THE INFLUENCE OF NITROGEN FERTILIZATION ON GROWTH, FLOWERING AND KEEPING QUALITY OF ALSTROEMERIA 'CARMEN' AND 'MARINA'

BY

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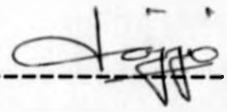
DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.



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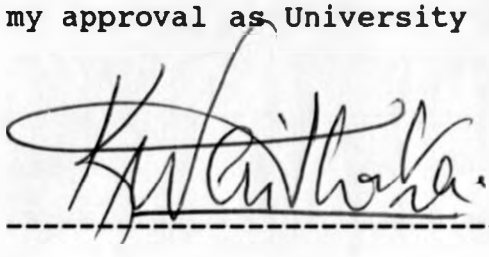

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DEDICATION

To my dear parents

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THE INFLUENCE OF NITROGEN FERTILIZATION ON GROWTH, FLOWERING AND KEEPING QUALITY OF ALSTROEMERIA 'CARMEN' AND 'MARINA'

ABSTRACT

The study was conducted in Limuru from June to November, 1990, to investigate the influence of nitrogen fertilization on growth, flowering and keeping quality of Altroemeria `Carmen' and `Marina'.

The number of total shoots/M^2 increased significantly with application of nitrogen in `Carmen' but the increase was not significant in `Marina'.

The average fresh weight of `Carmen' flowering and vegetative shoots increased significantly with application of 117 kgN/ha. In `Marina', the average fresh weight of vegetative shoots increased slightly with nitrogen application but that of the flowering shoots increased significantly with application of 78 kgN/ha then decreased with higher nitrogen application.

The average length of `Carmen' vegetative and flowering shoots increased significantly with application of 156 and 117 kgN/ha, respectively. In `Marina' the average length of vegetative and flowering shoots increased with application of 39 and 78 kgN/ha, respectively, but higher nitrogen fertilization decreased it significantly.

The thickness of both vegetative and flowering shoots of 'Carmen' was not significantly affected by nitrogen application. The vegetative shoots of 'Marina' had a similar trend but flowering shoots from plants fertilized with 39kgN/ha were significantly thicker than those from other nitrogen treatments. Nitrogen fertilization did not influence the number of leaves on flowering and vegetative shoots in both 'Carmen' and 'Marina'.

The number of flowering shoots/M^2 increased significantly with nitrogen application in 'Carmen' but slightly in 'Marina'. The percent of flowering shoots in 'Carmen' increased significantly with nitrogen fertilization but in 'Marina', it was not affected. Nitrogen fertilization did not affect onset to flowering of either 'Carmen' or 'Marina'. However, the number of cymes per inflorescence increased slightly with application of 156 kgN/ha in 'Carmen' and 39 kgN/ha in 'Marina'.

Nitrogen concentration in leaves and stalks of both 'Carmen' and 'Marina' increased with increased nitrogen fertilization. It was highest in young leaves, intermediate in old leaves and lowest in stalks.

Leaf chlorophyll content of cutflowers after harvest, on seventh and fourteenth day in vase remained high with application of 156 and 117 kgN/ha in 'Carmen'and 'Marina', respectively. There was a more rapid leaf chlorophyll breakdown of cutflowers in both cultivars during the first week than the second week in the vase especially those from plants treated with high nitrogen levels.

The average number of days to complete leaf yellowing in both cultivars increased signficantly with nitrogen fertilization. The average number of days to half petal fall in `Carmen' increased significantly with nitrogen application, but in `Marina', it increased slightly.

In `Carmen', split nitrogen applications did not affect shoot growth, flowering, cutflower quality and keeping quality. However, `Marina' plants fertilized with most nitrogen levels had more leaves on flowering shoots when nitrogen was applied in four splits than two splits. `Marina' cutflowers from plants fertilized with 39 and 78 kgN/ha in four splits interval lasted longer before complete leaf yellowing in vase than those fertilized in two splits.

1.INTRODUCTION

Cutflower production has become increasingly important to both small and large scale growers in Kenya as a source of income from domestic and export markets (Chepkairor, 1986). In the last five years between 1986 and 1990, the volume of cutflowers exported increased by 42% while the value increased by 71.3%. In 1990 cutflowers constituted 29% by volume and 52% by value of the total horticultural produce exported from Kenya (Waithaka, 1990).

Horticultural industry forms a major branch of Kenyan economy and if well developed could become the leading foreign exchange earner (Anon, 1990). At present, horticultural produce for export is the fifth largest foreign exchange earner in Kenya after tourism, tea, coffee and petroleum products (Stevens, 1991). Horticultural industry has helped in the creation of employment, increasing farm income for better living in rural areas and also supplies the local requirements of horticultural produce (Mulwa, 1988; Zalenka, 1975).

Kenya is one of the leading cutflower exporting countries in the world. Today numerous cutflower producers in Kenya grow a wide range of cutflowers which include Alstroemeria, Anthurium, Carnations, Chrysanthemum, Euphorbia, Gladiolus, Liatris, Mollucela, Orchids, Ornithogolum, Roses, Statice, Stretitzia, Tuberose, etc.

Most of the Kenyan cutflowers are exported to Western European markets especially in Netherlands, Germany, England, etc. The demand for this produce is highest in these countries during winter season when cost of

production is excessively high due to supplementary heating and lighting. Kenya is well established in European cutflower markets but the market has attracted so many other countries that Kenya faces a stiff competition. For Kenya to maintain it's market share, production of high quality cutflowers is a prerequisite (Anon., 1990).

Alstroemeria cultivars and hybrids have become very important cutflowers in Kenya (Chepkairor and Waithaka, 1988), particularly to small scale growers due to their simple management practices, ease of growing outdoors, presence of a wide range of cultivars with wide assortment of colours and excellent keeping qualities. The main cultivars grown in Kenya by small scale growers are `Carmen', `Marina', `Pink Perfection' and `Yellow King'.

In Kenya Alstroemeria cultivars do well in Naivasha, Limuru and Kinangop areas where soil temperatures can be low enough to induce flowering. The main flowering period of Alstroemeria cultivars `Marina', `Pink Perfection' and `Yellow King' in Limuru is from May to November when ambient and soil temperatures are as low as 15°C but Alstroemeria cultivar `Carmen' can flower throughout the year.

Nitrogen fertilization has been reported to influence production of Alstroemeria cutflowers (Bik and Berg, 1981) and their keeping quality (Kiara, 1989). However, local small scale farmers lack the knowledge of the correct rate and frequency of topdressing nitrogen fertilizer for production of Alstroemeria cutflowers. The other most pressing problem is the premature leaf yellowing of Alstroemeria cutflowers before petal abscission.

For Alstroemeria to remain an important floricultural crop in Kenya, production of long lasting high quality cutflowers is essential. This study was therefore conducted to investigate the influence of nitrogen fertilizer on:-

1. growth and flowering of Alstroemeria `Carmen' and `Marina'.
2. keeping qualities of Alstroemeria `Carmen' and `Marina' cutflowers with emphasis on premature leaf yellowing.

2. LITRERATURE REVIEW

2.1 Alstroemeria

Alstroemeria is a herbaceous plant belonging to the family Alstroemeriaceae (Healy and Wilkins, 1985). It is believed to be a native of South America and is an inhabitant of a wide range of ecological zones varying from tropical Amazon area to 2,000 M high in Andes and some spices are found in Atacama desert (Verboom, 1980; Robinson, 1963).

Alstroemeria is mainly propagated by division of fleshy underground sympodial rhizomes with few attached shoots and roots (Horton and McNair, 1986; Verboom, 1980) or by tissue culture (Healy and Wilkins, 1985). The aerial shoots arise from an underground rhizome. The rhizome apex develops from an auxillary bud of the first scale leaf of the previous aerial shoot (Healy and Wilkins, 1985). The auxillary bud in the second scale leaf also has the potential to become a rhizome or an aerial shoot but other nodes up the stem lack auxillary buds. The aerial shoot can be vegetative or reproductive depending on previous environmental conditions (Healy and Wilkins, 1985; 1979).

The roots of Alstroemeria can be thin and fibrous, thick and fleshy or a combination (Healy and Wilkins, 1985; 1986). The parallel-veined leaf twists at the junction of the sheath and blade causing the leaf to be inverted 180°. The stomata which appear on the anatomical adaxial surface are likewise inverted (Priestly, 1935). Alstroemeria inflorescence is a whorl of simple and compound cymes which form a branched cluster of flowers at the top of the stem (Healy and Wilkins, 1985).

Growth and flowering of Alstroemeria is greatly influenced by environmental factors such as soil and air temperature and photoperiod. In Alstroemeria, formation of flowering shoots is induced by vernalization (Healy and Wilkins, 1982; 1981; 1979) and rhizomes are the site of cold perception (Healy and Wilkins, 1986; Heins and Wilkins, 1979). Cold treatment in Alstroemeria 'Regina' is an accumulative response and can be acquired over a period of time at some temperature below 20°C or rapidly at 5°C (Healy and Wilkins, 1982). Once rhizome of Alstroemeria `Regina' plants are induced to flower and flowering begins, it continues until rhizomes are exposed to non-inductive temperature near 15°C or above (Healy and Wilkins, 1986).

At soil temperatures of 5, 10 and 15°C, flowering of Alstroemeria `Regina' continued indefinitely regardless of air temperature and photoperiods but when plants were exposed to highier soil temperatures of 20 to 25 °C, formation of flowering shoots was inhibited (Healy and Wilkins, 1986; 1981; 1979). However, high soil temperature of 21°C stimulated high production of shoots which were mainly vegetative (Heins and Wilkins, 1979) when Alstroemeria `Regina' plants were transferred from 13 to 15, 20 or 25°C soil temperature, shoot production from rhizome reverted to vegetative condition (Healy and Wilkins, 1986). This reversion was more rapid at 25 than 20 or 15°C.

Alstroemeria plants require a thermophase followed by a photophase. Once plants are vernalized, rapid flowering depend on interaction of duration and intensity components of light (Healy and Wilkins, 1982). Alstroemeria `Regina'

plants exposed to longday (16hr) in form of night interruption flowered earlier than the ones under normal day (10hr) and shortday (8hr) conditions (Healy *et al.*, 1982; Healy and Wilkins, 1981; 1979). A longday exposure of Alstroemeria 'Regina' plants also promoted production of high number of flowering and total shoots (Heins and Wilkins, 1979). High light intensity was reported to hasten flowering of Alstroemeria 'Regina' by promoting development of visible bud to authesis (Heins and Wilkins, 1979).

2.2 Nitrogen Nutrition in Plants

Importance of nitrogen in plants is emphasized by the fact that it is the fourth most abundant element in living plants (Salisbury and Ross, 1978; Epistein, 1972). Nitrogen is the most required element by plants (FAO, 1973) and most limiting nutrient in plant growth (Huffuker and Rains, 1978; Janick, 1963). Nitrogen is the principle constituent of plants accounting for at least one half of the total number of ions absorbed by plants (Reisenauer, 1978).

The main constituents of nitrogen in plants include proteins, purines, pyrmidines, amino acids, nucleotides, coenzymes, chlorophyll (Epistein, 1972), two of the three major classes of plant hormones, auxins and cytokinins (Luckwill, 1967) and a variety of soluble compounds such as nitrate, nitrite, amides and ureides (Hewit and Smith, 1975). Plant proteins contain approximately 18% nitrogen and their synthesis is important for growth and plant biochemical processes (Epistein, 1972).

Nitrogen deficiency in plants has been reported to interfere with major biochemical processes involved in protein synthesis and therefore delays growth and reduces crop production (Salisbury and Ross, 1978; Huffuker and Rains, 1978; Epistein, 1972). As a result photosynthesis slows down due to lack of amino acids and machinery for carbohydrate and carbon skeleton for all organic synthesis (Epistein, 1972).

An early and dramatic symptom of nitrogen deficiency in plants is the general yellowing of leaves due to inhibition of chlorophyll synthesis (Salisbury and Ross, 1978; Hewit and Smith, 1975). Lower leaves are affected first because nitrogen is translocated from old mature leaves to young actively growing leaves or inflorescence at stem apex (Woodson, *et al.*, 1984; Epistein, 1972). Plants also show unthrifty spindly appearance, prolonged dormancy, delayed swelling of buds, reduction in size of all morphological parts, reduced cell division and expansion, repression of apical meristems associated with secondary axes and lateral buds leading to growth of unbranched single stem, premature plant senescence (Hewit and Smith, 1975) and premature leaf abscission (Salisbury and Ross, 1978).

Plants grown in excess nitrogen usually have high vegetative growth (Janick, 1963), dark green leaves and show abundant foliage with poor root growth and retarded flowering (Salisbury and Ross, 1978).

2.3 Nitrogen Uptake and Metabolism in Plants

Plants can absorb available nitrogen in form of anionic ion, NO_3^- or cationic ion, NH_4^+ depending on their

availability in the soil. In most well aerated soils, NO_3^- is the principle form of nitrogen available (Epistein, 1972) and therefore the form most readily taken up by plants (Salisbury and Ross, 1978; Huffuker and Rains, 1978). In warm moist soils with neutral P^H, NO_3^- is more available to plants because NH_4^+ is rapidly oxidized by nitrifying bacteria to NO_3^- after fertilizer addition (Salisbury and Ross, 1979; Janick, 1963), NO_3^- is in high concentration in soil than NH_4^+ and it is readily mobile in soil by massflow and diffusion to root region (Reisenauer, 1978).

