002).

This study was conducted to evaluate effects of different levels of salicylic acid (SA) (50, 100, 150 and 200 mg/l), gibberellic acid (GA3) (150, 200, 250 and 300 mg/l), and cyco (CCC) (500, 1000, 1500 and 2000 mg/l) at pre-harvest stage on the quality, yield and vase life of cut rose (Rosa hybrida 'Poison'). Results showed that the effects of plant growth regulators on bud length, vase life and yield were significant. The effect of regulators has also been significant on fresh weight and flower height. The highest record of flower yield was obtained by application of 200 mg per liter GA3 with 192 cut flowers per year per m². The highest vase life (12.67 days) was obtained when 150 mg per liter SA applied to cut flowers. The best treatment to increase the stem flower length was application of 300 mg per liter GA3 which produced longest cm stems (49.33) (Hashemabadi and Zarchini, 2010).

This study evaluated the effects of different levels of salicylic acid (SA) (50, 100, 150 and 200 mg/l), Gibberellins (GA) (150, 200, 250 and
300 mg/l) and Cycocel (CCC) (500, 1000, 1500 and 2000 mg/l) at pre-harvest period on the quality, yield and vase life of rose (*Rosa hybrida* 'Poison'). The highest yield was obtained in 200 mg l-1 GA3 with 192 cut flowers per year per m² and the highest vase life was obtained from 150 mg per liter SA (12.67 days). 300 mg per liter GA3 with 49.33 cm flower height was the best between treatments (Abadi, 2010).

Study was conducted to clarify the effect of plant hormones on invertase activity and on the petal growth of cut roses. Petal discs of Rosa 'Febesa' were used for plant hormone (IAA, ABA, GA3, and JA) treatment. The results showed that IAA and GA3 could increase the activity of cell-wall bound invertase, and IAA, GA3, and ABA increase that of vacuolar invertase. For applied experiments with plant hormones, a scent rose Rosa 'Meivildo', which has a short vase life was used. The study found that, some of the plant hormones (IAA and JA) in vase solution affected the petal growth of cut rose. For example, flower opening was promoted by NAA treatment and delayed by JA treatment compared with control (Horibe *et al*., 2010).

Effects of postharvest application of two plant growth regulators *viz.*, benzyladenine (BA) and gibberellic acid (GA3) with sucrose in the pulse solution on the vase life of roses 'Red One' were investigated. Results show a maximum gain in fresh weight (18.01 per cent) in the cut roses in the treatment with a 20 mg per liter GA3+100 g per liter sucrose pulse solution. In contrast to the change in fresh weight, treatments of 10 or 20 mg per liter BA and the control recorded the maximum water uptake. A pulse solution of 10 or 20 mg per liter GA3+100 g per liter sucrose or 10 mg per liter BA+10 mg per liter GA3+100 g per liter sucrose significantly increased vase life of cut roses than the control. Treatments of 100 g per liter sucrose, control, 10 mg per liter GA, 10 or 20 mg per liter, BA+100 g per liter sucrose recorded higher petal tissue electrolyte
leakage and decrease in vase life. Pulsing with a solution of sucrose at lower concentrations along with GA$_3$ (10 mg/l) was promising in increasing vase life of cut roses 'Red One' (Gholami et al., 2011).

### 2.7 Economics of growth regulator application

Generally the investment on the cultivation of flowers crops under greenhouse is normally more but returns from those is higher when compared to traditional methods. Cost of cultivation of rose had risen with the time but profitability declined greatly (Rijssel and Oprel, 1979).

The investment on roses was found to be economically viable as it gave a Benefit: Cost ratio of 1.7 to 1.8 with hardly 2-3 years payback period depending upon channel of sale (Subramanyam, 1989).

Cost and returns of the five major greenhouse cut flower crops viz., carnation, chrysanthemum, freesia gerbera and roses in Netherlands over a ten year period was studied by Zawaneberg (1990). It proved that chrysanthemum production showed lowest increase in labour cost. Also rapid growing cycle and closer planting resulted in higher productivity. GA$_3$ at 500 ppm recorded the highest profit of Rs. 70.10 per plant per year in *Anthurium andreanum* (Beena, 2003).

