Influence of Level and Frequency Of Nitrogen Fertilization on Growth, Flowering and Postharvest Quality of Tuberose (*Polianthes tuberosa* L.)

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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DEDICATION

This thesis is dedicated to my parents Mr. and Mrs Kihara Ngamau and my late sister Rose Muthoni Ngamau

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ABSTRACT

This study was conducted to determine the influence of various levels of Nitrogen and frequency of application on growth, flowering and postharvest quality of tuberose.

Nitrogen tended to stimulate an increase of leaf length in Kabete but did not influence the number of basal leaves. With the application of 0, 21.25, 42.5 and 85.0 kg N/ha, leaf length increased from 38.2 cm to 39.2, 40.5 and 38.2 cm . However increase this was not significant.

Nitrogen application promoted the increase of the spike and rachis length and spike diameter both at Kiambu and Kabete. However, only the spike diameter increased significantly with application of N giving the highest spike diameter at the highest N level. Split N application also positively promoted greater spike and rachis length and spike diameter.The spike growth rate and the number of leaves and florets per spike were not significantly influenced by N level. The distal floret size and colour were not significantly affected by N level. However, the latter decreased while the former tended to increase with N levels.

Increased N levels delayed the senescence of flower sepals and the yellowing and senescence of distal florets but it did not prevent their abortion. The application of 0, 21.25, 42.5 and 85.0 kg N/ha significantly delayed senescence of sepals and the unopen distal florets giving the greatest delay at the highest N level. Split application of N did not significantly influence the period to senescence of sepals and the yellowing and senescence of the distal florets. However, the period to the wilting and senescence of the last open floret and the total number of open florets tended to decrease with split N application. Nitrogen application did not significantly influence the period to the wilting and senescence of the last open floret and the number of dry and senesced florets.

Both split N application and the levels of N increased the number of spikes produced. However, the increase due to N levels was not statistically significant. The spike yield increased with split N application and rose from 17.5 to 18.0 and 23.8 stems per plot (m^2) at 4 wk, 2 wk and 1 wk application interval, respectively.

Nitrogen application increased production and quality of cut tuberose. A level of 42.5 kg N/ha application promoted optimum response for most observed parameters.

Split N application was also found to improve yield and quality of cut tuberose with higher frequencies of application giving better results.

1.0 INTRODUCTION

Horticulture is an important subsector of the agricultural industry all over the world and it is increasingly becoming important in Kenya taking the third place after coffee and tea in foreign exchange earnings. Kenya was sixth in the world's export of cutflowers with 1% of the total volume after Holland (70%), Colombia (11%), Israel (6%), Italy (5%), and Spain (1%) (Anon , 1991).

In 1990, Kenya earned Kshs. 1.68 Billion up from 1.44 billions in 1989 from horticultural exports i.e. fresh fruits, vegetables and cutflowers, which weighed 49.15 tons. Among these produce, cutflowers constituted 14,42 tons. Export of cut flowers amounted to 29% by volume of the total horticultural exports and 50% by value. The importance of cutflower industry is further indicated by the increase of its contribution to the total value of horticultural exports from 44.6% in 1985 to 50% in 1990 (H.C.D.A., 1990).

Cutflowers exported from Kenya to foreign markets include *Alstroemeria,* carnations, roses, orchids, Statice, tuberose, *Ornithogalum, Liatris* and Helicornia (Chepkairor, 1986). The destination of Kenya's exported cutflowers include United Kingdom (34.8%), Holland (19.2%), France

(18.6%), Germany (11.8%), Belgium (6.8%), United Arab Emirates (2.0%) with other countries taking 6.8% (H.C.D.A., 1990).

Tuberose (*Polianthes tuberosa* L.) is usually grown by small scale farmers around Kiambu and Limuru. Large foreign owned flower companies do not grow it due to the narrow export market. The absence of competition, less capital intensive investment and simple field operations compared to other cutflowers such as roses and carnations have attracted many small scale farmers to grow tuberose. This is because it can be grown in the field under minimal management practices (Armitage and Laushman, 1990).

There is absence of information regarding tuberose production in the country and the recommended cultural practices are sketchy. Farmers have tended to use trial and error methods and their experience to determine the rate of fertilizer application and the type of fertilizer to use. Nitrogen is the major limiting nutrient in most agricultural soils and due to increasing costs the need for improving N uptake efficiency is important. This is greatly affected by N rate, source, timing and application method (Bosewell, *et al.*, 1985). Most tuberose research findings available have been conducted in India and may not be directly applicable in Kenya.

The application of different levels and forms of nitrogenous fertilizers may not only affect the yield of the crop but it also influences the quality and composition of the plant due to physiological reasons (Raju, 1978). It is therefore necessary to know the influence of various levels of nitrogen fertilization, time and frequency of application as well as the influence of different forms of N fertilizer on growth, flowering and fruiting of a crop. This study was therefore conducted with the following objectives:-

1. To evaluate the influence of various N levels on the growth, flowering and postharvest quality of tuberose.

2. To evaluate the influence of split N application on growth and flowering of tuberose.

3. To evaluate the influence of N application on tuberose in two areas with varying soil and environmental conditions.

2.0 LITERATURE REVIEW

2.1 Tuberose Botany:

Tuberose *(Polianthes tuberosa L.)* is in the family Agavaceae (Bailey, 1949; Naidu and Reid, 1989; Wilkins, 1985; Trueblood, 1974;). It was discovered in Mexico where it was cultivated before the Spanish conquest in 1522. It was used medicinally with root extracts being used to treat fever, suppression of tumours and against diarrhoea and heat (rash) (Trueblood, 1974).

Eleven or twelve different species of *Polianthes* have been discovered in the cool mountain valleys of Western and Northern Mexico and range in colour from white, orange-red, red to striped. These include *P. pringlei* Rose, *P. sessiflora* (Hemsley) Rose, *P. nelsonii* Rose, *P. gracilis* Rose, *P. palustris* Rose, *P. durangensis* Rose, *P. montana* Rose, *P. longiflora* Rose, *P. graminifolia* Rose and *P. geminiflora* (Lex) Rose. Only *P. tuberosa* appears sterile. It is propagated by the division of tubers (Trueblood, 1974).

Tuberose flower has single, semi-double and double florets which are all white in colour (Irulappan, *et al.*, 1980a; Sambandamurthi and Appavu, 1980). It has varied uses in table decoration as a cutflower and in making floral ornaments, most artistic garlands and buttonholes. It also

produces an essential oil used in preparation of high grade perfumes and cosmetics (Irulappan, *et al.*, 1980a; Trueblood, 1974). It is also used in cutflower trade and religious worship (Nanjan, *et al.*, 1980). It is cultivated for its fragrant cutflowers in India, New Zealand, Japan and Mexico and for perfume industry in India and France (Naidu and Reid, 1989).

Tuberose is a herbaceous perennial herb growing to a height of 0.5 to 1.0 m (Bailey, 1961; Dey, 1980; Wilkins, 1985). It has tuberous roots (Bailey, 1961). Leaves are mostly basal and 6-9 to a stem and are 30-36 cm long. They are clasping, grasslike and mostly basal (Wilkins, 1985). Flowering stems (spikes) are in clusters and are 60-96 cm long (Bailey, 1961; Naidu and Reid, 1989). A spike has 8-12 reduced leaves. The flowers are pure waxy white and tubular and are usually borne in pairs on a lax (loose) terminal spike which is 4-6 cm long (Bailey, 1961; Wilkins, 1985). The florets are borne in 15-20 pairs and have a distinct fragrance (Naidu and Reid, 1989). Florets open from the base upwards. Spikes are usually harvested when the lowest one or two floret open.

2.2 **Nitrogen in Plant Metabolism**

Nitrogen is vitally important in plant nutrition (Tisdale, *et al.*, 1985). It is central to the growth and

development of all plants and is usually required in high amounts (Huffaker and Rains, 1978). Plants normally contain 1-5% of this nutrient. It constitutes approximately 2% of the plant dry weight (Beevers and Hageman, 1969). It is absorbed into the plant in the form of nitrate (NO^-_3), ammonium ($NH4^+$) and urea (Tisdale, 1985; Webster, 1958) where it is utilised for amino acid production for protein synthesis. It is an essential constituent of amino acids, proteins, nucleotides, nucleic acids, amines and amides (Follet *et al.*, 1981). These are important components in the plant structure and therefore nitrogen is important in the growth and development of plants and without it plants grow very slowly (Salisbury and Ross, 1978).

Nitrogen is absorbed in the soil in highly oxidized forms and must be reduced by energy dependent processes before being incorporated into proteins and other cellular constituents (Salisbury and Ross, 1978). The absorbed NO^-_3 is reduced in the plant to NO^-_2 (nitrite) by nitrate reductase which is further reduced to ammonia by nitrite reductase giving a two stage reduction process (Beever, 1976a; Bray, 1983; James, 1963). This involves oxidation of NADH, to NAD. The ammonia thus produced unites with carbon compounds produced from photosynthesis to form amino acids. The first substance is usually σ-Ketoglutaric acid yielding glutamic acid (James, 1963). Glutamine synthetase and Glutamate synthase are the main pathway of ammonia

assimilation (Bray, 1983). Amino acids so synthesized serve as nitrogen sources for the plant and are built into proteins, alkaloids, chlorophyll and other complex substances.

2.3 **Nitrogen in Vegetative and Shoot Growth.**

Nitrogen markedly improves growth and flowering of many ornamental plants (Jana, *et al.*, 1974) and in others it may reduce vegetative growth and flowering (Bose and Roy, 1968). Poole and Seeley (1978) found that N concentration was the most important factor determining growth in three orchid Genera *Cattleya, Cymbidium* and *Phalaenopsis*. For *Phalaenopsis* and *Cymbidium*, 100 ppm N appeared to be adequate or near optimal for best plant growth giving 6.68g leaf dry weight and 53.4 cm plant height for *Cymbidium*. *Cymbidium* growth in 50 ppm N had a greater incidence of leaftip dieback of older leaves probably due to deficiency of N. Also, higher N application at 200 ppm resulted, in shorter *Cymbidium* plants with fewer leaves. The plant height reduced from 53.4 to 48.3 cm while leaf number reduced from 11.6 to 10.6 cm when N was increased from 100 to 200 ppm. Bik and Berg (1983) reported similarly that the increase of N from 4 to 6 mmol/l resulted in increased production of vegetative shoots in the orchid mini-cymbidium c.v. 'Pendragon Sikkim'.