After NO_3^- is absorbed, it maybe reduced in roots, translocated to the shoot (Reisenauer, 1978) or a significant amount maybe stored in the roots (Huffuker and Rains, 1978). Most plant species can reduce NO_3^- in both roots and leaves but the proportion reduced differ with species. Reduction of NO_3^- in either roots or leaves is altered markedly by increasing ambient NO_3^- level or changes in light regime (Rao and Rains, 1976) and root temperature (Salisbury and Ross, 1978). NH_4^+ in roots arising from absorption or reduction of NO_3^- is converted by reductive amination of α-Ketoglutarate to glutamate and by enzymatic synthesis to glutamine and asparagine (Goodwin and Mercer, 1972). These two amino acids are translocated rapidly to the top where they are readily utilized for protein synthesis (Cox and Reisenauer, 1977).

Usually some NH_4^+ is available in soil for plant use and it is absorbed rapidly. NH_4^+ is more efficiently used within the plant than NO_3^- and is less subject to loss

through leaching and volatilization in soil (Reisenauer, 1978). Addition of NH_4^+ to wheat treatment culture containing adequate NO_3^- improved growth and yield more than the culture containing NO_3^- only (Cox and Reisenauer, 1973). The large improvement in growth and yield due to supply of NH_4^+ source of nitrogen is attributed to energy saving of NH_4^+ assimilation in comparison to NO_3^- which requires energy dependent reduction process (Hardy and Havelka, 1975), better P^H control in rhizosphere and improved availability of phosphorus and micronutrients (Lewis, 1986).

Plants that are well adapted to aerated soil take mainly NO_3^- form of nitrogen but can also take NH_4^+ form. When NH_4^+ is the principle ion supplying nitrogen, these plants suffer various impairments (Cox and Seeley, 1984; Cox and Reisenauer, 1973; Barker, *et al.*, 1966). NH_4^+ assimilation is usually rapid and rarely accumulate in tissues before it is converted into amide (Salisbury and Ross, 1978; Reisenauer, 1978; Epistein, 1972).

Absorption of NO_3^- ion is favoured by high soil acidity while that of NH_4^+ ion increases with high soil P^H (Fried *et al.*, 1965). NO_3^- acquisition is also influenced by morphology of root system, effect of microclimate on plant transpiration such as relative humidity, plant metabolism, temperature and aerobic condition of root media (Huffuker and Rains, 1978), light and NO_3^- concentration in the media (Rao and Rains, 1976) and the level of carbon dioxide (Swader *et al.*, 1975). Other ions in the root medium such as calcium (Minotti *et al.*, 1969) and potassium (Ravein and Smith, 1976) increases NO_3^-

uptake while NH_4^+ inhibits it (Cox and Reisenauer, 1977; Rao and Rains, 1976).

NH_4^+ uptake and utilization is high in young plants with abundant carbohydrate supply and high growth rate than old plants with low carbohydrate supply due to high growth of rootsystem and high level of carboxylates for complexing with NH_4^+ without interfering with catio-chelate sink and causing NH_4^+ toxicity (Lewis, 1986; Reisenauer, 1978).

2.4 Effect of Nitrogen Fertilization on Growth and Flowering of Cutflowers

Several authors have reported that nitrogen fertilization affect growth and flowering of cutflowers. In greenhouse rose cultivar `Carol', the yield and fresh weight of cutflowers increased with nitrogen fertilization (Bik, 1972). A similar trend was observed in roses grown on partially weathered scoria media (Feigin *et al.*, 1980). Nitrogen supply of 100, 200 and 300 ppm produced an average of 232, 274 and 283 cutflowers per M^2 and the corresponding cutflowers average fresh weight was 8.25, 9.72 and 9.93 kg per M^2, respectively. Quality of cutflowers was not affected by nitrogen fertilization.

In orchid genera Minicymbidium high nitrogen supply from 4 to 8mMol per litre increased shoot formation and spike production but delayed flowering (Bik and Berg, 1983). The Spike length and fresh weight, the spike-shoot ratio and flower initiation decreased significantly with high nitrogen supply. However, continuous nitrogen supply was superior for shoot production but inferior than nitrogen withdraw during May and June period for spike

production, spike-shoot ratio and early flowering.

Bik and Berg (1981) observed that nitrogen fertilization greatly influenced growth and flowering of Alstroemeria grown on peat culture. The number of flowering shoots per plant and the number of flowers per flowering shoot increased with nitrogen fertilization. The optimum number of flowering shoots per plant in both `Carmen'and `Orchid' in the first crop was attained at 300 mgN per pot per week but the most favourable level for cultivar `Orchid' in the second crop was 220 mgN per pot per week. The length of flowering stems decreased with high nitrogen levels in the first crop but there was no effect in the second crop. The Fresh weight of flowering shoots increased only in the second crop and the most favourable nitrogen level was 300 mg per pot per week for cultivar `Orchid' and 220 mg per pot per week for cultivar `Carmen'. Flower production for the second crop was lower than the first crop and this was attributed to high temperatures in early months of the second crop.

In a study conducted on Alstroemeria cultivar `Marina' grown in the field, Kiara (1989) observed that the number of total shoots, flowering shoots and vegetative shoots per hill increased with high nitrogen levels though the percent of flowering shoots per hill was not affected. The fresh weight and the length of flowering shoots increased with application of 156 kgN per ha then decreased with higher nitrogen level. The number of leaves on both flowering and vegetative shoots decreased with high nitrogen levels but the leaf area increased. Flowering was slightly delayed by high nitrogen levels but the number of cymes per inflorescence was not affected.

Kiara (1989), further observed that split nitrogen application was more superior than single application in the production of flowering shoots but split nitrogen application did not affect other growth and flowering parameters. Optimum number of flowering shoots per hill was produced by plants receiving 78 kgN per ha in four-split applications at two weeks interval and 156 kgN per ha in two-split applications at four weeks interval.

Foliar nitrogen content is an indication of the amount of nitrogen in foliage and is likely influenced by the number of shoots the plant produces (Armitage and Tsujta, 1979b). Foliar nitrogen has been used as a quality measure in greenhouse roses (Bik, 1972) and a range of 3.0-5.0% N in young leaves at flowering stage was recommended.

Foliar nitrogen increased with high nitrogen levels in Minicymbidium (Bik and Berg, 1983) and gave a good linear relationship with the shoot production but a negative linear relationship with the spike-shoot ratio. In *Chrysanthemum morifolium* cultivar `Balcombe perfection', the best response to nitrogen fertilization evaluated in soluble nitrogen basis was found in petioles and blades and it was lowest in stems. Upper parts of stem reflected a better nutrient status of the plant than the lower parts (Komosa, 1981).

Bik and Berg (1981) reported that foliar nitrogen content increased with high nitrogen fertilization in Alstroemeria. Nitrogen content of eight upper leaves was higher in `Orchid' than `Carmen'. The best nitrogen level in the second crop of 220 mg per pot per week for `Orchid'

and 300 mg per pot per week for `Carmen' gave foliar nitrogen content of 4.9% and 5.14%, respectively (Bik and Berg, 1981).

2.5 Effect of Nitrogen Fertilization on Cutflower Vaselife

Nitrogen fertilization is known to influence cutflower keeping quality. Bik, (1972), reported that the vaselife of greenhouse rose cultivar `Carol' increased with high tissue nitrogen concentration. The keeping quality of rose `Forever Yours' improved with increased nitrogen supply from 100 to 200 ppm but higher level of 400 ppm had no extra improvement (Armitage and Tsujta, 1979b).

The vaselife of Alstroemeria `Marina' cutflowers improved significantly with nitrogen fertilization (Kiara, 1989). Cutflowers harvested four weeks after nitrogen application kept longer than those harvested one week after nitrogen application. Petal abscission occurred after 13.3, 15.0, 16.7 and 18.3 days when nitrogen was applied at levels 0, 78, 156 and 234 kg/ha, respectively, one week before cutflowers were harvested. However, at corresponding nitrogen levels, petals abscissed 14.0, 18.3, 19.7 and 20.0 days later after cutflowers were harvested four weeks after nitrogen application. High nitrogen fertilization also delayed foliage yellowing and cutflowers harvested four weeks after nitrogen application remained with green foliage longer than those harvested one week after nitrogen application.

2.6 Leaf Senescence

Senescence process is the final phase in development that leads to cellular breakdown and death of an organism or part of it. The first sign of leaf senescence is yellowing due to chlorophyll breakdown which exposes other leaf pigments particularly the Xanthophylls and carotenoids (Wareign and Phillips, 1970). Chlorophyll breakdown in the course of maturation and senescence is accompanied by a decline in both RNA and proteins in the leaf tissue (Fletcher and Adedipe, 1970; Osborne, 1967; Fletcher and Osborne, 1966).

Proteins in the leaf cells are in dynamic state of continuous degradation into amino acids and resynthesis (Sexton and Woolhouse, 1984; Thomas, 1982; Wollgiehn, 1967). A decline in leaf protein that accompanies senescence results from fall in protein synthesis due to reduced RNA synthesis from functional DNA template (Osborne, 1967; 1962), limitation of amino acid precursors as they are rapidly translocated away from the leaf to young organs at the shoot apex (Wollgiehn, 1967; Leopold and Kawase, 1964) or increased proteolysis (Thimann *et al.*, 1982; Martin and Thimann, 1972; Thimann *et al.*, 1970).

Nitrogen nutrition has been reported to influence senescence by affecting the level of phytohormones in plants. In seven weeks old sunflower plants (Goldbach *et al.*, 1975) and young tomato plants (Daie *et al.*, 1979), nitrogen deficiency increased the level of endogenous Abscisic acid (ABA) content more than in plants grown in normal nitrogen nutrition. In both cases ABA level increased more in old mature leaves than in young leaves.

Nitrogen deficiency has also been observed to reduce formation of cytokinin in roots and it's subsequent translocation to the shoot in young potato plants (Sattelmacher and Marschner, 1978a; 1978b). In fourty days old tomato plants, nitrogen deficiency led to disappearance of Gibberellic acid (GA) activity and increased the level of inhibitors in shoot apexes (Rajagophal and Rao, 1972).

ABA is known to accelerate leaf senescence in a number of plant species. Application of ABA at concentration of 250μM reduced chlorophyll content and accelerated protein degradation in detached oat leaves more than the control (Thimann *et al.*, 1982). ABA inhibited RNA and protein synthesis from their precursors in radish leaf discs (Parajothy and Wareign, 1971) while it reduced chlorophyll retention and protein synthesis in xanthium leaf discs (Osborne, 1967).

The highest level of endogenous ABA in detached lettuce head (Aharoni and Richmond, 1978) and in detached oat leaves (Gapstein and Thimann, 1980) corresponded to the rapid chlorophyll loss phase. In detached tobacco leaves ABA level is parallel to the onset and rate of senescence and therefore Even-chen and Itai (1975), suggested that ABA is important in induction and continuation of tobacco leaf senescence.

Ethylene (C_2H_4) is known to accelerate leaf and flower senescence. Application of ethephon on detached lettuce head caused more chlorophyll breakdown, disappearance of GA and increased ABA level than the control (Aharoni and Richmond, 1978). In rose petals, C_2H_4 triggered ABA

production that resulted in reduced flower longevity (Halevy and Mayak, 1973; Mayak *et al.*, 1972). In Sugar beet and tobacco leaf discs, a sharp rise in C_2H_4 production was accompanied by a rapid chlorophyll loss phase and an increased respiration rate (Aharoni and Lieberman, 1979a; 1979b). In tobacco leaf discs low endogenous C_2H_4 level in association with low level of auxins, GA and cytokinins was the cause of senescence (Aharoni and Lieberman, 1979b).

Among the growth promoters, only GAs and cytokinins are known to delay leaf senescence in herbaceous plants while auxins are important in deciduous woody plants (Wareign and Phillips, 1970; Osborne, 1967). Delay of leaf senescence on application of GAs and cytokinins is associated with their endogenous deficiency in plants (Fletcher and Adedipe, 1970). Infact 'chrysal SVB', a chemical used commercially to delay leaf yellowing in Alstroemeria, Lily and Euphorbia cutflowers is a constituent of GA and cytokinin (Hoffman, 1988).

Application of GA is known to delay leaf senescence in *Taraxacum officinale* (Fletcher and Osborne, 1966), *Taraxacum megalorrhizon*, *Tropaeolum majus* (Back and Richmond, 1969) and detached lettuce leaves (Aharoni and Richmond, 1978). GA effect on delaying leaf senescence is associated with DNA dependent RNA and protein synthesis (Fletcher and Osborne, 1966). GA also prevented rise of endogenous ABA level in detached lettuce leaves (Aharoni and Richmond, 1978).

Cytokinins are widely known to postpone leaf senescence. Application of Benzyladenine (BA) on intact

mature primary bean leaf caused chlorophyll retention and increased protein and RNA level than in the opposite control primary leaf (Fletcher, 1969). This was due to mobilization of assimilates (Leopold and Kawase, 1964), increased photosynthesis and retention of photosynthates on treated leaf (Fletcher and Adedipe, 1970).

Kinetin treatment on detached xanthium leaves increased leaf lifespan (Richmond and Lang, 1957) while it increased protein and RNA synthesis in radish leaf discs (Parajothy and Wareign, 1971). In detached oat leaves, kinetin retarded senescence by delaying proteolysis (Thimann *et al.*, 1982; Martin and Thimann, 1972). The effect of kinetin in retarding leaf senescence is accompanied by stimulation of protein synthesis by enhancing RNA transcription from DNA template (Osborne, 1967).

Kinetin is also known to reduce C_2H_4 production (Paulin and Muloway, 1979), cellular respiration and sensitivity of carnation flower to C_2H_4 (Nichols, 1979). Kinetin nullified the effect of ABA in enhancing leaf senescence in *Rumex obtusifolis* and *Taraxacum officinale* (Back and Richmond, 1971) and prevented ABA rise in lettuce leaves (Aharoni and Richmond, 1978). Kinetin also inactivated endogenous ABA by enhancing ABA binding and metabolism in tobacco leaves (Even-Chen and Itai, 1975). In lettuce leaves, kinetin delayed senescence through maintenance of high GA level in the tissue by reducing the level of bound GA (Aharoni and Richmond, 1978).

