NITROGEN AND POTASSIUM REQUIREMENT AND THEIR EFFECT ON FLOWER YIELD AND QUALITY OF MARIGOLD (*Tagetes erecta*) GROWN ON ALFISOL

By

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CERTIFICATE

Mr. A. KRISHNA MOHAN has satisfactorily prosecuted the course of research and that the thesis entitled **"NITROGEN AND POTASSIUM REQUIREMENT AND THEIR EFFECT ON FLOWER YIELD AND QUALITY OF MARIGOLD (*Tagetes erecta*) GROWN ON ALFISOL"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any university**.**

Date :

Place : Hyderabad

(Dr. G. PADMAJA)

Major Advisor

CERTIFICATE

This is to certify that the thesis entitled "**NITROGEN AND POTASSIUM REQUIREMENT AND THEIR EFFECT ON FLOWER YIELD AND QUALITY OF MARIGOLD (*Tagetes erecta*) GROWN ON ALFISOL"** submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** of the **Acharya N.G. Ranga Agricultural University, Hyderabad**, is a record of the bonafide research work carried out by **Mr. A. KRISHNA MOHAN** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of investigation have been duly acknowledged by the author of the thesis.

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DECLARATION

I, **A. KRISHNA MOHAN** hereby declare that the thesis entitled **"NITROGEN AND POTASSIUM REQUIREMENT AND THEIR EFFECT ON FLOWER YIELD AND QUALITY OF MARIGOLD (*Tagetes erecta*) GROWN ON ALFISOL"** submitted to the Acharya N.G. Ranga Agricultural University for the degree of **MASTER OF SCIENCE IN AGRICULTURE** in the major field of **Soil Science and Agricultural Chemistry** is the result of original research work done by me. I also declare that any material contained in the thesis has not been published earlier in any manner.

Date : **(A. KRISHNA MOHAN)**

Place: Hyderabad

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A. KRISHNA MOHAN

LIST OF ABBREVIATIONS

%	:	Per cent
@		At the rate of
c mol (p^+) kg^{-1}	:	Centi moles of positive charge per kilogram
CD	:	Critical Difference
Cm	:	Centimeter
DAT	:	Days after transplanting
dS m^{-1}	:	Desi Siemens per metre
EC	:	Electrical Conductivity
et al	:	And others
Fig.	:	Figure
g	:	Grams
ha	:	Hectare
i.e	:	That is
K	:	Potassium
kg ha^{-1}	:	Kilograms per hectare
Mg	:	Mega gram
mg g^{-1}	:	Milligram per gram
N	:	Nitrogen
nm	:	Nanometer
P	:	Phosphorus
q	:	Quintals
S.Ed.	:	Standard error of deviation
t	:	Tonne
viz.,	:	Namely

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Name of the author : **A. KRISHNA MOHAN**

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ABSTRACT

With a view to study the "Nitrogen and potassium requirement and their effect on flower yield and quality of marigold (*Tagetes erecta* L.)", a field experiment was conducted on an Alfisol at Students' Farm, College of Agriculture, Rajendranagar, Hyderabad during *kharif* 2005-06. The experiment was laid out in a Factorial Randomized Block Design using four levels each of nitrogen (0, 40, 80 and 120 kg ha^{-1}) and potassium (0, 40, 60 and 80 kg K_2O ha^{-1}) to have 16 treatment combinations, each treatment being replicated thrice. Nitrogen and potassium were applied as per treatments along with recommended dose of phosphorus (80 kg P_2O_5 ha^{-1}). Entire quantity of phosphorus and half of nitrogen and potassium were applied as basal in the form of single super phosphate, urea and muriate of potash, respectively. Rest of nitrogen and potassium was applied in two equal splits at 30 and 60 DAT. Marigold (cv. Pusa naringa gainda) was transplanted at 30 days age of seedlings on raised beds. The soil and plant samples were collected at 60 DAT and at final harvest. Soil samples were analysed for different forms of nitrogen and potassium along with available phosphorus. Dry matter production was recorded at 60 DAT and at harvest and the plant samples were analysed for concentrations of N, P and K to compute their uptake. Flower size and yield was recorded. The flowers and leaves were analysed for total

carotenoids (mg g^{-1}), and essential oil content (%), respectively to know the quality of marigold.

The experimental soil is sandy loam in texture. It was, slightly alkaline (pH 7.2) but non saline (0.11 dSm^{-1}). The soil was low in organic carbon (0.5 %) and available nitrogen (220 kg ha^{-1}) and medium in available potassium (198 kg K_2O ha^{-1}) and phosphorus (36.0 kg P_2O_5 ha^{-1}). The contents of ammoniacal and nitrate nitrogen were 18.0 and 28.7 kg ha^{-1}, respectively. The contents of water soluble, NH_4OAc extractable, exchangeable, 1N HNO_3 extractable, non exchangeable and total K were 0.045, 0.205, 0.25, 4.3, 4.05 and 50.2 c mol (p^+) kg^{-1}, respectively.