In Hibiscus (*Hibiscus rosa-sinensis* L.) increase of N fertilizer resulted in the decrease of plant height and width, while fresh weight increased (Neumaier, *et al.*, 1987). 100 ppm N resulted in a plant height of 73 cm while 400 ppm N resulted in 70 cm.

In the 'Whitmanii' fern (*Nephrolepsis exaltata* L.) increasing N application from 150 to 450 ppm resulted in a decrease in the dry weight from 40.6 to 27.0 g while the N content in the leaves increased from 4.1 to 5.2% (Crockett, *et al.*, 1984).

In marigold (*Tagetes erecta*) plant height progressively increased with an increase in the dose of N fertilizer applied and the highest plant height of 76.0 cm was obtained when 40 g/m^2, of N fertilizer, the highest N level was, applied. The lowest height of 60.96 cm, was in the control (Arora and Singh, 1980).

Vegetative growth of *Alstroemeria* 'Marina' was significantly influenced by N topdressing and the total number of flowering and vegetative shoots increased (Kiara, 1989; Muhuhu, 1990). Control plots produced 108.0 shoots per hill while the plots topdressed with 78, 156 and 312 kg N/ha produced 120.4, 122.7 and 139.9 shoots respectively (Kiara, 1989). Muhuhu (1990) reported

similarly an increased number of vegetative and flowering shoots to an optimum with the application of N.

Bose and Roy (1968) found that N deficiency also reduced leaf production in *Dianthus, Coreopsis* and *Cosmos*. In *Coreopsis*, N deficiency reduced the number of leaves while in *Cosmos*, the number and size of leaves were significantly decreased.

In Dahlia, N deficiency resulted in marked reduction in plant growth causing significant reduction in the number of leaves on the main stem, smaller leaf size and leaf yellowing in the low N treatments (Jana, *et al.*, 1974). However high N levels significantly increased plant heights.

Jana, *et al.* (1974) also working on tuberose noted a marked reduction in leaf number with N deficiency. Increased N application resulted in improved leaf production and size. Similarly, Yadav *et al.* (1985) reported that plant height and the number of shoots and leaves per clump in the plant crop as well as in the ratoon crops showed gradual increase with increasing levels of N. Thus, maximum vegetative growth was noted with the highest N application of 300 kg N/ha. Bankar and Mukhopadhyay (1985) also found that plant height and the number of leaves was significantly affected by N application.

Tuberose plant height increased from 36.53 cm with 0g N/m^2 to 40.06 and 40.63 cm with 25 and 35 g N/m_2. Similarly the number of leaves increased from 26.82 to 35.92 and 40.12 leaves, respectively. Mukhopadhyay and Bankar (1985) also found that split N application increased the growth of tuberose. A three split application of N resulted in significantly superior plant height and number of leaves per plant.

2.4 **Influence of Nitrogen on Flowering**

Flowering is a very important aspect of most floricultural crops and especially those produced for their flowers as cutflowers since it determines the productivity of those plants. Flowering is affected by various factors including temperature, moisture availability, photoperiod, plant variety, soil type and mineral nutrition. It stretches from flower induction and initiation through flower development (growth of the inflorescence) to anthesis (flower opening). Nitrogen fertilization may affect these stages differently in different plants and thus influence their productivity and quality. This is important as it affects the income of the farmer.

In orchid mini-cymbidium c.v. 'Pendragon Sikkim', spike production was slightly higher at the highest N level of 8 mmol N/l (Bik and Berg, 1983). Increasing N level from 4 to 6 Mmol N/l sharply reduced the spike per shoot ratio

showing that flower initiation was adversely affected by N application. Spike length, fresh weight and flower/spike ratio also showed a negative response to N application. The time of flowering was also delayed as N rate was increased. Continuous fertilizer supply was superior for shoot production to interrupted supply while the converse was true for spike production, spike per shoot ratio and earliness of flowering. In *Cattleya* orchids, the dry weight of flowers was 1.28, 0.95 and 0.56 g with 50, 100 and 200 ppm of N application showing a decrease with increased N levels (Poole and Seeley, 1978).

Nitrogen was found to delay flowering of Chrysanthemums (Bunt, 1973a). In the variety 'Golden Princess Anne' and 'Dark Red Star', treatments resulting in high N levels in leaf tissue analysis gave delays of 12 and 28 days respectively. An increase of 1% leaf N in 'Golden Princess Anne' delayed flowering by 4 days. Lunt and Kofranek (1958) also reported that slight N deficiency in the first 7 weeks in Chrysanthemums may adversely affect the quality of the bloom. Also in Chrysanthemums 'Blue chip' increase in N level led to increased stem length, diameter and flower yield (Joiner and Smith, 1962), however it also delayed flowering.

In Hibiscus (*Hibiscus rosa-sinensis* L.), the days to

flowering were not affected by increasing N levels while the flower number per plant and flower diameter increased with increasing N levels (Neumaier, *et al.*, 1987). The flower diameter reached optimum with 300 ppm N and reduced with further N application when NPK fertilizer 20: 8.8: 16.6 was used, while with controlled release fertilizer C.R.F., the highest N level gave the greatest flower diameter showing different effect with different N sources.

In *Alstroemeria*, the average response of the number of flowering stems produced after N application was markedly increased (Bik and Berg, 1981). The response of the flowering stem length of two Alstroemeria cultivars 'Carmen' and 'Orchid' was negative while the fresh weight showed no N response in the first crop. The number of flowers per flowering stem also increased with increasing N levels. Kiara (1989) reported contrasting results with the length of flowering shoots of Alstroemeria which increased with N levels reaching an optimum with 156 kg N/ha. The percentage of flowering shoots increased with increasing N application but resulted in the delay of flowering, however, the number of cymes (florets) in an inflorescence increased. Split N application increased the number of flowering shoots per hill but did not affect, length of flowering shoots, onset of flowering and the

number of cymes per inflorescence (Kiara, 1989). Muhuhu (1990) found no significant effect of N application on the onset of flowering. But there was an increase in the number of flowering shoots per pot. No significant difference in the number of flowering shoots as a percentage of flowering shoots in *Alstroemeria* 'Carmen'was observed. The increase in spike length also was not significant while the number of florets per inflorescence only increased slightly.

In 'Edward' rose (*Rosa bourboniana* Desp.) all N.P.K. 3:6:6 treatments showed appreciable increase in flower yield over the control (Irulappan *et al.*, 1980b).

In marigold (*Tagetes erecta*) the number of flowers per plant in the unplucked fields was significantly improved by N treatments (Arora and Singh, 1980). This was also the case in the fields that were plucked regularly but here the N effect was more pronounced. The flower yield (kg/plant) was also significantly increased by increased N levels which meant that N was necessary for growth and flower production in marigold.

Chan *et al*, (1958) found that in carnations, increase in N levels upto 60 ppm caused an increase in the number of flowers. Blake and Harris (1960) also reported that low levels of N application caused a delay in flower bud

initiation in carnations. Similar results were obtained by Bose and Roy (1968) who found a 20 day delay in flowering of carnations when N was applied at 1/18 of the normal N, P, K level. Deficiency of NPK was also found to affect the number of flowers and the duration of flowering. They also obtained similar results with *Cosmos* and *Coreopsis* flowers.

In Tuberose, low N was found to supress flowering while high levels increased the number of spikes from the clump produced from each bulb (Jana *et al.*, 1974). The number and size of flowers also improved appreciably under high N application. The mean number of flowers per spike increased from 8.1 for the control to 11.6 at high N level. Similar results were obtained by Nanjan *et al.* (1980) who found a progressive increase in the number of flowers harvested with N application upto 100 kg N/ha. But the highest N dose of 200 kg N/ha resulted in a reduced yield. Yields increased from 6506.0 flowers with 0 kg N/ha to 7552.7 with 100 kg N/ha. Yadav *et al.* (1985) also reported that treatment of tuberose with N resulted in improved flowering. They reported that a gradual increase in spike length and yield of spikes and flowers was recorded with high N levels in the plant crop and the 1st and 2nd ratoon crops. The spike length was 74.0, 76.9, 81.3, 83.0 and 88.0 cm with 0, 50, 100, 200 and 300 kg N/ha, respectively.

Similarly spike yield per ha was 331.2, 364.0, 415.6, 490.6 and 545.3 flower stems and the flower yield/ha was 5.0, 5.9, 7.7, 9.8 and 12.4 tons, respectively. Bankar and Mukhopadhyay (1985) found that several flower quality parameters such as length of spike and rachis and the number and weight of florets improved significantly with increased N application. Mukhopadhyay and Bankar (1985) also found that split application of N resulted in increased spike yield and other floral quality parameters such as spike, and rachis length and the number of florets per spike. The best treatment was when N was applied in 3 split applications.

2.5 The Effect of Nitrogen on the Postharvest Quality of Cutflowers.

The life of cutflowers starts at harvest (Harkema, 1988) and the aim is to give the consumers the highest quality which is measured by the flower's beauty and length of vaselife. The terms normally used in evaluating the post harvest quality of cutflowers are longevity, shelflife, display life, vaselife, keeping quality and lasting quality (Halevy and Mayak, 1979). The terms are all numbered in days but both the criteria and conditions for measuring longevity are ill defined and in some studies, not clearly indicated. The most important conditions and those greatly affecting cut flower longevity include temperature, relative humidity (R.H.), light, air velocity and ethylene

concentration.

Ambiguity is found in the time of commencing measurements of flower longevity and the point of termination (Halevy and Mayak, 1979). Halevy *et al.* (1984) started their measurements of flower longevity of cyclamen flowers when pretreated flowers were placed in de-ionized water, while Woodson (1987) started evaluations 24 hours after the initiation of treatments. Also Woodson (1987) considered vaselife was terminated when the last open flower wilted and lost decorative value. Heuser and Evensen (1986) working on peony (*Paeonia* spp.) used petal abscission after vigorous shaking of the flower or petal wilt as the criteria to determine the end of vaselife. Han *et al*, (1990) considered vaselife of Brodiaea flowers to have terminated when the number of senescent flowers exceeded number of open flowers, while Mor *et al.* (1984) considered it to be when more than 5 florets wilted or when more than 8 flower buds or florets abscised.