Nitrogen nutrition may influence leaf senescence process by affecting the leaf chlorophyll content

(Salisbury and Ross, 1978; Sheehani and Nell, 1979; Hewit and Smith, 1975; Epistein, 1972) or phytohormone balance in plant tissues (Daie *et al.*, 1979; Sattelmacher and Marschner, 1978a; 1978b; Goldbach, *et al.*, 1975; Rajagophal and Rao, 1972).

3. MATERIALS AND METHODS

3.1 Site

The study was carried out at Agricultural Development Corporation (ADC), Updown farm in Limuru.

Limuru experiences bimodal rainfall. Long rain falls from March to June while short rain falls from October to December. Annual rainfall ranges from 900 to 1000 mm.

Limuru is a cool area. The mean maximum day temperature is about 20.0°C while mean minimum day temperature is about 10.1°C. The period between June and October is cool, cloudy and dry while the period between December and Mid-March is dry and warm.

Soils in Limuru are dark reddish brown to dark red in colour, friable clay structure, have good water retaining capacity and are well drained (Humic nitosols) (Anon., 1987).

3.2 Plant Material

Uniform plants of two year old Alstroemeria 'Marina' and one year old Alstroemeria 'Carmen' grown on separate adjacent fields were used for the study. The plants were grown in a single row at the middle of 1M wide raised bed. Within beds there were three plants per M^2 and beds were spaced 0.5M apart. Each experimental field consisted of five rows of which three inner rows were used for data collection while the outer ones acted as guard rows.

Plants were cut at ground level in Mid-May and early June for Alstroemeria 'Marina' and 'Carmen', respectively, to stimulate new shoot growth for next season crop.

Excessive sideways growth of underground rhizomes was reduced into a uniform thin row at the middle of raised bed by use of hand hoe. New shoots were allowed to grow until the ninth week in 'Carmen' and twelfth week in 'Marina' when excessive vegetative shoots and weak shoots were thinned out while maintaining uniformity among the plants. Thereafter, thinning was continued at two weeks interval.

Alstroemeria 'Carmen' grew without support while in Alstroemeria 'Marina', the crop was supported at 60 cm height by use of wirelines crosslinked with bamboo sticks. This allowed production of straight stems. Fields were maintained weedfree by doing hand weeding when deemed necessary.

Fields were irrigated using hose-pipe (flood irrigation system) or sprinkle irrigation when it was dry. Pests such as aphids which are prevalent in wet season were controlled by alternate sprays of Thiodan (1 c.c./*l*) and Ambush (1 c.c./*l*) when infection signs were noticed.

3.3. Plant Culture

N.P.K. fertilizer in form of 20:10:10 and agricultural lime, magmax, were spread around the plants on the raised beds at the rate of $10g/M^2$ and $100g/M^2$ respectively and then incorporated in the soil by use of hand hoe in the fifth week in 'Carmen' field and eighth week in 'Marina' field after the crop was cut at ground level. N.P.K. fertilizer allowed adequate crop growth before the start of nitrogen treatments eight weeks later while agricultural lime maintained the soil slightly acidic.

3.4 Experimental Design

Two separate experiments for Alstroemeria 'Carmen' and 'Marina' were laid down on a split-plot design and replicated three times. Split nitrogen application at two levels comprised the main plots while nitrogen rate comprised the subplots. Five nitrogen levels in form of calcium ammonium nitrate (26% N) were considered as follows:- 0, 39, 78, 117 and 156 kgN/ha. Nitrogen fertilizer was applied in four split applications at two weeks interval and in two split applications at four weeks interval. Main plots were allocated randomly in each block after which subplots were randomly allocated within main plots.

Each main plot measured 13.5M long and 1M wide while subplots measured 2.7M long and 1M wide. Data was collected from four inner hills in each subplot. Two hills (i.e. 0.6M) on either side of the subplot acted as guard plants.

3.5 Data Collection

Data on plants except the date of flowering was collected once between the third and fifth week after the last nitrogen application.

3.5.1 Data on plants in the field included: The total number of shoots and number of flowering shoots per M^2, percentage of flowering shoots and number of days to flowering. Number of days to flowering was based on an average of five flowering shoots when 1-5 flowers had opened.

3.5.2 Shoot growth characteristics: Data on mean fresh weight, length, diameter and number of leaves per stem of five flowering and five vegetative shoots harvested at random were determined. Shoot length and fresh weight were measured from soil line position to the apex of the shoot. Shoot diameter was measured at the second internode from the soil line. In addition mean number of cymes per inflorescence was determined as an average of five flowering shoots.

3.5.3 Tissue nitrogen concentration: Six flowering shoots at `rolled petal stage' and six mature vegetative shoot were harvested at random from each plot for nitrogen analysis. Nitrogen concentration was analysed for young leaves above and old leaves below the middle of the shoot and the stalks of both flowering and vegetative shoots.

Nitrogen concentration (%) was analysed by Kjeldahl method according to Association of American Analytical Chemist (A.O.A.C.), 1984.

3.5.4. Leaf chlorophyll content during vaselife: Cutflowers were harvested at random from each plot at `rolled petal stage' and were transported to Kabete within two hours. In the laboratory, Alstroemeria `Carmen' and `Marina' cutflowers were recut at 50cm and 60 cm long, respectively. Lower leaves were removed upto 15cm long to avoid contamination of vase-solution and then dipped in distilled water containing 4 *ml/l* of 10% sodium hypochlorite as a desinfectant. Vase-solution was changed after every seven days. All cutflowers were kept under similar conditions at room temperature of 18.5-21°C, 65-84% relative humidity and continous lighting with

fluorescent light. The laboratory was maintained free of any contaminant such as old plant material, smoke and dust.

Chlorophyll content of the eight lower leaves from five cutflowers was determined after harvest (day 0), at seventh and fourteenth day during vaselife according to A.O.A.C. (1984).

3.5.5. Cutflower vaselife: Five cutflowers were harvested from each plot at `rolled petal stage' and prepared to be put in vase-solution as in the case of chlorophyll analysis. Data was collected on average number of days to half petal fall and complete leaf yellowing.

3.5.6. Soil sampling and analysis: Five soil samples at depth of 0-30 cm were taken at random from each of the two separate fields of Alstroemeria 'Carmen' and 'Marina' before the start of nitrogen treatment. Soil samples were analysed in laboratory for total nitrogen (excluding nitrite and nitrate) and organic carbon. Soil P^H was determined both in water and 1M $CaCl_2$ salt at soil-solvent ratio of 1:2.5 according to methods used in the Department of Soil Science, University of Nairobi (Ahn, 1975). Results of soil analysis are in Appendix B.

3.5.7 Meteorological data: Data on rainfall, mean maximum, mean minimum and mean temperature for each month during experimentation was taken from a nearby National Potato Research Station in Tigoni. Data is presented in Appendix A.

3.6 Data Analysis

Data was subjected to analysis of variance (ANOVA) according to Steel and Torrie (1960). The effect of nitrogen level and application frequency was presented in tables or graphs. Means due to nitrogen fertilization rate were separated by Duncan's New Multiple Range Test (DNMR) while least significant difference (LSD) was used to compare split nitrogen application levels within nitrogen rate (Little and Hill, 1978).

4.RESULTS

4.1 The Effect of Nitrogen Fertilization on Alstroemeria Growth

Nitrogen fertilization significantly increased the number of the total shoots (flowering and vegetative)/ M^2 in 'Carmen'. The number of total shoots/M^2 of plants topdressed with nitrogen was significantly greater than the control but there was no significant difference among the plants topdressed with various levels of nitrogen (Table 1a). There was significant interaction between nitrogen rate and split nitrogen application in total number of shoots/M^2 of 'Carmen'. The difference in total number of shoots/M^2 in 'Carmen' plants was significantly greater between plants topdressed with 39 and 78 kgN/ha and between those topdressed with 117 and 156kgN/ha when nitrogen was applied in four splits at two weeks interval than when it was applied in two splits at four weeks interval. In 'Marina' the number of total shoots/M^2 increased with increased nitrogen fertilization but it was not significant at 5% level (Table 1b). The total number of shoots/M^2 were 809, 857, 861, 870 and 876 for 'Carmen' and 610, 617, 630, 674 and 754 for 'Marina' for the control and those plants fertilized with 39, 78, 117 and 156 kgN/ha, respectively.

The mean fresh weight of vegetative shoot of 'Carmen' increased with nitrogen topdressing upto 117 kgN/ha then decreased at 156 kgN/ha. Mean fresh weight of vegetative shoots was not significantly different among the three highest nitrogen levels, between 39 and 78 kgN/ha and between the control and plants fertilized with 39 kgN/ha (Table 1a). Nitrogen topdressing did not affect mean fresh

Table 1a: Effect of nitrogen fertilization on growth of Alstroemeria 'Carmen' shoot.

Growth parameter	Nitrogen level (KgN/ha)				
	0	39	78	117	156
	z				
Total no. of shoots per M^2	809 b	875 a	861 a	870 a	876 a
Mean fresh weight (gm) of vegetative shoots	9.0 c	10.9 bc	12.6 ab	13.8 a	13.3 a
Mean fresh weight (gm) of flowering shoots	18.5 c	20.4 bc	23.7 ab	25.9 a	25.3 a
Mean length (cm) of vegetative shoots	33.9 b	41.1 a	44.3 a	46.0 a	47.4 a
Mean length (cm) of flowering shoots	49.3 b	54.9 ab	58.7 a	61.2 a	58.3 a
Mean diameter (cm) of vegetative shoots	0.413a	0.435 a	0.474 a	0.498 a	0.468 a
Mean diameter (cm) of flowering shoots	0.643a	0.669 a	0.721 a	0.715a	0.705 a
Mean no. of leaves on vegetative shoots	37.7a	38.2 a	40.8 a	42.1 a	39.3 a
Mean no. of leaves on flowering shoots	23.2a	21.5 b	22.7 a	22.8 a	22.8 a

Z - Mean separation within rows by Duncan's New Multiple Range Test, 5% level.

Table 1b: Effect of nitrogen fertilization on growth of Alstroemeria 'Marina' shoot.

Growth parameter	Nitrogen level (KgN/ha)				
	0	39	78	117	156
	z				
Total no. of shoots per M^2	610 a	617 a	630 a	674 a	754a
Mean fresh weight (gm) of vegetative shoots	37.8 a	46.0 a	39.8 a	44.3a	41.8a
Mean fresh weight (gm) of flowering shoots	76.9 b	83.8 ab	96.3 a	89.3a	76.7b
Mean length (cm) of vegetative shoots	83.4 b	93.3 a	88.5 ab	93.3a	87.8b
Mean length (cm) of flowering shoots	117.0 b	122.2 b	134.3 a	126.2ab	118.5b
Mean diameter (cm) of vegetative shoots	0.619 a	0.645 a	0.638 a	0.651a	0.631a
Mean diameter (cm) of flowering shoots	0.895 b	0.917 a	0.892 b	0.894b	0.845b
Mean no. of leaves on vegetative shoots	57.8 a	57.1 a	55.3 a	57.5a	55.4a
Mean no. of leaves on flowering shoots	45.8 a	44.6 a	46.2 a	43.8a	46.4a

Z - Mean separation within rows by Duncan's New Multiple Range Test, 5% level.

weight of 'Marina' vegetative shoot significantly but it increased slightly with the application of 39 kgN/ha then decreased with increased nitrogen application (Table 1b).

Mean fresh weight of flowering shoots of both cultivars increased significantly with increased nitrogen application upto 117 and 78 kgN/ha in 'Carmen' and 'Marina', respectively (Table 1a and 1b). For 'Carmen' there was no significant difference in mean fresh weight of the flowering shoots among the three highest nitrogen applications, between 39 and 78 kgN/ha and between the control and plants fertilized with 39 kgN/ha. In 'Marina' the mean fresh weight of the flowering shoots was significantly lower in plants topdressed with 156 kgN/ha and the control than those fertilized with 78 and 117 kgN/ha. The mean fresh weight of the flowering shoots were 18.5, 20.4, 23.7, 25.9 and 25.3g for 'Carmen' and 76.9, 83.8, 96.3, 89.3 and 76.7g for 'Marina' for the control and those plants fertilized with 39, 78, 117 and 156 kgN/ha, respectively.

Nitrogen topdressing significantly increased the mean length of vegetative shoots in both 'Carmen' and 'Marina'. The length of vegetative shoots of 'Carmen' consistently increased with every increase in nitrogen fertilization. Nitrogen topdressed plants produced significantly longer vegetative shoots than the control but there was no signficant differences among plants topdressed with nitrogen (Table 1a). In 'Marina', the length of vegetative shoots in the control and plants fertilized with 156kgN/ha were significantly shorter gthan those topdressed with 39 and 117 kgN/ha. However, there was no significant difference in the length of vegetative shoots between

plants topdressed with 78 kgN/ha and other nitrogen treatments (Table 1b).

The mean length of flowering shoots significantly increased with nitrogen application of 117 kg/ha in `Carmen' and 78 kgN/ha in `Marina' then decreased with higher nitrogen levels (Tables 1a and 1b). In `Carmen', flowering shoots from the plots topdressed with the three highest nitrogen levels were significantly longer than the control but there was no significant difference between the control and those topdressed with 39 kgN/ha and among plants topdressed with nitrogen. In `Marina' flowering shoots topdressed with 78 kgN/ha were significantly longer than the control and those fertilized with 39 and 156 kgN/ha but were not significantly different with flowering shoots from plants topdressed with 117 kgN/ha. The mean length of flowering shoots were 49.3, 54.9, 58.7, 61.2 and 58.3 cm for `Carmen' and 111.0, 122.2, 134.3 126.2 and 118.5 cm for `Marina' for the control and plants fertilized with 39, 78, 117 and 156 kgN/ha, respectively.