### 2.8 Influence of Humic acid on few crop species

The annual bedding plants 'Dazzler Rose Star' impatiens (*Impatiens walleriana*), 'Cooler Blush' vinca (*Catharanthus Rosaus*), 'Orbit Cardinal' geranium (*Pelargonium hortorum*), 'Janie Bright Yellow' marigold (*Tagetes patula*) and 'Bingo Azure' pansy (*Viola tricolor*) were grown on germination papers treated with deionized water (DI), 2500 or 5000 mg Humic Acid (HA) per liter or nutrient control (NC) solutions. Seedlings grown on HA-treated germination papers had higher dry root weights than those grown on DI or NC-treated germination papers.
Except for impatiens, seedlings germinated on HA-treated germination papers had higher lateral root numbers and higher total lateral root lengths than those grown on DI and NC-treated germination papers. Impatiens grown on NC-treated germination papers had higher lateral root numbers than those grown on DI or HA-treated germination papers. Overall, lateral root numbers for impatiens were higher for seedlings germinated on HA-treated papers than DI or NC-treated papers and highest lateral root numbers occurred on those impatiens germinated on papers treated with 5000 mg HA per liter. (Evans and Li, 2003).

Humic acid (HA) has a high cation exchange capacity and a stimulatory effect in turfgrass growth. In this study, creeping bentgrass (Agrostis stolonifera) turf was established from seed (6 g/m²) on an 85 per cent sand and 15 per cent peat, root zone mixture, in commercial 3-litre "Rose" (195 mm) containers under heated glass. Both nitrogen and phosphorus were applied to the turf at four levels (25, 50, 75 and Full Hoagland's solution) at 10-day intervals. HA was also applied to the turf at the same interval at a rate of 5 liter per hectare. Turf color, leaf fresh and dry weight, nitrogen and phosphorus content of leaf tissue and leachate were determined. HA ephemerally reduced nitrate but not phosphate leaching from the root zone. It did not affect the nutritional status of the leaf tissue. It was observed to have an effect on root architecture and growth of the growing plant and also the plant's resistance to drought (Hunter and Anders, 2004).

In a glasshouse experiment, Agrostis stolonifera 'Penn A4' seed was sown at 5 g m² on an 85 per cent sand and 15 per cent peat root zone in commercial 3L 'Rose' pots under heated glass and natural light conditions. Separate treatments of humic acid, seaweed extract and PHC organic plant feed were applied at their recommended rates. Additionally, humic acid per seaweed and humic acid per PHC organic plant feed
combinations were also set up. PHC organic plant feed and PHC organic plant feed per humic acid treatments significantly increased grass fresh and dry weights. Grass colour was best in plants treated with PHC organic feed. Leaf tissue phosphorus levels were greatly increased in plants treated with PHC organic feed. Treatments of the PHC organic feed gave phosphorus levels 10 times the permissible EU limit in the leachate. Nutrient leaching was minimized where humic acid per seaweed treatments were made (Hunter and Butler, 2005).

Humic acid (HA) might help plant growth by improving nutrient uptake and with hormonal effects. The effect of HA on growth, macro- and micronutrient contents, and postharvest life of gerbera (Gerbera jamesonii L.) cv. 'Malibu' were examined. Different levels of humic acid (0, 100, 500, and 1000 mg/L) was applied to nutrient solution. Root growth increased at 1000 mg/L HA incorporated into the solution. Macro- and micronutrient contents of leaves and scapes including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn) were significantly enhanced by HA. However, high levels of HA decreased some nutrient contents. Five-hundred mg per liter HA increased the number of harvested flowers per plant (52%). Higher HA levels extended the vase life of harvested flowers by 2-3.66 days and could prevent and delay bent neck incidence. These postharvest responses were most probably due to Ca accumulation in scapes and hormone-like activity of HA (Nikbakht et al., 2008).