Postharvest treatment of cutflowers is important and involves two conflicting roles, to enhance and ensure full opening of the flower and to postpone or delay onset of senescence to increase the vase life (Halevy and Mayak, 1979). The flower is a more complex organ than leaves, fruits, roots or seeds on which most studies on plant

senescence have been conducted (Mayak and Halevy, 1980). It includes usually a green calyx, achlorophyllus corolla, androecium, gynoecium and peduncle. Not all flower parts follow the same process of senescence. Termination of vaselife in many cutflowers is characterized by wilting even though they are constantly held in water (Halevy and Mayak, 1981) leading to the senescence of tissues. The most obvious symptoms of the final stage of senescence in petals is the loss of fresh weight, drying and wilting if abscission has not already occurred (Halevy and Mayak, 1979). Colour fading and discolouration is also an important factor in determining the display quality of cutflowers and therefore its occurrence results in the termination of vaselife of many flowers.

Senescence is a concert of related physiological and biochemical processes (Mayak, 1987) characterized by a loss of chlorophyll, decrease in protein and decline in RNA content (Beevers, 1976a; Beevers, 1976b) in leaves. Chloroplasts and free ribosomes are the first organelles to degenerate followed by the mitochondria and finally a disruption of the plasmalemma and nucleus (Beevers, 1976a; Bray, 1983). In petals, the first sign of aging is the invagination of the tonoplast indicating autophagic activity of the vacuole. Breakdown of the tonoplast results in release of hydrolytic enzymes which cause autolysis and result in cell death (Halevy and Mayak, 1979; Mayak and

Halevy, 1980). There is a drop in the level of macromolecular components starch, cell wall polysaccharides, proteins and nucleic acids as in senescing leaves.

The effect of N is variable in the keeping quality of various cutflowers. Kulwiec (1968) found no effect of N on keeping quality. Similarly no effect was found in "Caliente" roses (Armitage and Tsujita, 1979a) and Chrysanthemum (Joiner and Poole, 1965). On the other hand, the increase in N application linearly decreased the keeping quality of Chrysanthemums (*Chrysanthemum morifolium*) (Joiner and Smith, 1962; Waters, 1965). Conversely, Armitage and Tsujita (1979b) found that high N nutrition appeared to improve keeping quality in 'Forever yours' roses. Also, increased N rates decreased the longevity of cut Chrysanthemums in the dark but slightly increased their longevity in the light (Woltz and Waters, 1967). Kiara (1989) reported that the keeping quality of *Alstroemeria* 'Marina' was significantly improved by N topdressing. It significantly improved their vaselife and delayed the 50% yellowing of cutflowers leaves. The time between 50% leaf senescence and petal abscission was decreased from 13.3 days in the control to 15.0, 16.7 and 18.3 days with the application of 78, 156 and 312 kg N/ha respectively. However, Muhuhu (1990) found that N

application had no significant effect on the mean number of days to full opening of primary florets and the days to complete petal fall. There was only a slight increase with increasing N levels. However, the number of days to complete yellowing of leaves was significantly affected by N fertilization and increased with increasing N levels. This was attributed to increased content of chlorophyll in the leaves with high N application.

Plant hormones have varying effects on the vase-life of cutflowers (Muhuhu,1990) and may be responsible for the effect of N application on the postharvest quality of cutflowers. Ethylene has detrimental effect and is generally regarded as a senescence hormone (Baker, 1983; Halevy and Mayak, 1981; Mayak and Halevy, 1980; Mayak, 1987). Mayak (1987) reported that a climacteric rise in ethylene production signified the progression of senescence in carnation and 'Mercedes' roses. Mayak and Halevy (1980) mentioned that the onset of this phase signals the terminal step of senescence. Visual symptoms are usually pronounced toward the end of this phase. Whitehead *et al.* (1984) also found that at the climacteric peak in carnations the flower had started to wilt.

Cytokinins delay proteolysis and chlorophyll loss (Thimann, 1980). They also delay processes associated with senescence, thus maintaining cell integrity and decrease

sensivity to ethylene (Mayak and Halevy, 1980). Exogenous application of the cytokinin Benzyl Amino Purine directly to the flower bud delayed senescence of both fresh and aged rose flowers (Mayak and Halevy, 1970). Also, kinetin was found to delay fading of the cut rose (*Rosa* hyb cv. 'Golden Wave') and slowed down processes associated with both senescence and stress and maintained petal turgidity for an extended period (Mayak and Halevy, 1974). Richmond and Lang (1957) also found that kinetin reduced protein loss and that leaves supplied with kinetin retained their green colour thus preventing chlorophyll loss and thus extending their lifespan.

Auxins also influence senescence. Gilbert and Sink (1971) reported that the keeping quality of potted poinsettia (*Euphobia pulcherrima*) plants was related to the level of endogenous auxins and proposed that auxin concentration above a threshold level prevented senescence and abscision. Sacher (1973) reported that auxin in fruits is prominent as an endogenous senescence retardant as it counteracts the stimulatory effect of ethylene or abscisic acid on senescence. Auxin is thought to delay senescence by inducing synthesis of peroxidase which prevents the accumulation of free peroxide associated with aging (Halevy and Mayak, 1981; Mayak and Halevy, 1980). However, auxin levels only slightly above the physiological level

stimulates production of ethylene which in some tissues promotes senescence (Thimann, 1980). Also exogenous applied Indole acetic acid (IAA) was found to induce senescence in isolated carnation (*Dianthus caryophyllus* cv. White sim) petals by increasing the duration and amount of ethylene production (Wulster *et al.*, 1982).

The involvement of Gibberellins in flower senescence is not clear (Halevy and Mayak, 1981). Sacher (1973) suggested that Gibberellins may act in concert with auxin or alone in retarding senescence.

Abscisic acid (ABA) regulates the process of senescence (Baker, 1983; Halevy and Mayak, 1981; Mayak and Halevy, 1983). Control may be achieved via feedback mechanism where the rise in ethylene production is followed by an increase in the endogenous ABA production which suppresses ethylene production (Mayak and Halevy, 1972). Baker (1983) also reported that conditions which lead to deterioration of flowers such as exposure to ethylene and water stress produce higher levels of ABA. ABA was found to hasten senescence of carnation flowers (*Dianthus caryophyllus*) largely as a result of advancing the onset of autocatalytic ethylene production (Mayak and Dilley, 1976).

Very scant information is available on the postharvest of tuberose. Sambandamurthi and Appavu (1980) mention that tuberose has a high keeping quality but no information is given concerning its vaselife. Naidu and Reid (1989) working on postharvest handling of tuberose reported the abortion of many flower buds (florets) in normal display conditions, probably due to carbohydrate stress which limits the display quality of tuberose.

3.0 MATERIALS AND METHODS

3.1 Site

The study was conducted at the Muthithi plantation located close to Kiambu town and at the Field Station, University of Nairobi, College of Agriculture and Veterinary Sciences, Kabete.

The Kiambu farm is in the upper midland zone 3 (UM3) Agro-ecological zone which is the coffee zone. Here, good crop yields are obtained with additional irrigation provided by the closeby Riara River (Jaetzold and Schmidt, 1982). It is at an altitude of about 1520-1590 m above sea level and receives an average annual rainfall of 900-1100 mm per annum. In the year of study (1990) the rainfall recorded was 1125 mm (Appendix I). The mean annual temperatures are 19.0 - 19.5 ^{o}C. The mean temperature during the growing period was 19.3 (Appendix II).

The Kabete field station is at an altitude of 1910 m above sea level (Jaetzold and Schmidt, 1982). In the year of study the rainfall recorded was 1195.5 mm (Appendix I) and the mean temperature during the growing period was 17.7 ^{o}C (Appendix II).

The respective soil nitrogen status for Kiambu and Kabete were 0.23 % and 0.13%, respectively (Appendix III).

3.2 Plant Material and Culture

Tuberose bulbs harvested from earlier plantings were used for the study. Tuberose are true bulbs consisting of swollen leaf bases attached to a short stem, the basal plate, and covering the growing point. Divided bulbs were planted in raised beds which were 1.0 m wide at a spacing of 20 x 30 cm in plot sizes of 1.0 m^2. Farm yard manure was incorporated with DSP fertilizer and Furadan at 25 g/m^2 rate at planting. Planting was done in March 1990 in the 1st experiment and October 1990 in the 2nd experiment. The outer rows consisted of guard rows.

3.3 Cultural Practices

A standard basic N fertilizer was applied in the form of C.A.N. after 30 and 60 days after planting at 25 g/m^2. Irrigation was done twice a week when necessary to maintain a 8 cm depth of water. Dithane M45 was sprayed to control fungal diseases such as stem rot. Rogor M40 was applied at the rate of 35 ml/20l to control red spider mites. Hand weeding was done when necessary. Nitrogen treatments were done 5 months after planting on already established tuberose beds but before they came into flower production. This was to provide uniform tuberose beds and also to save time as tuberose takes about six months to start flowering (Dey, 1980).

3.4 Experimental Design

Experiment 1.

The effect of split applications of N fertilizer on growth, flowering and postharvest quality of Tuberose: There were three treatments as follows: single (non split) application, two-split application and four split application of N. Nitrogen was applied as N: P: K fertilizer 17:17:17 and applied at a level of 50 g/m^2 for each treatment. This was split into applications of 50 (non-split), 25 (two-split) and 12.5 (four-split) g/m^2. This gives N levels of 85, 42.5 and 21.25 kg N/ha, respectively. This was applied at monthly, 2 weekly and weekly intervals, respectively. Treatments were continued for 2 months and data collection started one month after treatments commenced. The experiment was designed in a randomized complete block design (R.C.B.D.) with 4 replications (Gomez and Gomez, 1984).

Experiment 2.

The influence of N levels on growth, flowering and postharvest quality of tuberose: 0, 12.5, 25 and 50 g/m^2 of complete NPK fertilizer 17:17:17 were used to give the N levels of 0, 21.25, 42.5 and 85 kg/ha of N, respectively.