The mean diameter of vegetative shoots was not significantly affected by nitrogen application in both `Carmen' and `Marina'. However, it increased slightly with increased nitrogen application upto 117 kgN/ha then decreased with application of 156 kgN/ha in both cultivars (Table 1a and 1b). A similar trend occured for `Carmen' mean diameter of the flowering shoots but the highest mean shoot diameter was achieved in plants topdressed with 78 kgN/ha (Table 1a). The mean diameter of `Marina' flowering shoot increased significantly with nitrogen topdressing of 39 kgN/ha then decreased with increased nitrogen application. `Marina' plants fertilized with 39 kgN/ha had

significantly thicker flowering shoots than plants treated with other nitrogen levels (Table 1b).

The mean number of leaves on both 'Carmen' and 'Marina' vegetative shoots was not affected by nitrogen application (Table 1a and 1b). In 'Carmen', mean number of leaves on the flowering shoots was significantly lower at 39 kgN/ha than in other nitrogen treatments (Table 1a). In 'Marina' nitrogen application level had no effect on the number of leaves on flowering shoots (Table 1b) but there was significant interaction between nitrogen rate and split applications. No consistent trend was observed on both 'Carmen' and 'Marina' number of leaves per stem due to nitrogen topdressing.

4.2 Effect of Nitrogen Fertilization on Flowering of Alstroemeria

The number of flowering shoots/M^2 in 'Carmen' and 'Marina' increased with the application of high nitrogen levels. In 'Carmen' the number of flowering shoots/M^2 were significantly higher in plots topdressed with nitrogen than the control plots but in 'Marina', there was no significant difference due to nitrogen topdressing (Table 2a and 2b). The number of flowering shoots/M^2 were 394, 454, 477, 490 and 507 for 'Carmen' and 400, 429, 400, 457 and 491 for 'Marina' in the control and those plots fertilized with 39, 78, 117 and 156 kgN/ha, respectively.

The percentage flowering shoots of the total number of shoots, increased significantly with increased nitrogen levels in 'Carmen' (Table 2a). There was no significant difference in percentage of flowering shoots among three highest nitrogen levels, between the control and at 39

Table 2a: Effect of nitrogen fertilisation on Alstroemeria 'Carmen' flowering.

Flowering parameter	Nitrogen level (KgN/ha)				
	0	39	78	117	156
No. of flowering shoots per M^2	394b[z]	454a	477a	490a	507a
% flowering shoots of total shoot	48.6c	53.0bc	55.4ab	56.3ab	57.8a
No. of days to onset of flowering	138.7a	137.7a	134.8a	137.2a	139.4a
No. of cymes per inflorescence	3.7a	3.8a	3.9a	4.0a	4.1a

Z- Mean separation within rows by Duncan's New Multiple Range Test, 5% level.

Table 2b: Effect of nitrogen fertilization on Alstroemeria 'Marina' flowering.

Flowering parameter	Nitrogen level (KgN/ha)				
	0	39	78	117	156
No. of flowering shoots per M^2	400a[z]	429a	400a	457a	491a
% flowering shoots of total shoot	65.9a	63.3a	66.4a	69.0a	65.8a
No. of days to onset of flowering	184.2a	178.2a	175.7a	178.6a	180.5a
No. of cymes per inflorescence	5.4a	5.9a	5.7a	5.8a	5.4a

Z- Mean separation within rows by Duncan's New Multiple Range Test, 5% level.

Table 5: Effect of nitrogen application frequency on Alstroemeria 'Carmen' growth.

Growth parameter	Frequency of nitrogen application	Nitrogen level (kgN/ha)					W $LSD_{(0.05)}$
		0	39	78	117	156	
		Z					
Total no. of shoots/M^2	1	802a	829a	851a	855a	828a	
	2	817b	884a	871a	885a	924a	243.5
Vegetative shoot mean fresh weight (g)	1	8.3b	10.8ab	11.9a	14.2a	12.9a	
	2	9.7b	11.0ab	13.3a	13.4a	13.6a	3.1
Flowering shoot mean fresh weight (g)	1	17.7c	20.6bc	22.7abc	26.6a	24.8ab	
	2	19.3c	20.3bc	24.7ab	25.3ab	25.7a	5.1
Vegetative shoot mean length (cm)	1	32.0b	41.7a	40.5ab	48.8a	46.3a	
	2	35.9b	40.4ab	48.1a	43.2ab	48.4a	10.4
Flowering shoot mean length (cm)	1	46.4b	54.5ab	55.8a	62.6a	58.3a	
	2	51.8a	55.3a	61.5a	59.8a	58.2a	9.3
Vegetative shoot mean diameter (cm)	1	0.400a	0.446a	0.485a	0.505a	0.451a	
	2	0.425a	0.424a	0.463a	0.491a	0.484a	0.275
Flowering shoot Mean diameter (cm)	1	0.626a	0.713a	0.710a	0.710a	0.728a	
	2	0.660a	0.624a	0.731a	0.719a	0.682a	0.977
Vegetative shoot mean Leaf no.	1	36.5a	35.6a	39.6a	41.4a	39.a	
	2	38.9a	40.8a	41.9a	42.8a	38.8a	5.4
Flowering shoot mean Leaf no	1	21.8ab	21.2b	22.4ab	22.5ab	23.1a	
	2	24.7a	21.9b	23.0b	23.0b	22.6b	3.5

Frequency 1 - application of nitrogen in two splits at four weeks interval

Frequency 2 - application of nitrogen in four splits at two weeks interval

Z - Mean separation within rows by Duncan's New Multiple Range Test, 5% level

W - $LSD_{(0.05)}$ between application frequency 1 and 2 within nitrogen level

Table 3a: The effect of nitrogen fertilization on nitrogen concentration in Alstroemeria 'Carmen' tissues.

Plant tissue nitrogen concentration (% N)	Nitrogen level (KgN/ha) 0	39	78	117	156
Young leaves of vegetative shoots	3.28b[Z]	3.30b	3.76a	3.79a	3.92a
Young leaves of flowering shoots	3.29c	3.38c	3.80b	3.87b	4.20a
Old leaves of vegetative shoots	2.60b	2.66b	3.04a	3.08a	3.30a
Old leaves of flowering shoots	2.93b	2.95b	3.28a	3.43a	3.50a
Vegetative stalks	0.81d	0.91cd	1.13bc	1.19ab	1.38a
Flowering stalks	0.82c	0.87c	1.08b	1.09b	1.28a

Z - Mean separation within rows by Duncan's New Multiple Range Test, 5% level.

Table 3b: The effect of nitrogen fertilization on nitrogen concentration in Alstroemeria 'Marina' tissues.

Plant tissue nitrogen concentration (% N)	Nitrogen level (KgN/ha) 0	39	78	117	156
Young leaves of vegetative shoots	2.70b[Z]	3.07ab	3.14ab	3.25a	3.34a
Young leaves of flowering shoots	2.97b	3.11ab	3.31ab	3.46a	3.52a
Old leaves of vegetative shoots	2.15c	2.75b	2.89ab	3.08ab	3.14a
Old leaves of flowering shoots	2.25b	2.92a	3.06a	3.40a	3.45a
Vegetative stalks	0.80a	0.80a	0.82a	0.82a	0.90a
Flowering stalks	0.76a	0.83a	0.86a	0.95a	0.99a

Z - Mean separation within rows by Duncan's New Multiple Range Test, 5% level.

level was increased (Table 3a and 3b). In `Carmen' the increase of nitrogen concentration in leaves and stalkswas significant but in `Marina', the increase was only statistically significant in leaves. In both Alstroemeria cultivars nitrogen concentration was highest in young leaves, intermediate in old leaves and lowest in the stalks at similar nitrogen fertilization levels (Table 3a and 3b).

Leaves of flowering shoots in both Alstroemeria `Carmen' and `Marina' had higher nitrogen concentration than those of vegetative shoots when treated with corresponding nitrogen levels. `Carmen' vegetative stalks had higher nitrogen concentration than that of flowering stalks at similar nitrogen fertilization levels except in the control but in `Marina' flowering stalks had higher nitrogen concentration than vegetative stalks at similar nitrogen fertilization levels except in the control (Table 3a and 3b).

`Carmen' maintained higher nitrogen concentration in leaves and stalks than `Marina' at similar nitrogen fertilization levels (Table 3a and 3b). Each increment of nitrogen fertilization had more distinct increase in nitrogen concentration of leaves and stalks in `Carmen' than in `Marina'.

4.4. Effect of Nitrogen Fertilization on Leaf Chlorophyll Content Of Alstroemeria Cutflowers during vaselife

Initial leaf chlorophyll content of cutflowers after harvest was significantly affected by nitrogen fertilization in both 'Carmen' and 'Marina'. In both cultivars, cutflower leaf chlorophyll content increased with increasing nitrogen level of 117 kgN/ha then decreased slightly at 156 kgN/ha. This was particularly visually evident in 'Carmen' where cutflowers from the control plots and those receiving 39 kgN/ha had pale green leaves while cutflowers from plots receiving three highest nitrogen levels had dark green leaves.

Leaves of 'Carmen' cutflowers from control plots had significantly lower chlorophyll content than cutflowers harvested from plots receiving three highest nitrogen levels. However, initial cutflower leaf chlorophyll content was not significantly different between the control and those treated with 39 kgN/ha and among plots topdressed with nitrogen (Table 4a). In 'Marina' three highest nitrogen levels produced cutflowers with significantly higher leaf chlorophyll content than the control and at 39 kgN/ha, although there was no significant difference on leaf chlorophyll content between control and at 39 kgN/ha and among three highest nitrogen levels (Table 4b). At similar nitrogen fertilization levels except the control, 'Carmen' cutflowers had higher initial leaf chlorophyll content than 'Marina' cutflowers.

The leaf chlorophyll content of 'Carmen' cutflowers remained significantly high with increased nitrogen fertilization on seventh day of cutflowers in vase.

Table 4a: Effect of nitrogen fertilization on the vaselife and leaf chlorophyll content of Alstroemeria 'Carmen' cutflowers in the vase.

Parameter	Nitrogen level (Kg N/ha)				
	0	39	78	117	156
No. of days to half petal fall	12.6c[z]	12.9bc	13.4ab	13.9a	14.0a
No. of days to complete leaf yellowing	7.5b	8.8b	11.1a	11.8a	12.3a
Leaf chlorophyll content (g/mg) at harvest	1.700b	2.003ab	2.379a	2.394a	2.382a
Leaf chlorophyll content (g/mg) on 7th day	0.336d	0.430cd	0.508bc	0.593ab	0.714a
Leaf chlorophyll content (g/mg) on 14th day.	0.184d	0.235cd	0.297bc	0.347ab	0.394a

Z - Mean separation within rows by Duncan's New Multiple Range Test, 5% level.

Table 4b: Effect of nitrogen fertilization on the vaselife and leaf chlorophyll content of Alstroemeria 'Marina' cutflowers in the vase.

Parameter	Nitrogen level (KgN/ha)				
	0	39	78	117	156
No. of days to half petal fall	11.3a[z]	12.1a	12.5a	12.8a	12.3a
No. of days to complete leaf yellowing	12.6b	13.5ab	13.5ab	13.6ab	14.2a
Leaf chlorophyll content (g/mg) at harvest	1.757b	1.832b	2.054a	2.076a	2.060a
Leaf chlorophyll content (g/mg) on 7th day	0.802a	0.869a	0.883a	0.887a	0.852a
Leaf chlorophyll content (g/mg) on 14th day.	0.516c	0.549bc	0.589ab	0.619a	0.608ab

Z - Mean separation within rows by Duncan's New Multiple Range Test, 5% level.

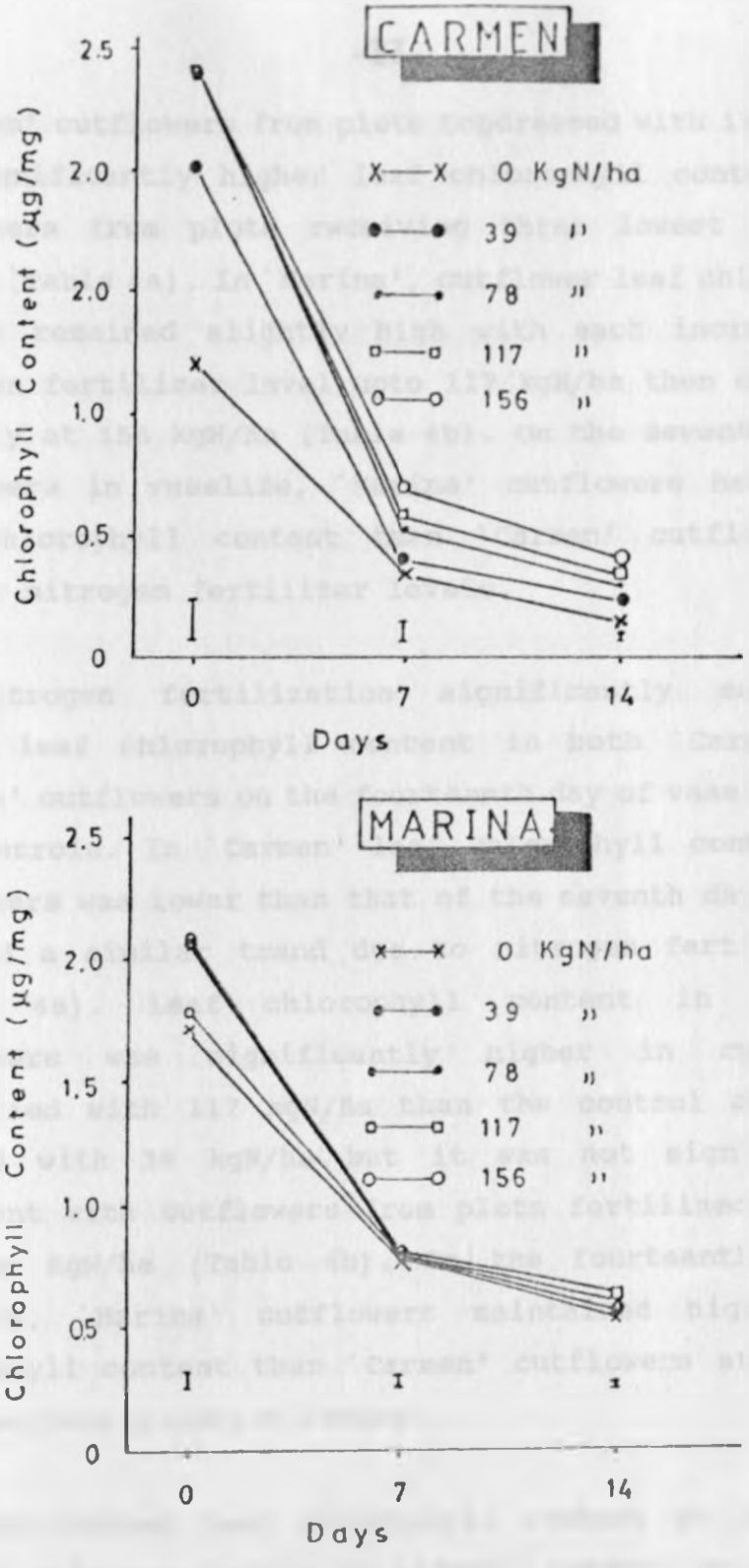

Fig 1: Effect of Nitrogen Fertilization on the leaf chlorophyll content of Alstroemeria Cutflowers in the vase. Vertical bars represent LSD at 5% level.