The results indicated that with increasing levels of nitrogen and potassium application, there was increase in dry matter production, concentrations of N, P and K and their uptake at both 60 DAT and at harvest. Highest quantity of dry matter production (9438.6 kg ha^{-1}), Concentrations of N (2.16 %), P (0.90 %), K (1.51 %) and their uptake (200.4, 85.32 and 143.6 kg ha^{-1}) were recorded at harvest where N was applied at 120 kg ha^{-1} (N_3). Similarly, highest dry matter production (5105.5 kg ha^{-1}), concentration of P and K (0.88 and 1.81 %) and their uptake (46.78 and 92.83 kg ha^{-1}) was recorded at K_3 level, while the concentration and uptake of N were not found effected by K levels at harvest stage of marigold crop.

Increasing levels of applied N and K also increased flower yield and size; the highest values of 141.8 q ha^{-1} and 7.2 cm being recorded at N_3K_3 level.

The N and K levels also influenced the total carotenoids content recording highest values at N_2 (3.43 mg g^{-1}) and K_2 (3.10 mg g^{-1}). Among the interactions, N_2K_3 showed highest carotenoid content of 3.54 mg g^{-1}. However, essential oil content was not found significantly affected by N and K fertilization.

The changes in forms of potassium in soil at different stages of crop growth period clearly indicated that easily available forms of K *viz.*, water soluble NH_4OAc extractable and exchangeable K were utilized by the crop, which reflected in increase in K concentration and uptake from initial to 60 DAT. The slowly available forms were found depleted at later stages (60-100 DAT), indicating the existence of dynamic equilibrium among these forms of K. With regard to nitrogen, NO_3^-N was more utilized by the crop than NH_4^+-N to result in highest DMP, N-concentration, uptake and in turn the flower yield..

Based on the results of investigation, it was concluded that application of 120 kg N and 80 kg K_2O ha^{-1} along with 80 kg P_2O_5 ha^{-1} is optimum for obtaining highest flower yield with quality improvement in marigold when grown on light textured Alfisols.

CHAPTER I

INTRODUCTION

Nitrogen and Potassium are major nutrients required for plant growth and development. Nitrogen is a component of amino acids, cytochromes and chlorophyll and is associated with synthesis of co-enzymes that play an important role in certain biochemical reactions.

Potassium also plays an important role in activation and stabilization of enzymes and cell membranes, protein and starch synthesis etc. It is also required for the operation of K^+ shuttle system, which mediates the transport of nutrients and photo synthesis between roots and shoot

Nitrogen and potassium consumption in Andhra Pradesh during 2003 – 04 is 1.139 and 0.240 million tonnes (Fertilizer news, 2004), respectively. Due to continuous cropping and use of high yielding varieties, there is depletion of nutrients from soil. Hence, to meet the crop demand in long run, there is a need to apply N and K nutrients based on soil fertility status.

Red soils belonging to the order Alfisols, which also occur in association with Entisols and Inceptisols, account to 66 per cent of total geographical area in Andhra Pradesh and are relatively poor in fertility status than Vertisols. Crops grown on these soils are likely to respond to N and K fertilizers.

Nitrogen is present both in organic and inorganic forms in soil. The inorganic nitrogen viz., ammoniacal and nitrate nitrogen contributes to plant growth and development. Alfisols have more NO_3^--N and less NH_4^+-N than Vertisols.

With regards to potassium, it is present in soils mostly in inorganic form which accounts to more than 95 percent of total potassium. Depending on its availability to crops, the different forms of K are classified as water soluble, exchangeable, fixed and mineral K. All these forms exists in dynamic equilibrium with each other.

Nitrogen and potassium uptake by many flower crops is equal to or higher than that of cereals and these nutrients play a vital role in improving quality and quantity of flowers through application of optimum doses of nutrients based on crop removal and soil type.

Marigold (*Tagetes erecta* Linn.) belonging to family Asteraceae, is one of the most important commercial flower crops grown in different parts of the world. In recent years, cultivation of marigold has gone up dramatically because of commercial importance of carotenoid pigments and essential oils extracted from marigold flowers and leaves, apart from making garlands for social functions. The carotenoid pigments extracted from marigold petals are used for imparting colour to poultry feed (Hencken, 1992) and for treating skin tumors, dermatological diseases and cancer in human beings (Mathews Roth, 1982). Purified extract of marigold petals containing xanthopyll dipalmitite is marketed as on optholmological agent under the name ‘Adaptinal’ (Gau *et al*., 1983).

Almost all the species of Tagetes are aromatic and contain essential oil, which is used in high grade perfumes and cosmetics. The oil of *Tagetes minuta* was known to have insecticidal and larvaecidal activity. (Maradufu *et al*., 1978). Marigold oil was also reported to possess bronchodilatory, tranquilising, hypotensive spasmolytic and anti inflammatory properties (Chandoke and Ghatak, 1969).

Mostly, three species of marigold viz., *Tagetes erecta, Tagetes patula* and *Tagetes minuta* are cultivated for various commercial purposes. In India, they are grown in an area of 12,000 hectares with a production of 2 lakh tonnes of fresh flowers annually. Among all the states of India, Andhra Pradesh ranks first with largest area of 4,500 hectares and produce 30,000 metric tonnes of fresh flowers (Raghava, 2000).