The experiment was designed in a R.C.B.D.with 4 replications (Gomez and Gomez, 1984). The experiment was conducted in Kiambu and Kabete (planted 30/10/90).

Treatments were applied at 2 week intervals for 3 months. Data collection begun one month after the onset of treatments. For both experiments spikes were harvested when the lowest one or two florets opened. Data were taken at harvesting on 5 stems (spikes) . Five plants from each treatment were used to obtain data. The outer rows consisted of guard rows.

Laboratory Experiments.

Cutflowers were harvested in the morning and brought into the laboratory within 2 hours. They were recut to a standard height of 75 cm and the leaves within the lower 15 cm were defoliated. They were then immediately placed into the vase-solution. The vase-solution contained 0.4% sucrose with sodium hypochlorite as biocide. Four grams of commercial sucrose was dissolved in one liter of water to make the vase solution (Chepkairor, 1986). This was maintained at 15 cm level in each vase. Five stems from each treatment were used for the study. Stems were observed each day for deteriorative changes. Vaselife was considered terminated when the last open floret wilted and lost decorative value (Woodson, 1987).

Laboratory Conditions.

The relative humidity was 70 ± 10% while the temperature was 21 ± 1 ^{o}C. There was continuous lighting with cool white fluorescent lamps of 40 W.

3.5 **Parameters for Observation.**

Plant growth:

1. Leaf length (Average of Ten basal leaves/plant,5 plants)
2. Number of basal leaves (Average of 5 plants). The number of basal leaves produced by the bulb.

Flowering:

1. Length of spike/cm (The length of the inflorescence from the base to the top at harvesting)-meter rule
2. Rachis length/cm (length of flowering portion of spike)-meter rule
3. Spike diameter/mm (Average of the top and base of spike)-vernier calipers (Plate I & II)
4. No. of leaves per spike (the number of leaves on each inflorescence of five plants/plot)
5. No. of florets per spike.(Counting the number of florets per spike, Plate II)
6. 'Colour' of distal florets. By visual colour rating 1 - lowest, 5- brightest.Comparing the intensity of the pink colouration (Plate I) to pre-set standards
7. 'Size' of distal florets, Size classes < 5mm 1; 5-10 mm 2; 10-15 mm 3; 15-20 mm 4; > 20mm 5.
8. No of days from spike appearance to anthesis. Flowers were tagged at spike appearance and the date noted and days to anthesis determined.

Postharvest Quality:

1. Number of days to the senescence of sepals (when 50% of the sepals are senesced). The number of days from initiation of vase treatments to onset of sepal senescence.(Plate IV)
2. Number of days to the yellowing of unopen distal (terminal) florets.(Plate III)
3. Number of days to senescence of unopen distal florets. (Plate IV)
4. Number of days to wilting and senescence of the last open floret (vase life).(Plate V)
5. % Opening of the florets at the end of vaselife. The number of florets as a percent of all florets at the end of vase life.(Plate V)
6. Number of dry and senesced florets. The number of florets that have dried and senesced by the of vaselife.(Plate V)

Yield:

1. No. of spikes per plot

3.6 **Data Analysis.**

Data analysis was done according to Gomez and Gomez,(1984). The analysis of variance done was for the influence of the Rate of N fertilization (N level) on the growth, flowering and postharvest quality . Analysis of variance was also done on the influence of split N application on the growth flowering and postharvest quality of tuberose.

Mean separation was done according to Duncan's Multiple Range Test, 5% level (Gomez and Gomez, 1984).

Plate I: Tuberose cut flower

- shows the one open floret harvesting index.
- stem size of 75 cm.
- defoliation of the bottom 15 cm.
- The rachis - flowering portion of the spike

Plate II: Distal floret colour and size.

- The topmost or distal florets are observed to have pink colouration. The intensity was determined by visual colour rating.
- The size of distal floret was classified in size classes.

Plate III: Yellowing of distal florets.

- The distal floret are observed to have lost their pink colour and have begun to yellow.
- The period to yellowing of distal floret was measured in days.

Plate IV: Senescence of sepals and distal florets.

- The topmost or distal florets are observed to have dried and senesced. The period to senescing of florets was measured in days.#
- The sepals at the base of the distal florets are also seen to have senesced. The period to senescence of the sepals was also measured in days.

Plate V: Wilting and senescence of the last open floret.

- **When all open florets have wilted and senesced. The period to wilting and senescence of all open florets was recorded in (days).**
- **The number of open florets as a percent of all florets per spike was recorded as percent open florets.**
- **The number of florets that dried and senesced was also recorded.**

4.0 RESULTS

4.1 The Influence of Nitrogen on Growth and Flowering of Tuberose

Length of leaves: In Kabete, leaf length tended to increase with increasing N levels until the 42.5 kg N/ha level, but this was not significant (Table 1). Leaf length increased from 38.2 cm to 39.2, 40.5 and 38.2cm with the application of 0, 21.25, 42.5 and 85.0 KgN/ha. Treatments with low or no N application resulting in the yellowing of leaves.

Number of basal leaves: Both the Kabete and Kiambu tuberoses showed no significant difference in the number of basal leaves at all levels of N application. The mean number of basal leaves was 14.4 in Kiambu and 14.0 at Kabete (Table 1 & 2).

Period from spike emergence to anthesis: There was no significant difference in the period from spike emergence to anthesis for both the Kiambu and Kabete grown tuberoses. The period from flower bud appearance to the opening of the first floret was 36.8 days in Kiambu and 43.1 days in Kabete showing that the growth rate was faster in Kiambu (Table 1 and 2). There was no significant difference in the period as influenced by N levels showing that it was not influenced by this factor.

Spike length: In both Kiambu and Kabete, the length of spikes tended to increase with increasing N levels upto 42.5 kg N/ha (Table 1). Further N application tended to reduce spike length. Spike length tended to increase from 95.6cm to 98.7, 107.9 and 104.3cm with the application of 0, 21.25, 42.5 and 85.0 KgN/ha at Kabete. Similarly, spike length increased from 98.2cm to 100.2, 101.4 and 97.4cm with similar N applications at Kiambu.

Rachis length: The effect of N application on rachis length was similar to that on spike length. In both Kabete and Kiambu, the rachis length tended to increase with increasing N level upto 42.5 kg N/ha after which further N application resulted in reduced rachis length (Table 1and 2). Rachis length increased from 23.3cm to 24.0, 26.1 and 27.0cm with the application of 0, 21.25, 42.5 and 85.0 KgN/ha at Kabete. The increase in rachis length was not significant.

The mean rachis length of tuberose in Kabete and Kiambu were 24.8 and 26.5 cm showing that Kiambu tuberoses tended to have longer rachis (Table 1 & 2).

Spike diameter: In Kiambu, the spike diameter was not significantly increased with increasing N levels (Table 2). Spike diameter tended to increase upto 21.25 kg N/ha after which it declined.

In Kabete, the application of 0, 21.25, 42.5 and 85.0 kg N/ha of NPK significantly increased spike diameter from 8.5 mm to 9.4, 9.5 and 9.7 mm, respectively (Table 1). All levels of NPK promoted a significant increase of spike diameter over the control. The difference in spike diameter between Kabete and Kiambu spikes was wide with Kiambu spikes yielding a mean diameter of 8.6 mm while Kabete spikes yielded 9.3 mm.

Leaves per spike: The number of leaves per spike was not significantly affected by N level at Kabete and Kiambu. The mean number of leaves per spike were 11.4 and 12.2 in Kiambu and Kabete, respectively (Table 1 and 2). Leaf number was thus not influenced by N application.

Number of florets per spike: Increase in N level had no significant effect on floret number per spike. The mean number of florets per spike in Kiambu and Kabete were only slightly different and was 41.2 and 40.7 florets per spike, respectively (Table 1 and 2).

Colour of distal florets: The distal floret colour (Plate II) decreased N application in Kabete. The distal floret colour rating decreased from 3.7 to 3.4, 3.2 and 3.4 units with the application of 0, 21.25, 42.5 and 85.0 KgN/ha at Kabete. The colour of distal florets was more intense in Kabete than Kiambu (Table 1 & 2).

Size of distal florets: The average size of distal florets (Plate II)given by various size classes was not significantly affected by N level. However, increased application of N resulted in the increase in size of distal florets. The distal floret size increased from 1.5 to 1.9, 2.1 and 2.3 units with the application of 0, 21.25, 42.5, and 85.0 KgN/ha at Kabete. The mean distal floret size was greater in Kiambu than Kabete.

Table 1: The Influence of N Levels on Tuberose Growth Flowering & Postharvest Quality in Kabete

Parameter	N levels(Kg N/ha)				
Growth and flowering	0	21.25	42.5	85.0	Mean
1.Leaf length (cm)	38.2a	39.2a	40.5a	38.2a	39.1
2.Number of basal leaves	14.5a	14.3a	13.3a	13.9	14.0
3.Spike emergence to anthesis (days)	42.2a	42.7a	43.3a	43.3a	42.9
4.Spike length (cm)	95.6a	98.7a	107.9a	104.3a	99.2
5.Rachis length (cm)	23.3a	24.0a	26.1a	27.0a	24.8
6.Spike diameter (cm)	8.5b	9.4a	9.5a	9.7a	9.3
7.Leaves per spike (number)	12.4a	12.1a	12.0a	12.3a	12.2
8.Florets per spike (number)	42.2a	41.7a	39.6a	39.4a	40.7
9.Distal floret colour	3.7a	3.4a	3.2a	3.4a	3.4
10.Distal floret size	1.5a	1.9a	2.1a	2.3a	1.9
Postharvest Quality					
1.Senescence of sepals (days)	1.9b	4.0a	5.3a	5.3a	4.1
2.Yellowing of Sepals (days)	4.4a	4.5a	4.6a	4.7a	4.6
3.Senescence of distal florets (days)	6.5b	7.0a	7.2a	7.3a	7.0
4.Senescence of last open floret	14.8a	14.3a	14.1a	13.5a	14.2
5.Open florets (%)	48.6a	48.6a	47.6a	45.3a	47.5
6.Dry & Senesced florets (number)	15.3a	15.4a	15.3a	14.6a	15.1
Yield					
1.Spikes per m^2	11.0a	10.7a	12.3a	12.0a	11.5