'Carmen' cutflowers from plots topdressed with 156 kgN/ha had significantly higher leaf chlorophyll content than cutflowers from plots receiving three lowest nitrogen levels.(Table 4a). In 'Marina', cutflower leaf chlorophyll content remained slightly high with each increment of nitrogen fertilizer level upto 117 kgN/ha then decreased slightly at 156 kgN/ha (Table 4b). On the seventh day of cutflowers in vaselife, 'Marina' cutflowers had higher leaf chlorophyll content than 'Carmen' cutflowers at similar nitrogen fertilizer levels.

Nitrogen fertilization significantly maintained higher leaf chlorophyll content in both 'Carmen' and 'Marina' cutflowers on the fourteenth day of vaselife than the controls. In 'Carmen' leaf chlorophyll content of cutflowers was lower than that of the seventh day in vase but had a similar trend due to nitrogen fertilization (Table 4a). Leaf chlorophyll content in 'Marina' cutflowers was significantly higher in cutflowers fertilized with 117 kgN/ha than the control and those treated with 39 kgN/ha but it was not significantly different with cutflowers from plots fertilized with 78 and 156 kgN/ha (Table 4b). On the fourteenth day of vaselife, 'Marina' cutflowers maintained higher leaf chlorophyll content than 'Carmen' cutflowers at similar nitrogen fertilization levels.

The initial leaf chlorophyll content at the three highest nitrogen levels in either 'Carmen' or 'Marina' cutflowers was almost the same. However, there was a more rapid fall in leaf chlorophyll content during the first week than the second week of cutflowers in the vase (Fig. 1). The fall of cutflowers leaf chlorophyll content was

more rapid at higher nitrogen levels than at low levels in both `Carmen' and `Marina' and it was more pronounced in `Carmen' than in `Marina' during their vaselife.

4.5 Effect of Nitrogen Fertilization on the Vaselife of Alstroemeria Cutflowers

Nitrogen topdressing significantly increased the number of days to complete leaf yellowing of both `Carmen' and `Marina' cutflowers in the vase (Table 4a and 4b). The period to complete leaf yellowing of `Carmen' cutflowers was significantly longer when plants were fertilized with the three highest nitrogen levels than the control and at 39 kgN/ha. However, there was no significant difference in the number of days to complete leaf yellowing between cutflowers from control plots and those fertilized with 39 kgN/ha and among cutflowers from three highest nitrogen levels. The mean number of days to complete leaf yellowing of `Marina' cutflowers were only significantly higher in cutflowers from plots fertilized with 156 kgN/ha than the ones from the control plots. There was a significant interaction between nitrogen rates and the method of nitrogen applications in the number of days to complete leaf yellowing in `Marina' cutflowers. The mean number of days to complete leaf yellowing were 7.5, 8.8, 11.1, 11.8 and 12.3 for `Carmen' cutflowers and 12.6, 13.5, 13.5, 13.6, and 14.2 for `Marina' cutflowers in the control plots and those fertilized with 39, 78, 117 and 156 kgN/ha, respectively.

The mean number of days to half petal fall in `Carmen' cutflowers increased significantly with increased nitrogen fertilization rates. The number of days to half petal falls was significantly longer in cutflowers from

plants fertilized with two highest nitrogen levels than in the control and at 39 kgN/ha. However, there was no significant difference in number of days to half petal fall of cutflowers from the control and plants fertilized with 39 kgN/ha, between 39 and 78 kgN/ha and among cutflowers from plants fertilized with three highest nitrogen levels (Table 4a). The number of days to half petal fall of 'Marina' cutflowers was not significantly affected by nitrogen topdressing but it increased slightly with the application of 117 kgN/ha then decreased slightly at 156 kgN/ha (Table 4b). The number of days to half petal fall were 12.6, 12.9, 13.4, 13.9 and 14.0 for 'Carmen' and 11.3, 12.1, 12.3, 12.8 and 12.3 for 'Marina' cutflowers in control plots and those fertilized with 39, 78, 117 and 156 kgN/ha, respectively.

4.6 Effect of Split Nitrogen Application on Growth, Flowering and Postharvest Vaselife Characteristics Of Alstroemeria

Four split and two split nitrogen applications at two and four weeks intervals, respectively had no significant effect on shoot growth, cutflower quality (Table 5), flowering (Table 7) and nitrogen concentration in tissues (Table 8) of Alstroemeria 'Carmen'. Similarly, leaf chlorophyll content and vaselife (Table 9) of 'Carmen' cutflowers was not significantly influenced by split nitrogen applications. In Alstroemeria 'Marina' a similar trend was observed (Table 6, 7, 8 and 9) but the number of leaves on flowering shoots and the period taken to complete yellowing of leaves of cutflower in vase was significantly influenced by split nitrogen applications.

The number of leaves per flowering shoot was

significantly higher in Alstroemeria 'Marina' plants fertilized with 39, 78 and 156 kgN/ha in four splits at two weeks interval than those under two splits at four weeks interval (Table 6). Alstroemeria 'Marina' cutflowers from plots receiving four split nitrogen applications at two weeks interval took longer to become completely yellow in comparison to cutflowers harvested from plots fertilized in two split applications at four weeks interval. However, only cutflowers from plants fertilized with 39 and 78 kgN/ha in four splits at two weeks interval had significantly longer period before complete yellowing of leaves than cutflowers from plots under two split applications at four weeks interval (Table 9).

Table 5: Effect of nitrogen application frequency on Alstroemeria 'Carmen' growth.

Growth parameter	Frequency of nitrogen application	Nitrogen level (kgN/ha) 0	39	78	117	156	W $LSD_{(0.05)}$
		Z					
Total no. of shoots/M^2	1	802a	829a	851a	855a	828a	
	2	817b	884a	871a	885a	924a	243.5
Vegetative shoot mean fresh weight (g)	1	8.3b	10.8ab	11.9a	14.2a	12.9a	
	2	9.7b	11.0ab	13.3a	13.4a	13.6a	3.1
Flowering shoot mean fresh weight (g)	1	17.7c	20.6bc	22.7abc	26.6a	24.8ab	
	2	19.3c	20.3bc	24.7ab	25.3ab	25.7a	5.1
Vegetative shoot mean length (cm)	1	32.0b	41.7a	40.5ab	48.8a	46.3a	
	2	35.9b	40.4ab	48.1a	43.2ab	48.4a	10.4
Flowering shoot mean length (cm)	1	46.4b	54.5ab	55.8a	62.6a	58.3a	
	2	51.8a	55.3a	61.5a	59.8a	58.2a	9.3
Vegetative shoot mean diameter (cm)	1	0.400a	0.446a	0.485a	0.505a	0.451a	
	2	0.425a	0.424a	0.463a	0.491a	0.484a	0.275
Flowering shoot Mean diameter (cm)	1	0.626a	0.713a	0.710a	0.710a	0.728a	
	2	0.660a	0.624a	0.731a	0.719a	0.682a	0.977
Vegetative shoot mean Leaf no.	1	36.5a	35.6a	39.6a	41.4a	39.a	
	2	38.9a	40.8a	41.9a	42.8a	38.8a	5.4
Flowering shoot mean Leaf no	1	21.8ab	21.2b	22.4ab	22.5ab	23.1a	
	2	24.7a	21.9b	23.0b	23.0b	22.6b	3.5

Frequency 1 - application of nitrogen in two splits at four weeks interval

Frequency 2 - application of nitrogen in four splits at two weeks interval

Z - Mean separation within rows by Duncan's New Multiple Range Test, 5% level

W - $LSD_{(0.05)}$ between application frequency 1 and 2 within nitrogen level

Table 6: Effect of nitrogen application frequency on Alstroemeria 'Marina' growth.

Growth parameter	Frequency of nitrogen application	Nitrogen level (kgN/ha) 0	39	78	117	156	W $LSD_{(0.05)}$
		Z					
Total no. of shoots/M^2	1	611a	684a	727a	765a	805a	
	2	495a	549a	585a	609a	703a	329.0
Vegetative shoot mean fresh weight (g)	1	35.3a	42.7a	41.6a	43.4a	42.7a	
	2	40.3a	49.3a	38.1a	45.1a	40.9a	14.9
Flowering shoot mean fresh weight (g)	1	77.4a	77.2a	82.9a	91.9a	75.4a	
	2	76.3b	90.4b	109.8a	86.7b	78.0b	29.0
Vegetative shoot mean length (cm)	1	82.0a	92.6a	90.6a	92.0a	86.0a	
	2	84.8a	94.0a	86.4a	94.6a	89.6a	15.1
Flowering shoot mean length (cm)	1	116.8a	123.2a	130.0a	124.1a	117.7a	
	2	117.2b	121.2b	138.6a	128.4ab	119.4b	20.3
Vegetative shoot mean diameter (cm)	1	0.602a	0.620a	0.646a	0.646a	0.615a	
	2	0.637a	0.669a	0.630a	0.656a	0.646a	0.120
Flowering shoot Mean diameter (cm)	1	0.905a	0.897a	0.832a	0.913a	0.867a	
	2	0.884ab	0.936a	0.953a	0.875ab	0.822b	0.173
Vegetative shoot mean Leaf no.	1	54.9a	57.3a	54.5a	57.3a	55.8a	
	2	60.7a	57.0a	56.1a	57.7a	54.9a	18.7
Flowering shoot mean Leaf no	1	43.8a	41.4a	43.8a	45.8a	44.1a	
	2	47.9a	47.9a	48.6a	41.8b	48.7a	4.2

Frequency 1 - application of nitrogen in two splits of four weeks interval

Frequency 2 - application of nitrogen in four splits at two weeks interval

Z - Mean separation within rows by Duncan's New Multiple Range Test, 5% level

W - $LSD_{(0.05)}$ between application frequency 1 and 2 within nitrogen level

Table 7: Effect of nitrogen application frequency on Alstroemeria flowering.

CULTIVAR 'Carmen'

Flowering parameters	Frequency of nitrogen application	Nitrogen level (KgN/ha) 0	39	78	117	156	W $LSD_{(0.05)}$
		Z					
No. of flowering shoots/M^2	1	375b	455ab	474a	473a	474a	
	2	413b	453ab	480ab	508a	539a	129.2
% Flowering shoot of the total shoot	1	46.8b	54.9a	55.7a	55.3a	55.3a	
	2	50.6b	51.3b	55.1ab	57.4ab	58.4a	7.9
No. of days to onset of flowering	1	138.3a	137.5a	135.0a	136.0a	140.7a	
	2	139.7a	138.0a	134.7a	138.3a	138.1a	13.8
No. of cymes per inflorescence	1	3.6a	3.7a	3.9a	4.1a	3.9a	
	2	3.8a	3.8a	4.0a	4.0a	4.3a	0.56

CULTIVAR 'Marina'

Flowering parameters	Frequency of nitrogen application	Nitrogen level (KgN/ha) 0	39	78	117	156	W $LSD_{(0.05)}$
		Z					
No. of flowering shoots/M^2	1	391a	509a	411a	499a	513a	
	2	409a	349a	389a	415a	468a	175.5
% Flowering shoot of the total shoot	1	63.6a	65.9a	59.9a	64.7a	61.9a	
	2	68.2a	60.8a	72.9ab	73.3ab	69.7a	17.8
No. of days to onset of flowering	1	175.5a	177.8a	174.4a	177.2a	179.5a	
	2	193.0a	178.6a	177.0a	179.9a	181.5a	28.1
No. of cymes per inflorescence	1	5.5a	5.9a	5.3a	5.6a	5.4a	
	2	5.3a	5.8a	6.2a	5.9a	5.4a	1.04

Frequency 1 - application of nitrogen in two splits at four weeks interval

Frequency 2 - application of nitrogen in four splits at two weeks interval

Z - Mean separation within rows by Duncan's New Multiple Range Test, 5% level

W - $LSD_{(0.05)}$ between application frequency 1 and 2 within nitrogen level

Table 8: Effect of nitrogen application frequency on nitrogen concentration in Alstroemeria tissues.