Study was carried out to know the effects of a commercial product, containing humic substances, Humyk-Fer (Duclos International), on woody cutting-plant development (Lantana camara). Infrared, fluorescence, atomic absorption and 13C-NMR spectrometry's analysis indicate that Humyk-Fer is composed respectively of 73 per cent and 27 Per cent of Humic Acid (HA) and Fulvic Acid (FA) acids but equally
present a high content of metal ions (Fe$^{2+}$, K$^+$, Na$^+$). The biological effects of Humyk-Fer were then investigated on plant development. Different levels (0, 1, 2 and 4 per cent (v/v)) and various numbers of treatments (1 and 2) were tested in greenhouse for *L. camara*. First results show that Humyk-Fers drastically increase the growth (170x), but also reduce the delay of floral transition of *L. camara* (Costa *et al.*, 2008).

In this study, the effect of different rate of fertilizers (0, 3, 6, 9, 12 g/pot composite fertilizer – 12% N; 12% P; 12% K; 20% Humic Acid) on some agronomical and floristic characters (length, leaf number, leaf dry matter percentage, dry weight of leaves, flower-bud number, root dry matter percentage, dry weight of roots) of rose plants were tested by pot experiments in greenhouses of Bayndr Technical College, Ege University. Most favourable results were obtained by 6 g per pot of fertilizer treatment. However, 3 g per pot of fertilizer treatment had also positive effect on all characters except dry matter content and dry weight of roots. It was also concluded that this type of studies on plant nutrients should be conducted separately (Gunes *et al.*, 2009).

An experiment was conducted in order to study the effect of foliar application of organic nutrients on the growth, flowering and flower quality of *Dendrobium* orchid cv. Sakura Pink. Charcoal, brick pieces and coconut husk have been used as potting media for nourishing the plants. Foliar organic nutrients *viz.*, Vermiwash (1 per cent and 2 per cent), Panchakavya (1 per cent and 2 per cent), Humic acid (0.2 per cent and 0.3 per cent) and tender coconut water (1:1 and 1:2 dilutions) were sprayed at four days and eight days interval. The results revealed that Vermiwash 1 per cent at 4 days interval found to be optimum for flower quality of *Dendrobium* orchid cv. Sakura pink. Even though recommended dose of chemical fertilizers recorded higher values in vegetative growth and flowering characters, it was on par with the plants
treated with vermiwash 1 per cent at 4 days interval (Karuppaiah and Sendhilnathan, 2011).

Turf seeds were sowed in polyethylene pots and following the establishment of the plants, they were monthly sprayed with Leonardite humic acid in concentrations of 0, 100, 400 and 1000 mg per liter. The results revealed that application of humic acid in concentrations of 100 and 400 mg per liter were more effective than 1000 mg per liter. The concentration of 100 mg per liter positively affected the fresh and dry weight as well as the visual quality of the plants while the 400 mg per liter concentration more profoundly affected K and Fe. The two concentrations of 400 and 1000 mg per liter exerted a more serious effect on Zn content. None of these concentrations played any role on P content. An increase in humic acid concentration (1000 mg/l) caused a reduction in the height of the plants (Meybodi et al., 2012).

Experiment was carried out to know the effects of Hinokitiol (0.1, 1, 5 and 10 Micro molar), Humic acid (100, 500, 1000 and 10000 ppm), Sucrose (2.5, 5, 7.5, and 10 %), and Silver Thiosulphate (0.25, 0.5, 1 and 2 mM) treatments on longevity and some quality characteristics of cut yelloween lily flowers. The results indicated that Silver Thiusulfate at 0.25 to 1 mM increased the vase life of cut lily as compared with control and other treatments. Hinokitiol at 5-10 Mm decreased the vase life of the flower up to 2.4 days. The applied treatments, except for their higher concentrations, increased the uptake of in-vase solution, maintaining their relative fresh weight. Humic acid, a substitute with Cytokinin-like activity, markedly extended leaf longevity. In other words, a pulse treatment of the flower with 1000 ppm humic acid was found out as the most suitable treatment in preventing the flower from leaf yellowing under the general experimental conditions (Keshavarzi and Chamani, 2012).