[z] -Mean separation within rows by Duncan's Multiple Range Test (5%)

Table 2: The Influence of N Levels on Growth, Flowering & Postharvest Quality of Tuberose in Kiambu

Parameter	N levels(Kg N/ha)				
Growth and flowering	0	21.25	42.5	85.0	Mean
1.Leaf length (cm)	30.6a	28.1a	28.6a	27.3a	28.7
2.Number of basal leaves	14.8a	15.0a	13.7a	14.5	14.5
3.Spike emergence to anthesis (days)	37.2a	36.9a	36.3a	37.9a	37.1
4.Spike length (cm)	98.2a	100.2a	101.4a	97.4a	99.3
5.Rachis length (cm)	26.0a	27.7a	26.8a	25.7a	26.5
6.Spike diameter (cm)	8.6a	8.6a	8.6a	8.5a	8.6
7.Leaves per spike (number)	11.9a	11.4a	11.1a	11.2a	11.4
8.Florets per spike (number)	42.5a	41.8a	40.3a	40.3a	41.2
9.Distal floret colour	2.7a	2.6a	2.6a	2.7a	2.6
10.Distal floret size	2.5a	2.4a	2.3a	2.5a	2.4
Postharvest Quality					
1.Senescence of sepals (days)	3.9a	4.3a	4.9a	4.8a	4.4
2.Yellowing of Sepals (days)	3.8a	4.2a	4.2a	4.3a	4.1
3.Senescence of distal florets (days)	6.4a	6.2a	6.5a	6.1a	6.3
4.Senescence of last open floret	11.7a	10.4a	10.0a	11.2a	10.8
5.Open florets (%)	37.4a	35.2a	32.1a	34.5a	35.6
6.Dry & Senesced florets (number)	14.8a	15.4a	13.1a	14.1a	15.6

[1] -Mean separation within rows by Duncan's Multiple Range Test (5%)

4.2 Postharvest Quality

Senescence of sepals: Senescence of sepals (Plate IV) tended to delay with increased application of Nitrogen in both Kabete and Kiambu. In Kabete, the period to senescence of sepals increased significantly with the increase of the levels of N applied (Table 1). The application of 0, 21.25, 42.5 and 85.0 kg N/ha of NPK delayed senescence of sepals from 2.0 days to 4.0, 5.0 and 5.0 days, respectively. Application of 42.5 and 85.0 kg N/ha of NPK significantly delayed the senescence of sepals over the control.

The average period to senescence of sepals was 4.4 and 4.1 days in Kiambu and Kabete, respectively. Treatments with low or no N application were observed to have sepals at various stages of senescence even at harvest. Nitrogen treatments therefore delayed the onset of senescence of sepals and thus improved the keeping quality.

Yellowing of unopen distal florets: The period to yellowing of the unopen distal florets (Plate III) similarly tended to increase with the application of N in Kabete and Kiambu. However, the extent of delay of yellowing induced by N level was not statistically significant. The mean period to yellowing of distal florets was 4.1 days for Kiambu and 4.6 for Kabete. Nitrogen treatment thus tended to delay the onset of yellowing of distal florets.

Senescence of distal florets: The period to senescence of distal florets (Plate IV) at Kabete significantly increased with the increase in N level to a maximum at the highest N level of 85 Kg N/ha (Table 1). However at Kiambu no such responce was observed. In Kabete, the application of 42.5 and 85.0 kg N/ha of NPK significantly delayed the senescence of distal florets over the control. The application of 0, 21.25, 42.5 and 85.0 kg N/ha of NPK delayed the senescence of distal florets from 6.5 days to 7.0, 7.2 and 7.3 days. The average period to senescence of distal florets at Kabete and Kiambu was 7.0 and 6.3 days, respectively. Nitrogen treatments thus tended to delay the onset of senescence of distal florets.

Wilting and senescence of the last open floret: The period to wilting and senescence of the last open floret (Plate V) was not significantly affected by N application in Kiambu and Kabete. The period was 10.8 and 14.2 days for Kiambu and Kabete, respectively (Table 1 and 2).

Percent open florets: The percent open florets (Plate V) was not significantly influenced by N application at Kiambu and Kabete.

Number of dry and senesced florets: The number of dry and senesced florets (Plate V) were not significantly reduced by increasing N levels. The mean number of dry and

senesced florets at Kabete and Kiambu was 15.0 and 14.6 florets, respectively.

Yield of cut tuberose spikes: The yield of tuberose spikes in Kabete was not significantly affected by N treatment. Nevertheless, the spike yield tended to increase with increasing levels of N upto 42.5 kg N/ha, then decreased thereafter.

4.3 **The Influence of Split N Application on Tuberose:**

Growth and flowering: Spike length showed significant response to split N application (Table 3). Spike length increased from 104.3 cm with non-split application to 111.8 cm with 4 splits of N application.

There was also a significant increase in rachis length with split N application (Table 3). Rachis length increased from 20.6 cm with non-split to 25.1 cm with 4 splits of N application.

The spike diameter was also significantly influenced by split N application (Table 3). Spike diameter increased from 7.9 mm with non-split application to 9.3 mm with 4 splits of N application.

The number of florets per spike also tended to increase with split N application but the increase in floret number per spike was not significant.

Postharvest quality: The period to senescence of sepals, yellowing of distal florets and senescence of distal florets were not affected by split application of N. However, the period to the wilting and senescence of the last open floret decreased with split N application. However, the decrease was not significant.

The yield of tuberose spikes increased with split N application (Table 3). The number of spikes increased from 17.5 spikes with non-split to 23.8 spikes with 4 splits of N application, respectively thus giving significant increase in the number of spikes.

Table 3: The Influence of Split N Application on the Growth Flowering and Postharvest Quality of Tuberose.

Parameters	Non-split	2-split	4-split
Growth and Flowering		z	
1. Length of spike(cm)	104.3a	104.3a	111.8b
2. length of rachis(cm)	20.6a	21.9a	25.1b
3. Diameter of spike(cm)	7.9a	8.3a	9.3b
4. No. of flowers/spike	41.2a	41.8a	44.3a
Postharvest quality			
1. Days to senescence of sepals	6.1a	5.9a	6.0a
2. Yellowing of terminal florets (Days)	4.7a	4.8a	4.7a
3. Senescence of terminal florets	7.1a	7.3a	6.6a
4. Vaselife (Days)	12.6a	10.9b	10.7b
5. Total No. of open florets	14.0a	13.3a	11.1a
. Yield of stems	17.5a	18.0a	23.8b

Mean separation within rows by Duncan's Multiple nge Test (DMRT), 5% Level.

5.0 DISCUSSION

5.1 The Influence of N Application on Growth and Flowering of Tuberose:

Leaf length: Leaf length, tended to increase with the increasing levels of N applied. This indicated that N is important in the growth of foliage in tuberose and that the increase in N levels results in increased substrate for further leaf growth.

Jana, *et al.* (1974) similarly observed that increased N application resulted in improved production and leaf size of tuberose. Yadav *et al.* (1985) also found that leaf length of tuberose showed gradual increase with increasing levels of N and that maximum vegetative growth was observed with the application of the highest dose of N. Plant height increased from 34.6 cm to 40.4, 44.0, 46.0 and 52.7 cm with the application of 0, 50, 100, 200 and 300 Kg N/ha, respectively. Bankar and Mukhopadhyay (1985) also found that the plant height increased with N application in tuberose. Here, plant height increased from 36.53 cm to 40.06 and 41.63 cm with the use of 0, 25 and 35 gN/m^2, respectively. Jana *et al.* (1974) observed that N deficiency resulted in marked reduction of plant growth. Jana *et al*,(1974) also observed that N deficient plants had smaller leaves which abscised earlier than those in full nutrient

solution. He also reported that nitrogen deficiency resulted in the yellowing of tuberose leaves. Conversely, high doses of N, P, K significantly increased the plant height of tuberose.

Similarly, the highest plant height of 76.00 cm in marigold (*Tagetes erecta*) was recorded under the highest N level of 40 g N/m^2 and the lowest height of 60.96 cm in the control as plant height progressively increased with increasing N levels (Arora and Singh, 1980).

Bik and Berg (1981) found a distinct increase of leaf N content with increased plant growth as a result of raising the N fertilizer levels in Alstroemeria. The percentage of leaf N increased to 3.26, 3.84, 4.59 and 4.98% in variety 'Carmen' and 3.35, 4.29, 5.39 and 6.40% in 'Orchid' with the use of 60, 140, 220 and 300 Mg N/pot/week.

Basal leaf number: Nitrogen levels did not show any significant effect on the number of basal leaves of tuberose. It appears that the number of basal leaves of tuberose is not influenced by N. This may be due to the fact that N treatments were commenced when tuberose plants were five months old and the number of leaves per plant were already determined. At this time the bulbs may have already produced the maximum number of basal leaves at that

level of fertilization and were just about to come into flower production. Other authors have reported an increase in the number of basal leaves of tuberose with increased N application. Yadav, *et al*. (1985) reported that the number of leaves per clump increased gradually with increased levels of N for the plant crop and first and second ratoons. The number of tuberose leaves increased from 50.9 to 59.0, 71.5, 78.5 and 90.0 with the application of 0, 50, 100, 200 and 300 kg N/ha, respectively. The number of leaves per clump in the first ratoon crop was even higher. Conversely, Jana, *et al*. (1974) found that N deficiency led to a marked reduction in leaf number. Bankar and Mukhopadhyay (1985) also reported a significant increase in the number of tuberose leaves as compared to the control with the increased N application . Here, leaf number increased from an average of 26.82 leaves to 35.95 and 40.12 with the application of 0, 25 and 35 gN/m^2. In all these instances, half of N dose was applied before or during planting and the other dose was applied at spike emergence.

Therefore, it appears that N may affect the number of leaves produced from each clump or bulb at the early stages of sprouting and the later application may only influence leaf length.

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Therefore, it appears that N may affect the number of leaves produced from each clump or bulb at the early stages of sprouting and the later application may only influence leaf length.

Length of the spike, rachis and spike diameter: The spike and rachis length and the spike diameter were characteristics of flower quality that tended to increase with increased N levels at both Kiambu and Kabete. Spike diameter was significantly influenced by increasing N levels in Kabete.