CULTIVAR 'CARMEN'

Plant tissue % N	Frequency of nitrogen application	Nitrogen level (KgN/ha) 0	39	78	117	156	W $LSD_{(0.05)}$
		Z					
Vegetative shoot young leaves	1	3.25b	3.27b	3.63ab	3.65ab	3.90a	
	2	3.32b	3.33b	3.89a	3.94a	3.94a	0.80
Flowering shoot young leaves	1	3.20b	3.22b	3.71a	3.82a	4.08a	
	2	3.35c	3.56bc	3.90ab	3.93ab	4.31a	0.99
Vegetative shoot old leaves	1	2.56b	2.61b	2.87ab	2.99ab	3.34a	
	2	2.64b	2.70b	3.08ab	3.28a	3.25a	0.85
Flowering shoot old leaves	1	2.84b	2.97b	3.22ab	3.49a	3.51a	
	2	2.93b	3.01b	3.34ab	3.36ab	3.48a	0.83
Vegetative stalk	1	0.79c	0.92bc	1.13ab	1.19ab	1.34a	
	2	0.83c	0.89bc	1.14abc	1.19ab	1.42a	0.39
Flowering stalk	1	0.79c	0.87c	0.96abc	1.05ab	1.19a	
	2	0.87c	0.87c	1.13b	1.13b	1.38a	0.23

CULTIVAR 'Marina'

Plant tissue % N	Frequency of nitrogen application	Nitrogen level (KgN/ha) 0	39	78	117	156	W $LSD_{(0.05)}$
		Z					
Vegetative shoot young leaves	1	2.65b	3.02ab	2.98ab	3.36ab	3.44a	
	2	2.75a	3.13a	3.31a	3.13a	3.25a	0.76
Flowering shoot young leaves	1	2.83b	3.13ab	3.20ab	3.44ab	3.53a	
	2	3.11a	3.13a	3.42a	3.47a	3.51a	0.60
Vegetative shoot old leaves	1	2.09b	2.69a	2.83a	3.02a	2.96a	
	2	2.22b	2.82a	2.95a	3.15a	3.31a	0.54
Flowering shoot old leaves	1	2.04b	2.84b	2.87b	2.96b	3.95a	
	2	2.46b	3.00ab	3.25ab	3.40ab	3.75a	0.81
Vegetative stalk	1	0.85a	0.83a	0.87a	0.81a	0.92a	
	2	0.76a	0.76a	0.77a	0.83a	0.89a	0.50
Flowering stalk	1	0.87a	0.92a	0.78a	0.91a	0.93a	
	2	0.80a	0.81a	0.74a	0.99a	1.06a	0.65

Frequency 1 - application of nitrogen in two splits at four weeks interval

Frequency 2 - application of nitrogen in four splits at two weeks interval

Z - Mean separation within rows by Duncan's New Multiple Range Test, 5% level

W - $LSD_{(0.05)}$ between application frequency 1 and 2 within nitrogen level

Table 9: Effect of nitrogen application frequency on the vase life and leaf chlorophyll content of Alstroemeria cutflowers in the vase.

CULTIVAR 'CARMEN'

Parameters	Frequency of nitrogen application	Nitrogen level (KgN/ha) 0	39	78	117	156	W $LSD_{(0.05)}$
		Z					
No. of days to half petal fall	1	12.6b	12.9b	14.1a	13.4ab	14.3a	
	2	12.5b	12.9ab	13.6ab	13.4ab	13.7a	1.4
No. of days to complete leaf yellowing	1	6.8c	8.9bc	10.9ab	12.0a	11.6a	
	2	8.1c	8.7c	11.2ab	11.5ab	13.1a	2.8
Foliage chlorophyll content (µg/mg) at day 0	1	1.681b	1.978ab	2.320ab	2.382a	2.455a	
	2	1.718b	2.028ab	2.438a	2.406a	2.310a	0.613
Foliage chlorophyll content (µg/mg) at day 7	1	0.255b	0.408ab	0.408ab	0.510ab	0.597a	
	2	0.416b	0.451b	0.608ab	0.675ab	0.832a	0.274
Foliage chlorophyll content (µg/mg) at day 14	1	0.141b	0.219ab	0.247ab	0.322a	0.322a	
	2	0.227c	0.251bc	0.346abc	0.372ab	0.456a	0.145

CULTIVAR 'Marina'

Parameters	Frequency of nitrogen application	Nitrogen level (KgN/ha) 0	39	78	117	156	W $LSD_{(0.05)}$
		Z					
No. of days to half petal fall	1	11.0b	12.3ab	12.0ab	13.2a	12.0ab	
	2	11.7a	11.9a	12.9a	12.4a	12.5a	4.123
No. of days to complete leaf yellowing	1	13.2ab	12.5ab	11.7b	13.2ab	13.9a	
	2	12.0b	14.4a	15.2a	14.0a	14.5a	1.793
Foliage chlorophyll content (µg/mg) at day 0	1	1.828b	1.883ab	2.067ab	2.144a	2.102ab	
	2	1.686b	1.774ab	2.041a	2.007a	2.017a	0.361
Foliage chlorophyll content (µg/mg) at day 7	1	0.743a	0.877a	0.879a	0.882a	0.883a	
	2	0.726a	0.856a	0.886a	0.892a	0.962a	0.486
Foliage chlorophyll content (µg/mg) at day 14	1	0.516a	0.516a	0.550a	0.605a	0.560a	
	2	0.516b	0.581ab	0.628a	0.633a	0.657a	0.195

Frequency 1 - application of nitrogen in two splits at four weeks interval

Frequency 2 - application of nitrogen in four splits at two weeks interval

Z - Mean separation within rows by Duncan's New Multiple Range Test, 5% level

W - $LSD_{(0.05)}$ between application frequency 1 and 2 within nitrogen level

5. DISCUSSION

5.1 Shoot growth

In this study the number of total (Vegetative and flowering) shoots/M^2 of both Alstroemeria `Carmen' and `Marina' plants increased with application of 156kgN/ha. A similar increase in total number of shoots of Alstroemeria plants due to nitrogen fertilization has been reported in other studies. Kiara (1989) reported that the number of total shoots of Alstroemeria `Marina' planted in field increased as nitrogen fertilization was increased to 234 kgN/ha. In Alstroemeria `Orchid' and `Carmen' grown in peat culture, the number of total shoots per plant increased with high nitrogen application of 300mg/pot/week in `Orchid' and 220mg/pot/week in `Carmen' (Bik and Berg, 1981).

Nitrogen fertilization is also known to influence growth and yield of other cutflowers. Increased nitrogen application increased the yield of cutflowers per M^2 in Rose cultivar `Baccara' (Feign *et al.*, 1979), statice cultivar `Iceberg', `Kampf's Blue' and `Gold coast' (Paparozzi and Hatterman, 1988) and *Chrysanthemum morifolium* cultivar `Bluechip' (Joiner and Smith, 1962). Nitrogen fertilization also increased the number of flowering shoots per plant in *Streptocarpus xhybridus* (Lyons *et al.*, 1987) and Minicymbidium cultivar `Pendragon Sikkim' (Bik and Berg, 1983).

Nitrogen nutrition in plants has been reported to promote vegetative growth (Huffuker and Rains, 1978; Salisbury and Ross, 1978; Janick, 1963) and promotes growth of auxillary buds in plants leading to the formation of branched stems (Hewitt and Smith, 1975). In

this study it is possible that increased nitrogen fertilization from 0 to 156 kg/ha in Alstroemeria 'Carmen' and 'Marina' promoted rhizome development from auxillary buds on aerial shoots that gave rise to production of more aerial shoots that were thicker and longer. However, the average fresh weight, length and diameter of flowering and vegetative shoots increased with increased nitrogen rates upto optimum level of 117 kgN/ha in 'Carmen' and at 39 and 78 kgN/ha in 'Marina'. This confirmed Muhuhu's (1990) observation that Alstroemeria 'Carmen' tolerates higher nitrogen fertilization than 'Marina'. Several other studies have reported a decrease of individual stem growth despite an increased production of total number of stems per plant as nitrogen fertilizer rates were increased (Armitage and Tsujta, 1979b; Poole and Seeley, 1978; Joiner and Smith, 1962).

There could be several factors that led to the reduction of individual shoot growth at higher nitrogen levels. High nitrogen rates could have stimulated high production of shoots per M^2 that led to competition for light, CO_2 and nutrients among the leaves to a critical point when net assimilation of photosynthates in shoots was reduced leading to a decline in individual shoot growth. In rose cultivar 'Forever Yours' high nitrogen fertilization of 400 ppm reduced the length and diameter of flower stems than when plants were fertilized with 200 ppmN in supplementary lighting due to excessive branching of the stems that caused light, CO_2 and nutrients competition among the shoots (Armitage and Tsujta, 1979b). High nitrogen supply that promoted shoot production might also have caused excessive shading of the lower leaves by upper leaf canopy to an extent that the lower leaves and

high number of shoots were dependent on upper leaves for their dark respiration substrates. This could have depleted the photosynthates in plant that would have been used for further individual shoot growth thereby limiting individual shoot growth.

It has been reported that high nitrogen fertilization in orchid genera Cattleya (Poole and Seeley, 1978), Chrysanthemum (Joiner and Smith, 1962) and carnations (Campbell and Spelman, 1962) increased nitrogen concentration in leaves but reduced accumulation and concentration of potassium, magnesium and calcium that resulted in creating their deficiency in leaves. Potassium and magnesium are important for photosynthesis and protein synthesis in plants (Salisbury and Ross, 1978). In this study, it is possible that high nitrogen fertilization created deficiency of these cations in Alstroemeria leaves that reduced photosynthesis and protein synthesis and thereby limited further individual shoot growth.

Heins and Wilkins (1979) reported that Alstroemeria `Regina' grown under alternated 15°C (40 days) and 21°C (20 days) soil temperatures and short day photoperiod produced flowering shoots with more leaves than plants grown in 15°C constant soil temperature under long day photoperiod. In this study, all nitrogen treatments were applied under similar field conditions and therefore nitrogen treatments did not affect the number of leaves on both flowering and vegetative shoots of either Alstroemeria `Carmen' or `Marina'.

In Kenya, the main criterion used to grade Alstroemeria cutflowers is the length of flower stem. In

addition, cutflowers with strong shoots with few number of leaves are of high quality. Cutflowers with high fresh weight are not desirable because of high costs incurred in air transport. The quality of Alstroemeria 'Marina' cutflowers was not affected by nitrogen treatments as all cutflowers produced were strong and attained the white grade (≥ 70 cm long). Alstroemeria 'Carmen' plants receiving 117 kgN/ha on average produced cutflowers of the highest quality, 'blue grade' (60-69 cm long) while plants fertilized with 39, 78 and 156 kgN/ha produced cutflowers of lower 'yellow grade' (50-59 cm long). Plants in the control plots produced on average market reject cutflowers (≤ 49 cm long).

5.2 Flowering

In the current study, the number of flowering shoots/M^2 increased significantly in Alstroemeria 'Carmen' but slightly in 'Marina' with high nitrogen application. Production of flowering shoots in Alstroemeria is induced by low soil temperature (Healy and Wilkins, 1986; 1982; 1981; 1979; Healy *et al.*, 1982) and rhizomes are the site of temperature perception (Heins and Wilkins, 1979). In this study all nitrogen treatments were applied under similar environmental conditions and therefore, high nitrogen application promoted development of rhizomes from the auxillary buds of aerial shoots that gave rise to development of more flowering shoots under inductive soil temperatures.

The percent of flowering shoots was not affected by nitrogen fertilization in Alstroemeria 'Marina'. A similar trend was reported in Alstroemeria 'Carmen' (Muhuhu, 1990) and 'Marina' (Kiara, 1989). Healy and Wilkins (1982)

observed that once Alstroemeria 'Regina' plants were adequately vernalized, high forcing temperature increased the percentage of total shoots that flowered. The percent of flowering shoots of Alstroemeria 'Marina' in this study was not affected by nitrogen fertilization possibly because all nitrogen treatments were applied under similar environmental conditions. However, in this study Alstroemeria 'Carmen' had a striking different response where the percent number of flowering shoots increased with high nitrogen fertilization, although all treatments were conducted under similar environmental conditions.

In Alstroemeria 'Marina' the number of total shoots and flowering shoots per M^2 were not statistically affected by nitrogen treatments and the optimum individual shoot growth occurred at a low nitrogen application of 78 kg/ha unlike in 'Carmen' where the converse was true and the best nitrogen fertilization level for individual shoot growth was achieved at 117 kg/ha. It could be that increased nitrogen fertilization increased photosynthetic capacity in 'Carmen' plants as was observed in *Chrysanthemum morifolium* cultivar 'Bluechip' (Woltz and Water, 1967). This could have caused more photosynthetic accumulation in storage roots during flowering under inductive temperatures than in plants under low nitrogen fertilization. Healy and Wilkins (1986), observed that high rhizome and storage root dry matter accumulation is directly related to high percent number of flowering shoots in Alstroemeria 'Regina'. In this study it is possible that there was high dry matter accumulation in storage roots and rhizomes in 'Carmen' plants under high nitrogen fertilization that promoted the production of more flowering shoots than those plants fertilized with

low nitrogen levels.

Healy and Wilkins (1982) reported that specific plant growth substances (PGS) accumulated in Alstroemeria 'Regina' plants and became conjugated with stored carbon. Once a critical mass of metabolites and/or PGS has accumulated, flowering occurred. When 'Regina' plants pretreated for 8 weeks at 5°C and forced at 13°C under night interruption were treated with 1000 mg/*l* of gibberellin precursors as a drench upon removal from the cooler, the resulting shoot morphology resembled that of flowering shoot in comparison to the plants that were treated with an inhibitor of gibberellin synthesis. Normal nitrogen nutrition maintained moderate gibberellin activity in tomato shoot apices while gibberellin activity disappeared in nitrogen deficient plants (Rajagopal and Rao, 1972). In this study it could be that 'Carmen' plants under low nitrogen nutrition had lower gibberellin accumulation in storage roots than the critical required level and therefore formed fewer flowering shoots that gave lower percent number of flowering shoots than plants receiving high nitrogen levels.

Nitrogen has been reported to delay flowering in plants such as Chrysanthemum (Bunt, 1973; Joiner and Smith, 1962), orchids (Bik and Berg, 1983) and Antirrhinium (Bunt, 1969) but had no effect on the flowering date in roses (Armitage and Tsujta, 1979a) and *Streptocarpus xhybridus* (Lyons *et al.*, 1987). In Alstroemeria 'Carmen' grown in sand culture, nitrogen fertilization did not affect the onset of flowering (Muhuhu, 1990) but delayed flowering in field grown Alstroemeria 'Marina' (Kiara, 1989). Days to flowering in

Alstroemeria 'Regina' decreased with increasing number of days plants were vernalized at 5°C but after proper vernalization, 18°C forcing temperature hastened flowering than 13°C (Healy and Wilkins, 1982). Long photoperiod hastened flowering and it had more effect on flowering onset than soil temperature. Powell and Bunt (1986) reported that onset to flowering in Alstroemeria 'Regina' was greatly affected by seasonality than propagation date. In this study Alstroemeria plants were in the field for a long time and since nitrogen treatments were applied under similar field conditions, flower induction and initiation occurred at the same time within each cultivar and therefore nitrogen treatment did not affect flowering time in 'Carmen' and 'Marina'.

In Alstroemeria 'Marina' nitrogen fertilization did not affect the number of cymes per inflorescence (Kiara, 1989) but increased the number of flowers per inflorescence in Alstroemeria 'Carmen' and 'Orchid' (Muhuhu, 1990; Bik and Berg, 1981). The number of cymes per inflorescence is an important quality criteria as Alstroemeria cutflowers with many cymes have high market value. In this study nitrogen fertilization did not significantly affect the number of cymes per inflorescence although it was highest in cutflowers from plants fertilized with 156 kgN/ha in 'Carmen' and 39 kgN/ha in 'Marina'. Heins and Wilkins (1979) reported that large and vigorous shoots did not only have many number of cymes but oftenly had a similar number of primary, secondary, tertiary and quaternery flowers. Thus, though nitrogen fertilization did not affect the number of cymes significantly, it might have increased the total number of flowers per inflorescence in plants fertilized with 117

kgN/ha in 'Carmen' and 78 kgN/ha in 'Marina'.

5.3 Nitrogen Concentration in Plant Tissues

In both Alstroemeria 'Carmen' and 'Marina', nitrogen concentration in leaves and stalks increased significantly with increased nitrogen fertilization levels except in 'Marina' stalks where the increase was not statistically significant. At similar nitrogen levels, nitrogen concentration was highest in young leaves, intermediate in old leaves and lowest in stalks. Tissues of flowering shoots maintained higher nitrogen concentration than those of vegetative shoots in both cultivars except the stalks of 'Carmen' plants fertilized with nitrogen and the control in 'Marina'.

Alstroemeria 'Carmen' had higher nitrogen concentration in tissues than 'Marina'. Bik and Berg (1981) observed a similar cultivar difference where an increase in leaf nitrogen concentration with increased nitrogen fertilization was more dramatic in Alstroemeria 'Orchid' than 'Carmen'. In this study, the number of total and flowering shoots per M^2 among nitrogen topdressed plants was not significantly affected by nitrogen fertilization. However, the average fresh weight and length of individual vegetative and flowering shoots of both cultivars and the average diameter of 'Marina' flowering shoots were significantly increased by nitrogen fertilization. Therefore, individual shoot growth was used as a criterion for judging the best fertilizer level to be used. The optimum growth of vegetative and flowering shoots and the highest cutflower quality was attained when plants were fertilized with 117 kgN/ha in 'Carmen' and 78 kgN/ha in 'Marina' that gave nitrogen concentration of

3.87 and 3.31%, respectively in young leaves of the flowering shoots.

Muhuhu (1990) reported that best shoot growth of Alstroemeria 'Carmen' and 'Marina' grown in sand medium was attained when plants were fertilized with nitrogen to achieve nitrogen concentration of 4.97 and 4.89%., respectively in upper leaves of the flowering shoots. Similarly, Bik and Berg (1981) reported that best growth of Alstroemeria 'Carmen' and 'Orchid' grown in sphagnum peat medium, was attained when nitrogen concentration in young leaves was 5.14 and 4.9%, respectively. Foliar nitrogen concentration is an indication of the amount of nitrogen in foliage and not necessarily the uptake as it is determined by the number of shoots the plant has (Armitage and Tsujta, 1979b). At optimum nitrogen fertilization, the bigger the crop (i.e. dry weight per area) the less nitrogen concentration it has due to dilution effect caused by growth that obscures the nutrient accumulation (Greenwood *et al.*, 1980; Cox and Reisenauer, 1973). Foliar nitrogen concentration in roses 'Cliente' (Armitage and Tsujta, 1979a) and 'Forever Yours' (Armitage and Tsujta, 1979b) increased with nitrogen fertilization but decreased with high light intensity that stimulated excessive shoot production thereby causing dilution of nitrogen in tissues due to competition among shoots.

In this study, the optimum growth of Alstroemeria 'Carmen' and 'Marina' individual shoots was achieved at a lower leaf nitrogen concentration than that reported by Muhuhu (1990) and Bik and Berg (1981). Alstroemeria plants used in this study were well established in the field for

a long time and produced high number of shoots. It is convinceable that high number of shoots produced by Alstroemeria plants caused competition for nitrogen among the tissues that resulted in lower leaf nitrogen concentration than that reported in studies conducted in hydroponic cultures.

5.4 The Postharvest Leaf Chlorophyll Content of Cutflowers.

High nitrogen fertilization maintained high initial and subsequent leaf chlorophyll content of Alstroemeria `Carmen' and `Marina' cutflowers in the vase. Other studies have reported similar findings in Alstroemeria `Carmen' and `Marina' vegetative shoots (Muhuhu, 1990) and Chrysanthemum cutflowers (Woltz and Waters, 1967). High nitrogen fertilization also increased leaf chlorophyll content in creeping bentgrass (Mancino and Troll, 1990), Okra (Mclaurin, *et al.*, 1984), *Euphorbia fulcherrim* (Lin, 1979), Kalanchoe (Sheehan and Nell, 1979) and carnations (Campbell and Spelman, 1962).

Nitrogen is an essential component of chlorophyll molecule (Salisbury and Ross, 1978; Goodwin and Mercer, 1972) and this could be the reason why increased nitrogen fertilization increased initial and subsequent leaf chlorophyll content of `Carmen' and `Marina' cutflowers during vaselife. However, in this study Alstroemeria `Marina' cutflowers had a higher leaf chlorophyll content than Alstroemeria `Carmen' cutflowers on seventh and fourteenth day in vase unlike the findings of Muhuhu (1990) where leaf chlorophyll content of Alstroemeria `Carmen' was higher than `Marina' on twenty first day in vase. The difference could be because Muhuhu (1990) used

vegetative shoots while in this study cutflowers were used.

Premature leaf yellowing of cutflowers is caused by hormonal imbalance in plants when the supply of hormones from the roots is cut off after cutflowers are harvested (Hoffman, 1988). Nitrogen nutrition delays leaf senescence by maintaining high level of cytokinin (Sattelmacher and Marschner, 1978a; 1978b) and GA (Rajagopal and Rao, 1972) but low level of ABA (Daie *et al.*, 1979; Goldbach *et al.*, 1975) in leaf tissues.

Gibberellin and cytokinin are widely used to prevent premature leaf yellowing of Alstroemeria cutflowers (Healy and Lang, 1989) and cytokinin is known to promote chloroplast development (Salisbury and Ross, 1978). In this study it is therefore possible that high nitrogen fertilization increased the levels of cytokinins and gibberellins but reduced ABA and C_2H_4 levels in the leaves of Alstroemeria cutflowers. This maintained high initial leaf chlorophyll content and delayed subsequent leaf chlorophyll breakdown thereby maintaining high leaf chlorophyll content during vaselife.

5.5. Keeping Quality

Alstroemeria cutflowers are attractive due to their green foliage and colourful flowers. Condition of green leaves on the floral stem increases marketability of Alstroemeria cutflowers. In this study, application of 156kgN/ha increased the number of days to complete leaf yellowing by 4.8 and 1.6 days in 'Carmen' and 'Marina', respectively. A similar trend of increased cutflower leaf longevity due to increased nitrogen fertilization was

reported in 'Carmen' (Muhuhu, 1990), 'Marina' (Kiara, 1989) and in Chrysanthemum cutflowers (Woltz and Waters, 1967).

Increased nitrogen fertilization resulted in increased leaf longevity of Alstroemeria 'Carmen' and 'Marina' cutflowers in the vase. The first sign of leaf senescence is yellowing and is caused by chlorophyll breakdown which exposes other leaf pigments (Wareign and Phillips, 1970). Since increasing nitrogen fertilization produced cutflowers with increased initial and subsequent leaf chlorophyll content during vaselife, it is possible that leaf vaselife was affected by the same factors that influenced leaf chlorophyll content of Alstroemeria cutflowers in the vase.

In this study, the number of days to half petal fall was significantly increased by nitrogen fertilization in Alstroemeria 'Carmen' but slightly in 'Marina'. Similarly, nitrogen fertilization was reported to increase flower vaselife of Alstroemeria 'Carmen' (Muhuhu, 1990) and 'Marina' (Kiara,1989). Woltz and Waters (1967) observed that high nitrogen application increased the level of sugars in chrysanthemum flowers at harvest that increased flower longevity. High sucrose level in petals enhanced cytokinin in delaying petal senescence and attenuated effect of C_2H_4 and ABA on petal senescence (Mayak and Dilley, 1976). High sugar level in petals are also known to increase petals osmotic potential (Borocher *et al.*, 1976) and provided respiration substrate to maintain cell membrane integrity of petals (Dilley and Carpenter, 1975). It is therefore, possible that increased nitrogen application increased initial and subsequent sugar level

in Alstroemeria flowers that delayed the process of flower senescence and thus prolonged flower vaselife.

Other studies have shown that nitrogen fertilization increased cytokinin (Sattelmacher and Marschner, 1978a; 1978b) but reduced ABA (Daie, *et al.*, 1979; Goldbach *et al.*, 1975) level in plant tissues. Since ABA stimulates flower senescence and cytokinin delays it (Mayak and Dilley, 1976), it is possible that Alstroemeria cutflowers from plants under high nitrogen fertilization had high cytokinin level but low ABA level in flowers than that of cutflowers from plants under low nitrogen fertilization which delayed flower senescence during vaselife. In roses, long lived cultivar 'Lovita' had a higher cytokinin level and delayed rise of C_2H_4 and ABA in petals than the short lived cultivar 'Golden Wave' (Halevy and Mayak, 1973; Mayak *et al.*, 1972). Similarly in this study 'Carmen' cutflowers might have had higher cytokinin level in petals that delayed rise of C_2H_4 and ABA levels than in 'Marina' cutflowers and therefore caused longer petal longevity in Alstroemeria 'Carmen' than 'Marina'.

5.6. Split Nitrogen Application

In this study nitrogen treatments were applied during the months of September, October and November when the corresponding rainfall was 37.5, 257.6 and 273.8mm, respectively (Appendix A). Half of nitrogen was applied in September when rainfall was low and supplemental irrigation was necessary and therefore there could have been little or no nitrogen leaching losses during this period. The other half of nitrogen was applied in October-November period when high rainfall could have caused a substantial nitrogen leaching losses. Nitrogen topdressed

'Carmen' plants had very vigorous growth as indicated by the high number of shoots produced per M^2 in comparison to 'Marina' plants. High growth vigour of 'Carmen' plants topdressed with nitrogen could have increased efficiency of rootsystem in exploiting available soil nitrogen despite high expected nitrogen leaching losses and therefore split nitrogen application did not affect shoot growth, flowering and keeping quality of cutflowers in 'Carmen'.

Alstroemeria 'Marina' plants topdressed with nitrogen had comparatively lower growth vigour. Huffaker and Rains (1978) reported that wheat seedlings of cultivar 'Anza' absorbed 30% less nitrate than the seedlings of cultivar 'UC 44-111' in two hours period. In this study, it is possible that 'Marina' plants had lower nitrate absorption capacity leading to less nitrate uptake as more nitrogen leaching losses might have occurred when nitrogen fertilizer was applied in two split than four split applications during the period of heavy rainfall. This might have caused production of more leaves on flowering shoots and increased leaf longevity of Alstroemeria 'Marina' cutflowers in vase from plants under four split than those fertilized in two split nitrogen applications.

6. CONCLUSIONS AND RECOMMENDATIONS

The study evidently showed that Alstroemeria 'Carmen' required higher nitrogen fertilizer level for optimum growth and development of individual shoots and production of high quality cutflowers than Alstroemeria 'Marina'. It is suggested that small scale outdoor growers of Alstroemeria cutflowers in Limuru area should fertilize 'Carmen' plants with 117 kgN/ha and 'Marina' plants with 78 kgN/ha in order to produce higher number of cutflowers per unit area that are finally harvested to give high quality cutflowers for sale. Establishment of best nitrogen application level of other Alstroemeria cultivars in main growing areas is also necessary.

Nitrogen fertilization did not significantly affect the onset to flowering and the number of cymes per inflorescence in both 'Carmen' and 'Marina'. However, nitrogen concentration in Alstroemeria plants varied with the part of plant used for analysis, nitrogen fertilizer level and Alstroemeria cultivar. It is suggested that the growers of Alstroemeria 'Carmen' and 'Marina' should aim at nitrogen fertilization such that nitrogen concentration in young leaves at flowering stage is 3.87 and 3.11%, respectively, for production of high quality cutflowers.