Therefore, it is apparent that N is very crucial for the growth of tuberose inflorescence and determines its major quality characteristics. Increase in N levels resulted in concomitant increase in spike length upto 42.5 kg N/ha after which no further length increases were observed. Nitrogen is utilized in the production of enzymes, growth substances such as hormones and structural components of plants. Increased N may promote increased cytokinin production since cytokinin has a high N content (Miller *et al.*, 1956). Cytokinins have been known to have characteristic physiological effect to permit cytokinesis and continuous growth of various plant tissues (Miller et al., 1956). Cytokinins have also been found to increase protein synthesis by 35% in tobacco (MaaB and Klambtt, 1977) and thus may have been responsible for the increased growth in tuberose. They have also been reported to promote inflorescence development in Bourgainvillea (Ramina *et al.*, 1979). Therefore increased N application may have resulted in the increased production of cytokinins. This may have

caused the observed increased plant growth. Similar results have been obtained by other workers in tuberose. Yadav *et al.*, (1985) found that there was a gradual increase in spike length with higher N levels in tuberose. The length of tuberose spike increased from 74.0 cm to 76.9, 81.3, 85.0 and 88.0 cm with the application of 0, 50, 100, 200 and 300 Kg N/ha, respectively. Bankar and Mukhopadhyay (1985) also reported a significant increase in spike and rachis lengths with the increasing N levels. They reported the increase of rachis length from 19.66 to 22.57 and 23.54 cm and spike length from 72.48 to 81.91 and 82.73 cm with the application of 0, 25 and 35 gN/m^2, respectively.

For most crops, increments of N application result in increased plant growth upto a point when N concentration in tissues becomes toxic or other factors necessary for plant growth become limiting (Poole and Seeley, 1978). Bik and Berg (1981) reported an increase in the length of flowering stems of Alstroemeria 'Orchid' second crop while the first crop of both 'Orchid' and 'Carmen' cultivars decreased with increasing N applications. Bik and Berg (1983) also reported a negative response to N application in the Orchid Mini-cymbidium cv. 'Pendragon-sikkim' for both spike length and spike fresh weight. Spike length reduced from 43.9 to 41.8 and 40.0 cm with the application of 4, 6 and 8 Mmol N/litre in nutrient solution. Similarly, freshweight also

reduced from 75.1 to 69.8 and 64.8 g, respectively. This was attributed to the limiting conditions. Limiting conditions may have thus set in beyond 42.5 kg N/ha and thus no further increase was observed. This may include toxicity due to the presence of high soluble salt content in the medium. Joiner and Poole (1967) obtained reduction in stem length of Chrysanthemum with N application due to root injury occassioned by high soluble salt content in the medium.

Spike and rachis lengths and spike diameter are important plant quality parameters. Spike length is important in determining cutflower grade with longer spikes being more marketable (Chepkairor, 1986; Kiara, 1989). Long spikes and rachis are also sought by many tuberose buyers. On the other hand spike diameter may determine postharvest vaselife of cut flowers and has been included as a parameter of quality (Naidu and Reid, 1989). Thus, increased N application improves greatly the quality of tuberose cutflowers.

Period from spike emergence to anthesis: The period from spike emergence to anthesis was not significantly affected by N levels . However, stems grown in Kiambu and Kabete displayed wide differences. This may have been due to environmental differences at the two locations and especially temperature. Temperature has been known to

affect the rate of flower development (Bunt, 1973b; Kosugi and Kimura, 1961). The rate of flower development was found to be temperature dependent in carnations (Bunt, 1973 b). High temperatures were reported to be necessary for flower initiation, development and maturation in tuberose (Kosugi and Kimura, 1961).

The mean temperature during the growing period was 19.3 and 17.7 °C for Kiambu and Kabete respectively (Appendix II). The rate of spike growth was thus faster at Kiambu than Kabete. Similar results were obtained by Runger and Albert (1975) who found that flower development was faster in higher temperature environment for *Euphorbia fulgens*. Powell and Bunt (1978) also reported that raising temperature from 11 °C to 13 °C advanced flowering by 10 days in *Pelargonium x Domesticum* flowers. Berninger (1979) also reported that the maturation period of Gerbera flowers and the elongation rate were increased by higher temperatures.

Number of leaves per spike and florets per spike: Bailey (1961) estimated the number of leaves per tuberose spike to be 8 to 12. This concurred with the current study where leaf numbers ranged from 9 to 13. The number was not significantly influenced by N levels. It thus appears that N does not influence the number of leaves on the spike.

The number of florets per spike was not significantly influenced by N levels. However, the number of florets tended to decrease with increasing application of NPK. Bankar and Mukhopadhyay (1985) reported that the number and weight of florets significantly increased with increasing N levels. They obtained 34.46, 41.95 and 41.51 florets with the application of 0, 25 and 35 gN/m^2, respectively. Application of P resulted in 39.52, 40.00 and 38.41 florets with the application of 0, 60 and 80 gP/m^2, respectively. Thus, a high P application reduced the number of florets per spike.

In the current study, the number of florets was not significantly influenced by N levels, however, it tended to decline with increased NPK application. At high NPK levels there was reduced number of florets per spike at Kabete. The reduction may have been due to the P component of NPK inducing a reduced number of florets at the high NPK levels. Similar effect has been reported in Azalea and Chrysanthemums where high P was found to be unfavourable to flower development (Kinet, *et al.*, 1985). Hill *et al.* (1934) also reported that an increase of N and P application in Chrysanthemum caused a decrease in the number of blossom buds as compared to increasing N application alone. High P was also found to reduce flower grades and the number of cutflowers in greenhouse roses (Johansson, 1979). However, at Kiambu such an effect was not clearly discernable.

Distal floret 'colour' and 'size': The distal (terminal) florets yellowed and senesced prematurely in the vase and therefore reduced the aesthetic value and shortened the keeping quality of the tuberose cutflower. The distal floret 'colour' and 'size' were suggested as simple parameters which could be used as indicators to predict the expected vaselife of the cutflower. Nitrogen application was hoped to promote the development of the distal florets to full maturity. The maturing of the distal florets would then lead to the delay of their yellowing and senescence and probably result in the full opening of the spike. This would improve postharvest quality. The intensity of the pink colour of the distal floret and its size were hoped to indicate the level of floret maturity at spike harvest and therefore indicate its postharvest quality.

The intensity of the pink colouration in the distal floret determined by visual colour rating declined with increasing N application. Also distal floret colour was more intense in Kabete than at Kiambu.

The pink colouration of the unopen distal florets of tuberose was and was due to anthocyanin pigments which are the intensely coloured sap soluble glycoside plant pigments responsible for most scarlet, crimson (purple), mauve and

blue colouring in higher plants (Harbone, 1976). Anthocyanin level has been found to decrease with increasing N application in 'Early Black' cranberry fruits (Eck, 1976). Eck (1976) attributed this to the shading effect of the increased foliage stimulated by increased N supply. Similarly, Biran and Halevy (1974a) also found that darkening or removal of leaves resulted in inhibition of pigmentation in 'Baccara' roses. They postulated that shading of leaves reduced photosynthesis and consequently reduced sugar content which in turn caused decreased pigmentation. Similar results were obtained by Biran *et al.* (1973) and Biran and Halevy (1974 b). Therefore, increasing N level which resulted in increased vegetative growth of tuberose resulting in a bushy appearance may have enhanced shading of the lower leaves and this adversely affected anthocyanin production in tuberoses. This is especially so since tuberose leaves are mostly basal and are borne in rosette form (Wilkins, 1985).

The difference between the intensity of the pink colour of distal florets of Kiambu and Kabete spikes may have been due to different temperatures at the two locations. Temperature has been known to influence the level of anthocyanins in flowers (Biran *et al.*, 1973; Biran and Halevy, 1974a; Biran and Halevy, 1974b). High temperatures decreased the concentration of cyanin in

'Baccara' roses (Biran and Halevy, 1974b) while low temperatures enhanced pigmentation (Biran and Halevy, 1974a). Biran and Halevy (1974a) postulated that low temperatures prolonged the period in which pigments were synthesized by increasing the time required for flower development until flowering. Since Kabete was at a lower temperature (17.7 $^{\circ}$ C) than Kiambu (19.3 $^{\circ}$ C) flower development took longer (43.8 days as compared to 36.7 days in Kiambu) and thus had enhanced pigmentation.

On the other hand, the distal floret size for both Kiambu and Kabete tuberoses increased with increasing N levels although it was not significantly different. Increased application of N may have led to increased plant growth resulting in the production of larger florets. Also, higher N levels promoted the production of longer and thicker spikes with longer rachis which were able to bear larger distal florets.

5.2 **Postharvest Quality**

The periods to complete senescence of sepals and yellowing and senescence of the unopen distal florets: The postharvest periods to complete senescence of sepals and yellowing and senescence of the unopen distal florets all tended to increase with increasing N application and resulted in delaying of each of these deteriorative

phenomena. Since the aesthetic value of tuberose cut flowers is negatively affected by these deteriorative processes, application of N thus enhanced the keeping quality of cutflowers. This is because colour fading and discolouration are an important factor in determining the display quality of cutflowers and in many cases are the major reason for the termination of vaselife (Halevy and Mayak, 1979).

The delay in the onset of the senescence of sepals and the yellowing and senescence of the unopen distal florets may be due to the influence of N on the various plant hormone levels (Muhuhu, 1990). These hormones have various effects on plant senescence.

Increasing N levels may have resulted in increased cytokinins in the plants thus resulting in delayed senescence. This is because cytokinins which are purine derivatives with high N content in their molecular structure (Miller *et al.*, 1956) may have been increased by increased N application. Decrease of cytokinins with N deficiency has been reported by Wagner and Michael (1971). Thus, increased cytokinin content of the spikes resulted in the delay of yellowing by preventing chlorophyll loss and the delay of senescence by delaying protein loss in the sepals and the unopen distal florets.