The highest number of days to complete yellowing of leaves in both Alstroemeria cultivars was observed in cutflowers from plants fertilized with 156 kgN/ha. This gave a corresponding nitrogen concentration in young leaves of 4.20 and 3.52% in 'Carmen' and 'Marina', respectively. Since yellowing of leaves in Alstroemeria cutflowers occur before the petal abscission, leaf longevity of cutflowers is a major determinant of Alstroemeria cutflower vaselife. It is therefore evident

nitrogen fertilization and/or higher nitrogen concentration in leaves to delay leaf yellowing which prolongs cutflower vaselife than that required for production of high quality cutflowers.

Split nitrogen application did not affect flowering and postharvest vaselife of `Carmen' cutflowers. In `Marina' four split applications at two weeks interval produced flowering shoots with more leaves for most fertilizer levels than when nitrogen was applied in two splits at four weeks interval. Alstroemeria `Marina' plants fertilized with 39 and 78 kgN/ha in four splits produced cutflowers with significantly longer leaf longevity than those under two split applications. This evidently shows that `Carmen' plants were more efficient in exploiting available soil nitrogen than `Marina' plants and therefore, there was more nitrogen leaching losses in `Marina' than `Carmen' fields when nitrogen was applied in two splits. It is suggested that outdoor growers of Alstroemeria in Limuru should topdress `Carmen' plants with 117 kgN/ha in two splits at four weeks interval inorder to achieve production of high yield and quality of cutflowers that can stay longer in vase while minimizing the cost of labour incurred in nitrogen application. However, `Marina' plants should be topdressed with 78 kgN/ha in four splits at two weeks interval in order to improve cutflower keeping quality.

Establishment of nitrogen application frequency of other Alstroemeria cultivars grown under different production techniques specifically fertigation in various main growing areas is essential. Nitrogen uptake and metabolism in plants that influenced productivity and

keeping quality of Alstroemeria cutflowers is highly affected by availability of other nutrients in plants. It is therefore undisputable that a more elaborative study on nitrogen fertilizer recommendation on various Alstroemeria cultivars grown in main growing areas should be coupled with other nutrients recommendation.

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8. APPENDICES

Appendix a: Rainfall and Temperature recorded during period of experimentation (1990) at National Potato Research Centre Station in Tigoni

Month	Jan	Feb	Mar	Apr.	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.
Temp.(°C)												
Mean min	13.8	14.4	14.0	14.4	14.2	11.8	9.9	10.0	11.6	13.6	17.5	15.0
Mean	18.5	19.2	18.1	17.6	17.8	15.6	13.7	13.6	16.3	17.6	18.8	17.6
Mean max	23.2	24.0	22.2	20.9	21.5	19.4	17.5	17.2	21.1	21.5	20.1	20.1
Rainfall (mm)	53.7	54.4	503.1	335.7	472.3	40.2	67.4	53.9	37.5	257.6	273.8	36.7

Total amount of rainfall received = 1912.5mm

Appendix b: Laboratory soil analysis data prior to start of experimentation

Soil reaction	Field	
	'Carmen'	'Marina'
P^H - H_2O	4.65 (0.35)	4.60 (0.10)
P^H - $CaCl_2$	4.60 (0.50)	4.55 (0.05)
Total nitrogen (excluding NO^-_3, NO^-_2) (%)	0.134 (0.034)	0.041 (0.029)
Carbon (%)	2.16 (0.36)	2.94 (0.11)

( ) Standard deviation

Appendix C: Analysis of variance (ANOVA) tables

C1: ANOVA for number of total and flowering shoots/M^2 of Alstroemeria

Source of variation	d.f	Mean sum of squares			
		Total no. of shoots/M^2		No. of flowering shoots/M^2	
		'Carmen'	'Marina'	'Carmen'	'Marina'
Blocks	2	20210.53n.s.	20196.4n.s.	50808.9n.s.	45915.7n.s.
Application frequency (A)	1	7176.53n.s.	141728.1n.s.	6106.1n.s.	25579.2n.s.
Main plot error	2	23963.33	25404.9	5453.7	6649.6
Nitrogen rate (R)	4	4199.67**	21347.3n.s.	11442.5**	9074.7n.s.
A X R	4	3340.87*	14588.1n.s.	1098.8n.s.	6923.2n.s.
Subplot error	16	835.22	24316.3	2249.7	7429.3
Total	29				

n.s. - not significant * - significant, 5% level ** - significant, 1% level

C2: ANOVA for mean fresh weight (g) of Alstroemeria shoots

Source of variation	d.f.	Mean sum of squares			
		Flowering shoot		Vegetative shoot	
		'Carmen'	'Marina'	'Carmen'	'Marina'
Blocks	2	23.863n.s.	153.661n.s.	28.425*	33.969n.s.
Application frequency (A)	1	2.523n.s.	389.216n.s.	2.411n.s.	19.521n.s.
Main plot error	2	3.951	285.705	0.492	59.977
Nitrogen rate (R)	4	61.244**	423.489*	22.999**	65.040n.s.
A x R	4	2.821n.s.	250.857n.s.	1.449n.s.	27.889n.s.
Sub-plot error	16	7.798	101.001	3.371	42.799
Total	29				

n.s. - not significant * - significant, 5% level ** - Significant, 1% level.

C3: ANOVA for mean length (cm) of Alstroemeria shoots

Source of variation	d.f.	Mean sum of squares			
		Flowering shoot		Vegetative shoot	
		'Carmen'	'Marina'	'Carmen'	'Marina'
Blocks	2	34.473n.s.	30.965n.s.	185.033n.s.	95.414n.s.
Application frequency (A)	1	24.661n.s.	50.960n.s.	13.601n.s.	23.941n.s.
Main plot error	2	11.412	124.493	22.297	50.974
Nitrogen rate (R)	4	130.261**	288.985*	171.726**	83.696n.s.
A X R	4	20.176n.s.	24.459n.s.	37.887n.s.	20.364n.s.
Sub-plot error	16	26.792	65.826	24.846	52.854
Total	29				

n.s. - not significant * - significant, 5% level ** - significant, 1% level

C4: ANOVA for mean diameter (cm) of Alstroemeria shoots

Source of variation	d.f.	Mean sum of squares			
		Flowering shoot		Vegetative shoot	
		'Carmen'	'Marina'	'Carmen'	'Marina'
Blocks	2	0.00333n.s.	0.01083n.s.	0.00145n.s.	0.00820n.s.
Application frequency (A)	1	0.00146n.s.	0.00095n.s.	0.0 n.s.	0.00363n.s.
Main pilot error	2	0.00118	0.10938	0.00112	0.00438
Nitrogen rate (R)	4	0.00666n.s.	0.00422n.s.	0.00677n.s.	0.00091n.s.
A x R	4	0.00410n.s.	0.00732n.s.	0.00108n.s.	0.00093n.s.
Sub plot error	16	0.39749	0.00260	0.03061	0.00228
Total	29				

n.s. - not significant * - significant, 5% level ** - Significant, 1% level

C5: ANOVA for mean number of leaves per shoot of Alstroemeria

Source of variation	d.f.	Mean sum of squares			
		Flowering shoot		Vegetative shoot	
		'Carmen'	'Marina'	'Carmen'	'Marina'
Blocks	2	0.1120n.s.	19.4623n.s.	3.1410n.s.	22.5053n.s.
Application frequency (A)	1	10.2107n.s.	77.4413*	32.2403*	47.3763n.s.
Main plot error	2	4.6860	1.5643	0.7724	130.6013
Nitrogen rate (R)	4	6.9667**	7.4688n.s.	20.3113n.s.	7.5975n.s.
A x R	4	0.9940 n.s.	25.5388*	7.5195n.s.	22.4722n.s.
Sub plot error	16	0.8344	6.2896	11.4398	26.9583
Total	29				

n.s. - not significant * - significant, 5% level ** - significant, 1% level.

C6: ANOVA for Alstroemeria flowering

Source of variation	d.f.	Mean sum of squares					
		% flowering shoot		Onset to flowering (days)		No. of cymes per inflorescence	
		'Carmen'	'Marina'	'Carmen'	'Marina'	'Carmen'	'Marina'
Blocks	2	417.657*	423.327n.s.	59.124n.s.	179.258n.s.	0.0373*	0.3523n.s.
Application frequency (A)	1	12.675n.s.	251.141n.s.	0.133n.s.	197.120n.s.	0.1763**	0.2083n.s.
Main plot error	2	14.656	89.626	66.057	127.990	0.0013	0.1743
Nitrogen rate (R)	4	83.540**	24.1 35n.s.	18.275n.s.	60.876n.s.	0.1637n.s.	0.2805n.s.
A X R	4	9.321n.s.	69.125n.s.	4.893n.s.	73.014n.s.	0.0430n.s.	0.2675n.s.
Sub-plot error	16	13.774	56.501	21.829	227.158	0.1318	0.3125
Total	29						

n.s. - not significant * - significant, 5% level ** - significant, 1% level.

C7: ANOVA for nitrogen concentration (%) in Alstroemeria young leaves

Source of variation	d.f.	Mean sum of squares			
		Flowering shoot		Vegetative shoot	
		'Carmen'	'Marina'	'Carmen'	'Marina'
Blocks	2	0.1269n.s.	1.2437*	0.0399n.s.	0.3211n.s.
Application frequency (A)	1	0.3162n.s.	0.0770n.s.	0.1512n.s.	0.0043n.s.
Main plot error	2	0.3777	0.0516	0.2097	0.1063
Nitrogen rate (R)	4	0.8392**	0.3120n.s.	0.5304**	0.3622n.s.
A X R	4	0.0154n.s.	0.0294n.s.	0.0214n.s.	0.0805n.s.
Sub plot error	16	0.0543	0.1099 0.0885	0.1543	
Total	29				

n.s. - not significant * - significant, 5% level ** - significant, 1% level.

C8: ANOVA for nitrogen concentration (%) in Alstroemeria old leaves

Source of variation	d.f.	Mean sum of squares			
		Flowering shoot		Vegetative shoot	
		'Carmen'	'Marina'	'Carmen'	'Marina'
Blocks	2	0.0017n.s.	0.6162*	0.0251n.s.	0.7042n.s.
Application frequency (A)	1	0.5952n.s.	0.4296n.s.	0.0963n.s.	0.2219n.s.
Main plot error	2	0.2535	0.0294	0.2576	0.0415
Nitrogen rate (R)	4	0.4198**	1.9709**	0.5275**	0.9312**
A X R	4	0.1169n.s.	0.1071n.s.	0.0493n.s.	0.0144n.s.
Sub plot error	16	0.0536	0.2539	0.0706	0.0866
Total	29				

n.s. - not significant * - significant, 5% level ** - significant, 1% level

C9: ANOVA for nitrogen concentration (%) in Alstroemeria stalks

Source of variation	d.f.	Mean sum of squares			
		Flowering shoot		Vegetative shoot	
		'Carmen'	'Marina'	'Carmen'	'Marina'
Blocks	2	0.0229n.s.	0.1938n.s.	0.0136n.s.	0.0734n.s.
Application frequency (A)	1	0.0811n.s.	0.0003n.s.	0.0026n.s.	0.0219n.s.
Main plot error	2	0.0079	0.1465	0.0342	0.0813
Nitrogen rate (R)	4	0.2015**	0.0501n.s.	0.3111**	0.0106n.s.
A X R	4	0.0085n.s.	0.0156n.s.	0.0033n.s.	0.0039n.s.
Sub plot error	16	0.0165	0.0491	0.0353	0.0355
Total	29				

n.s. - not significant * - significant, 5% level ** - significant, 1% level.

C10: ANOVA for the leaf chlorophyll content (µg/mg) of Alstroemeria cutflowers in the vase

Source of variation	d.f.	Mean sum of squares					
		Initial		Seventh day		Fourteenth day	
		'Carmen'	'Marina'	'Carmen'	'Marina'	'Carmen'	'Marina'
Blocks	2	1.9170*	0.3155n.s.	0.0808n.s.	0.0340n.s.	0.0207n.s.	0.0205n.s.
Application frequency (A)	1	0.0021n.s.	0.0744n.s.	0.1941n.s.	0.0010n.s.	0.0462n.s.	0.0217n.s.
Main plot error	2	0.0325	0.0335	0.0125	0.0888	0.0049	0.0147
Nitrogen rate (R)	4	0.5816*	0.1359**	0.1279**	0.0072n.s.	0.0426**	0.0111**
A X R	4	0.0142n.s.	0.0034n.s.	0.0078n.s.	0.0267n.s.	0.0021n.s.	0.0023n.s.
Subplot error	16	0.1313	0.0267	0.0213	0.0173	0.0047	0.0023
Total	29						

n.s. - not significant * - significant 5%, level ** - significant, 1% level.

C11: ANOVA for vaselife (days) of Alstroemeria cutflowers

Source of variation	d.f.	Mean sum of squares: days to complete leaf yellowing		days to half petal fall	
		'Carmen'	'Marina'	'Carmen'	'Marina'
Blocks	2	35.577*	2.906n.s.	2.475n.s.	1.425n.s.
Application frequency (A)	1	1.875n.s.	9.633*	0.385n.s.	0.176n.s.
Main plot error	2	0.918	0.212	0.558	6.372
Nitrogen rate (R)	4	25.935**	1.869n.s.	2.198**	1.809n.s.
A x R	4	1.092n.s.	4.459*	0.111n.s.	0.874n.s.
Sub plot error	16	2.573	1.176	0.377	1.283
Total	29				

n.s. - not significant * - significant, 5% level ** - significant, 1% level.