The delay in yellowing may also have been due to the increase in chlorophyll content with increases of N levels. Muhuhu (1990) found that increased N application resulted in increased chlorophyll content of Alstroemeria leaves and resulted in the delay of complete leaf yellowing. The number of days to the complete leaf yellowing increased to 12.42, 17.21, 23.01 and 23.47 days with the application of 0, 0.25, 0.50 and 0.75 g N/pot, respectively. This was attributed to increased cytokinin level in cutflowers which delayed chlorophyll breakdown and hence delayed leaf senescence. Chlorophyll formation has been known to be promoted by cytokinin treatment (Fletcher and McCullagh, 1971). High N application has also been found to delay yellowing in Kalanchoe (Sheehan and Nell, 1979). High foliar N content has been associated with higher keeping quality in 'Forever yours' roses (Armitage and Tsujita, 1979b). Also increased N application has been found to result in increased leaf and flower N content (Waters, 1965; Woltz and Waters, 1967) and increased chlorophyll content (Woltz and Waters, 1967) and resulted in increased keeping quality in the light.

Delay in yellowing and senescence of leaves may also have been achieved by interaction with other phytohormones. Halevy and Mayak (1973) reported that senescence of petals was controlled by at least 3 phytohormones, wich include cytokinins, ethylene and ABA. ABA is known to increase with

N deficiency (Goldbach *et al.*, 1975) while cytokinins decrease (Wagner and Michael, 1971). Kinetin treatment was found to prevent increase in ABA level showing possible cytokinin control of the inactivation or synthesis of ABA (Even-chen and Itai, 1975). In the current study the level of ABA which is high in low N treatments and which may result in enhancing the rate of yellowing and senescence in those treatments is thus controlled by cytokinin in the high N treatments thus delaying the rate of senescence.

Percent open florets and the number of days to wilting and senescence of the last open floret: The percent open florets were not significantly influenced by N levels. However, there was a decrease in percent open florets with an increase in N levels. Naidu and Reid (1989) reported that solution uptake in tuberose was positively correlated with the size of the flower spikes and that high uptake resulted in increased opening of florets and better display quality. In the current study increase in N level resulted in increase in the spike and rachis length and the spike diameter. Therefore, this increase may have resulted in increased solution uptake and subsequently we would expect the increased opening of florets. However we obtained contrasting results.

The percent open florets was higher in Kabete than at Kiambu. This may have been due to the larger spike diameter

of the Kabete spikes resulting in increased solution uptake and subsequently the increased opening of florets.

On the other hand, the period to the wilting and senescence of the last open floret was not significantly influenced by N treatments. This is not a very important stage as by this time the distal florets are already senesced and the rest of the open florets are wilted and thus the cutflower has already lost its aesthetic value for the customer (Plate V). However, this severe endpoint of longevity was selected in order that treatment differences could be fully recognized (Woltz and Waters, 1967). Plots topdressed with NPK showed a slight reduction in the period to wilting and senescence of the last open floret with increasing N application but this was not significant. The keeping quality of 'Caliente' roses (Armitage and Tsujita, 1979) and Chrysanthemum (Joiner and Poole, 1967) flowers was not significantly affected by increasing N treatments. On the other hand N treatments have been found to be detrimental to the keeping quality of Chrysanthemum 'Blue chip' (Joiner and Smith, 1962; Waters, 1965). Therefore, although N increase was found to result in the delay of yellowing and senescence of sepals and of the distal unopen florets, it may not influence or may have some detrimental effect on the period to wilting and senescence of the last open florets.

On the other hand, the period to wilting and

senescence of the last open floret in Kabete and Kiambu spikes was quite different with Kabete spikes showing a longer period than those from Kiambu. Since spike diameter did not appear to affect this period in the various treatments it is unlikely to be the cause of the difference in vaselife of the Kabete and Kiambu spikes. The difference may be due to the content of cytokinins in the spikes. Cytokinins have been implicated in determining vaselife of cutflowers (Einsinger, 1977; Halevy and Mayak, 1973; Mayak and Halevy, 1970). Forsline and Langille (1975) reported that cytokinins content was significantly higher in potato (*Solanum tuberosum*) plants grown in 21 °C than those under 26.5 °C temperature showing that lower temperatures may result in higher cytokinin production. Kabete (17.6 °C) was at a lower environmental temperature than Kiambu (19.3 °C) and thus may have had higher endogenous cytokinin levels. Cytokinins are known to extend the vaselife of cutflowers (Ensinger, 1977; Halevy and Mayak, 1973; Mayak and Halevy, 1970; Mayak and Halevy, 1974; Richmond and Lang, 1957).

Number of dry and senesced florets: The number of dry and senesced florets did not decline with increasing N levels. Kiambu spikes also had fewer number of dry and senesced florets than those from Kabete.

Naidu and Reid (1989) reported difficulty in the opening of terminal buds (distal unopen florets) of

tuberose which often aborted. Woodson (1987) also reported that harvesting freesia in budstage resulted in incomplete development of inflorescence with more than 30% of their flowers failing to open by the termination of their vaselife. Han *et al.*, (1990) reported that 50% of the buds on brodiaea inflorescences placed in water failed to open and that they required an external supply of carbohydrate. Terminal buds of tuberose (distal unopen florets) may have failed to open and later senesced and dried due to carbohydrate stress (Naidu and Reid, 1989) or incomplete inflorescence development. Increase in N levels resulted in concomitant increase in the distal floret size but the increase was not significant. Therefore despite its effect on the delay of the yellowing and senescence of unopen distal florets, increase in N levels failed to prevent their abortion. Therefore N treatments did not promote inflorescence development sufficiently to ensure full maturity of the distal florets. External carbohydrate treatments such as sucrose pulsing may thus be required to prevent this postharvest drying and senescence of florets.

Yield of spikes: The yield of tuberose spikes at Kabete was not significantly influenced by increasing N application. However, spike yield determined as the number of spikes/m^2 increased with increasing N levels. Yadav *et al.* (1985) also obtained a gradual increase in the yield of

tuberose spikes with higher N levels. They obtained yields of 331.2, 364.0, 415.6, 490.6 and 545.3 x 10^3 spikes per ha with the application of 0, 50, 100, 200 and 300 Kg N/ha, respectively. Similar results were obtained with the use of NPK on 'Edward' rose (*Rosa bourboniana*) (Irulappan *et al.*, 1980b) and Marigold (*Tagetes erecta*) (Arora and Singh, 1980). Bik and Berg (1983) also obtained a slightly higher spike yield of Mini-cymbidium orchids cv. 'Pendragon Sikkim' at the highest N rate compared to lower rates but the increase was not statistically significant. They also found that the average response of the number of flowering stems to increasing N application was markedly increased in Alstroemeria cultivars 'Orchid' and 'Carmen' grown in peat (Bik and Berg, 1981). The effect of increased N application was also found to be favourable in rose culture in Sconia and it significantly increased flower yields. Average flower yields were 232, 274 and 284 flowers/m^2 with the application of 100, 200 and 300 ppm N, respectively (Feigin *et al.*, 1980).

Nitrogen may enhance spike production in tuberose through increased number of bulbs produced per plant thus giving an increased number of spikes per plant. This may explain why Bankar and Mukhopadhyay (1985) obtained increased number of spikes/plant with an increase in N levels. They obtained 1.53, 1.89 and 2.03 spikes/plant with the use of 0, 25 and 35 gN/m^2, respectively.

5.4 The Influence of Split N Application on tuberose

Growth and flowering: Characteristics of flower quality such as spike and rachis lengths, spike diameter and the number of florets per spike increased with split N application. Significant increases were obtained in all the flower quality characteristics except the number of florets per spike. Since at higher levels of N, most N is probably lost through leaching and denitrification (Venkaleswarla, 1978), most N in the nonsplit application may have been leached resulting in concomitant lack of N availability at a later date (Mclaurin, *et al.*, 1984). Also, applying N in a few large doses instead of split application may result in reduced quality due to plant injury. Joiner and Poole (1967) obtained reduction in stem length and the number of flowers per treatment in Chrysanthemum when N was applied in fewer applications. They attributed this to root injury caused by high soluble salt content in the medium.

Thus, split application of N may have prevented plant injury and nutrient loss through leaching and hence availed more N to plants. This resulted to greater growth of inflorescences resulting in longer spikes, and rachis and more florets per spike.

Similar results were obtained by Mukhopadhyay and Bankar (1985) in tuberose. They observed that split N

application resulted in significant increase in spike and rachis length and the number of florets per spike. Highest spike and rachis lengths which were 103.6 cm and 33.4 cm, respectively, were obtained when N was applied as one third before planting, a third at 60 days and a third at 90 days. When the full dose was applied before planting, it yielded a spike and rachis length of 88.4 and 25.8 cm, respectively. Similarly the number of florets per spike increased from 45.5 to 50.7 with split N application. Kiara (1989) observed that split N application had some influence on the length of the flowering stem of Alstroemeria 'Marina'. However, this effect was not significant. Split N application is especially important in tuberose since it is a slow growing crop (Bailey, 1961) and begins to flower (spike production) in 4 to 6 months. Thus, application of the entire N dose at planting may result in most of the N being lost by the time spike production commenced. Since spikes are the commercial product of tuberose, N application needs to be done at the appropriate time(s) to ensure the production of the highest spike quality.

Postharvest Quality: The period to complete senescence of sepals and the yellowing and senescence of the unopen distal florets were not significantly influenced by split N application. On the other hand the period to wilting and senescence of the last open floret and the total number of open florets tended to decrease with split N application.

Limited improvement is thus obtained from split N application in the postharvest quality of cut tuberose. Similarly, Joiner and Poole (1967) reported that the keeping quality of Chrysanthemum was not affected by split N application.

Generally the responce of tuberose to the application of Nitrogen tended to be low especially in Kiambu where most parameters showed no significant effect. This may be due to the fact that the Kiambu soil had higher soil N levels (Appendix 3). Also, the experiment was conducted on already established tuberose beds. This had recieved a basic dose of N at planting time. This may have provided for most N requirements of the plants. Subsequent applications thus had only limited effect especially on growth and flowering parameters. Dey (1980),mentions that tuberose bulbs may be planted and harvested at six months for bulb production. Subsequently planted bulbs flower in four to six weeks. This indicates that their requirements were met during the bulb production period.

6.0 CONCLUSION AND RECOMMENDATIONS

The growth, flowering and postharvest quality of tuberose was influenced by Nitrogen fertilization. Nitrogen application tended to increase leaf length but did not influence the number of basal leaves. Tuberose plants showed better response to NPK fertilizer 17:17:17 at Kabete where P was limiting than at Kiambu. At Kiambu no significant effect was obtained probably due to the higher soil N content.

Nitrogen application tended to increase spike and rachis length and the spike diameter giving significant increase in spike diameter in Kabete. Split N application also increased spike and rachis length, spike diameter and the number of florets per spike. Spike and rachis length and spike diameter are important flower quality characteristics of tuberose. Long spikes and rachis are preferred by customers. Long spikes were of higher or prime grades which fetch better prices. Cutflowers can be recut several times while in the vase and thus may give longer vaselife. Larger diameter spikes are also preferrable since they allow better solution uptake leading to more open florets. Increased N application thus markedly enhanced the quality of tuberose cutflowers.

The number of tuberose leaves and florets per spike were not influenced by N levels. The colour and size of the distal florets were affected differently by N level. The former decreased while the latter increased although not significantly. Kabete spikes had more intense colour than those from Kiambu possibly due to the longer period of pigment synthesis as Kabete spikes took longer to mature in the field.

The postharvest quality of tuberose was influenced by N nutrition. Increased N level resulted in the delay of senescence of sepals and the yellowing and senescence of the distal florets but it did not prevent their abortion. Split N application did not significantly influence the senescence of sepals and the yellowing and senescence of the unopen distal florets. However the wilting and senescence of the last open floret and the total number of open florets tended to reduce with split N application.

Increasing N level did not significantly influence the period to wilting and senescence of the last open floret (vaselife), percent open florets and the number of dry and senesced florets. Location of production also influenced the postharvest quality of cutflowers with Kabete spikes giving higher percent open florets and consequently longer vaselife than those from Kiambu. This was probably due to larger spike diameter of Kabete tuberoses and cytokinnin content.

Both split N application and increasing N levels increased the number of spikes/m^2. However, the increase was not statistically significant for the N level. Yields of tuberose observed were quite low probably due to an unpredictable flowering pattern of tuberose with flowering occuring in patches.

Optimum response to the increasing levels of N for most parameters was obtained at 42.5 kg N/ha. Response to N corresponded to soil requirements with Kabete plants showing better responce for most growth parameters than Kiambu which had higher soil contents of N and P. Thus, appropriate soil tests are important and are thus recommended before application of N in tuberose production. Many parameters did not show significant effect on N application probably due to the fact that already established tuberose plants were used which had received a basic N dose at planting. This may have reduced the N requirement.

Environmental temperature also influenced the growth of tuberose. Kiambu spikes took shorter time in the field and were longer, had longer rachis, less spike diameter and shorter vaselife than Kabete spikes. This is because temperature affects the elongation rate of the spike with higher temperatures promoting a faster elongation rate. Kiambu being at a higher temperature could be more suitable for tuberose production.

Split N application enhanced the growth and flowering of tuberose but did not influence its postharvest quality.

Application of Nitrogen fertilizer at the rate of 42.5 kg N/ha is recommended for production of tuberose. Nitrogen fertilizer should be applied as compound fertilizer with P and K where the soil has low contents of these elements. Care should especially be taken as very high amounts of P and K may have adverse effect on tuberose cutflower.

Split N application is recommended as it results in the production of higher cutflower grades. The split application should be timed to coincide with the critical periods of tuberose development such as spike emergence. Application of large single doses of Nitrogen may result in leaching losses or may be injurious to the plant.

Areas requiring further study include the flowering of tuberose especially to achieve full spike emergence by tuberose bulbs and preventing delay or failure of spike emergence. This is because tuberose were found to flower unevenly in the field. Studies may be required to determine if tuberose has a dormancy requirement for flowering and the conditions required to overcome it. Also studies could be conducted to investigate the tuberose flower induction and initiation to ascertain the specific local conditions required.

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8.0 APPENDIX

APPENDIX I

RAINFALL DATA - KIAMBU

1990 Month	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov	Dec.	Total
Rainfall/ mm	141.0	29.0	291.0	204.5	155.0	22.5	0	0	25.0	116.0	141.0	56.5	1181.5
No. of days in Rain	4	3	15	13	14	4	0	0	3	8	13	7	
1991													
Rainfall/mm	34.5	11.0	78.0	124.0	197.0	24.0							468.5
No. of days in Rain	3	1	4	12	16	2							

Source - Muthithi plantation, Kiambu.

RAINFALL DATA - KABETE

1990 Month	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov	Dec.
Total												
Rainfall/mm	47.8	199.7	275.2	309.3	6.5	13.6	21.0	31.8	90.0	126.0	74.6	1195.5
Rain days	2	17	20	10	2	2	2	4	11	17	14	
1991												
Rainfall/mm	33.9	0.4	84.8	158.3	281.4	12.5	12.9	40.3				820
Rain days	4	0	9	14	24	3	3	5				8.6

Source - Meteorological Office, Kabete

APPENDIX II: TEMPERATURE DATA - KIAMBU

						1990							
Month		Jan	Feb	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov	Dec.
Temp C	Max	26.7	28.4	26.7	26.2	26.2	26.1	23.1	22.2	26.2	26.5	24.9	25.4
	Min	11.9	13.2	14.3	14.3	13.9	11.7	10.5	11.5	10.6	13.6	13.2	12.7
						1991							
	Max	27.0	29.0	28.8	27.1	25.3	23.4						
	Min	11.1	11.3	12.5	13.3	14.1	12.1						

Mean temperature in growing period - 19.3 °C

Source - Kenya Meteorological Department, Nairobi.

						Kabete - 1990							
Month		Jan	Feb	Mar.	Apr.	May	Jun.	Jul	Aug.	Sept.	Oct.	Nov.	Dec.
Temp C	Max		24.9	23.3	22.9	22.7	21.8	21.5	20.3	23.6	23.8	22.0	22.3
	Min		14.0	14.3	14.7	13.9	11.6	10.4	11.5	11.3	11.3	12.8	13.2
						1991							
Temp C	Max	24.4	25.2	26.1	23.9	22.4	21.9	20.3	22.0				
	Min	12.7	13.1	13.7	11.4	14.8	12.6	9.9	10.1				

Mean temperature during growing period - 17.7 °C

Source - Meteorological Office, Kabete.

APPENDIX III:

SOILS (KIAMBU) Field (0-20cm)

	1	2	3	Average
pH	6.1	5.6	6.0	5.9
Na m.e.%	0.54	0.59	0.62	0.58
K m.e. %	1.00	1.00	1.28	1.09
Ca m.e. %	6.0	5.2	9.8	7.0
Mg m.e. %	2.2	2.5	5.4	3.37
Mn m.e. %	0.81	1.08	1.08	0.99
P. ppm	21	100	162	94
N %	0.13	0.34	0.22	0.23
C%	0.95		2.21	1.58
Hp m.e. %	-	-	-	

SOILS (KABETE) Field (0-20cm)

	1	2	3	4	Average
pH	5.2	5.0	5.6	5.0	5.2
Na m.e. %	1.06	1.16	1.06	1.06	1.09
K m.e. %	1.90	1.96	2.50	2.00	2.09
Ca m.e. %	14.0	12.8	14.0	2.8	10.9
Mg m.e. %	2.50	2.30	0.85	2.10	1.94
Mn m.e. %	0.08	0.26	1.04	1.22	0.65
P ppm	6	4	4	2	4
N %	0.33	0.39	0.39	0.41	0.38
C %	2.22	1.75	2.05	2.24	2.07
Hp m.e. %	0.2	0.1	-	0.2	0.13

Appendix IV: Influence of split application of N on the growth, flowering and postharvest quality of Tuberose (*Polianthes tuberosa* L.)

			df	mean square	F
	Flowering				
1.	Length of spike	2	75.25	**	
2.	Rachis length	2	20.57	***	
3.	Spike diameter	2	2.01	***	
4.	Florets/spike	2	11.44	ns	
	Postharvest quality				
1.	Senescence of sepals/days	2	0.04	ns	
2.	Yellowing of terminal florets	2	0.02	ns	
3.	Senescence of distal florets (days)	2	0.44	ns	
4.	Senescence of last open floret	2	4.34	**	
5.	Total No. of open florets	2	1.77	ns	
	Yield				
6.	Spikes/plot	2	48.25	*	

n.s. - not significant

* - significant (5%)

** - significant (1%)

*** - significant (0.1%)

Appendix V: Influence of N levels on tuberose(Kabete)

Growth	df	mean square	F
1.Leaf length	3	3.47	ns
2.Leaf number	3	1.43	*
Flowering			
3.Spike length	3	92.23	ns
4.Rachis length	3	5.96	ns
5.Spike diameter	3	0.81	**
6.Spike growth rate	3	0.79	ns
7.Leaves/spike	3	0.09	ns
8.Florets/spike	3	7.15	ns
9.Distal floret 'colour'	3	0.14	ns
10.Distal floret 'size'	3	0.35	ns
Postharvest quality			
1.Sepal senescence	3	7.98	*
2.Floret yellowing	3	0.05	ns
3.Floret senescence	3	0.44	**
4.Senescence of last open floret	3	0.82	ns
5.% open florets	3	63.85	ns
6.Dry & senesced florets	3	5.24	ns
Yield			
1.Spikes/plot	3	1.89	ns

ns -not significant;* -5%;** -1% significant level

Appendix VI: Influence of N level on tuberose (Kiambu)

Growth	df	mean square	F
1.Leaf length	3	6.75	*
2.Leaf number	3	1.46	ns
Flowering			
1.Spike length	3	13.72	ns
2.Rachis length	3	3.38	ns
3.Spike diameter	3	0.06	ns
4.Spike growth rate	3	1.68	ns
5.Leaves/spike	3	0.51	ns
6.Florets/spike	3	14.07	ns
7.Distal floret 'colour'	3	0.02	ns
8.Distal floret 'size'	3	0.05	ns
Postharvest quality			
1.Sepal senescence	3	0.62	ns
2.Floret yellowing	3	0.23	ns
3.Floret senescence	3	0.14	ns
4.Senescence of last open floret	3	2.37	ns
5.Percent open florets	3	19.26	ns
6.Dry & senesced florets	3	0.81	ns

ns -not significant; * -significant (5%)