It has been established that nutrition plays an important role in improving growth and yield of marigold (Arul Mozhiyan and Pappiah, 1988 and Anuradha *et al*., 1990). Since marigold is hardy in nature and adaptable to varying climatic conditions and soil types easily, very less research work was done on the nutritional requirement of this crop.

Keeping in view the commercial importance of marigold and gaps in research, the present investigation “Nitrogen and potassium requirement and their effect on flower yield and quality of African marigold (*Tagetes erecta*) grown on Alfisol” was undertaken with the following objectives:

1. To determine the optimum level of N and K application for marigold grown on Alfisol
2. To know the content and uptake of N, P and K by marigold at different stages of crop growth
3. To know the changes in status of available N, $P_2 O_5$ and K_2O along with N and K fractions
4. To know the effect of N and K on flower yield and quality (viz., carotenoids and essential oil) of marigold

CHAPTER II

REVIEW OF LITERATURE

Nitrogen is a major essential nutrient required for crop growth and development. Majority of the Indian soils have very low nitrogen content because of the tropical climate. The high mean annual temperature of the central and peninsular India hinders nitrogen accumulation in the soils and the available N status is rarely enough for normal plant growth. The nature and amount of N fraction were found to vary with the soil type. Red soils of Andhra Pradesh were rated low in N fertility status (Sreenivasa Raju and Narasimham, 1995) and nitrogen application is essential to obtain good crop growth and yield.

Potassium is mostly present in inorganic form in soils and this fraction accounts to more than 95 per cent of total potassium. As it is abundant in earth's crust, most of the crop requirement is met from the soil. However, in modern intensive agriculture, the natural supply of potassium from soils in general and light textured soils in particular, is not adequate to sustain high yields as the availability of potassium depends on several factors viz., parent material, mineralogy of soils, soil texture, temperature, moisture etc. Hence, it is necessary to apply potash fertilizers for balanced nutrition.

Marigold is a commercially important crop for its attractive flowers, carotenoid pigment and essential oils. This crop is a heavy feeder of nutrients and is generally grown on light textured Alfisols with little management practices. The information pertaining to response of marigold to balanced fertilization, their effect on flower yield and other quality parameters, nutrient uptake etc., is lacking.

Keeping in view the above mentioned facts, the available literature on N and K nutrition and response of marigold to these nutrients when grown on light textured Alfisols and other soils was reviewed under the following subheads:

2.1 Nitrogen status of soils

2.2 Forms of nitrogen in soils

2.3 Potassium status of soils

2.4 Forms of potassium in soils

2.5 N and K concentrations of marigold and other flower crops

2.6 Nutrient uptake by marigold and other flower crops

2.7 Response of marigold to N and K fertilization

2.8 Effect of applied N and K on quality parameters of marigold

2.1 NITROGEN STATUS OF SOILS

Nitrogen is an important nutrient required for crop growth and development. Raheja (1966) recorded the average nitrogen content of major soil groups of India viz., Indus alluvium, Gangetic alluvium, black cotton soils, red soils and laterite soils as 0.05, 0.04, 0.06, 0.03 and 0.04 per cent respectively. Many of the Indian soils are deficient in nitrogen. Raychoudhary (1963) attributed the low levels of N in Indian soils primarily to tropical climate and secondarily to cropping pattern.

In general, annual release of available N by soil organic matter lies in the range of 2-4 per cent. Muhr *et al*. (1963) grouped the soils into low, medium and high fertility classes based on soil test values below 280, 280 to 560 and above 560 kg N ha^{-1}, respectively. The first map on the available nitrogen status of Indian soils was prepared by Ramamoorthy and Bajaj (1969) utilizing the data of about 1.4 million soil tests for organic carbon in respect of 224 districts. In 117 districts (52.2 per cent), the soils were classified as low in available N, in 97 as medium and high in 10 districts. While Ghosh and Hassan (1980) updated this data and reported that 62.5 per cent districts and union territories covering about two thirds of the grassland area were low in available nitrogen status and 32.6 per cent were in the medium fertility status while 4.9 per cent of the districts were in the high fertility status.

On a worldwide basis, the total N content of soils ranged from less than 0.02 per cent in sub soils to more than 2.5 per cent in peats (Kanwar, 1976). Singh *et al*. (1992) reported that the Alfisols of Kaul area of Haryana contained 620 ppm of total N while forest soils in other parts of the state contained 840 – 950 ppm. According to Dipak Sarkar *et al.* (2002), the available nitrogen content in Loktak catchment area in Manipur was high (538 – 1035 kg ha^{-1}) while in Andhra Pradesh, red soils were poor in all the major plant nutrients. According to N.B.S.S. & L.U.P. (1996), in Andhra Pradesh, about 57.1 per cent of soils were low in available nitrogen. Phanendra Bhaskar (1985) reported that different pedons of laterites and associated soils of Nellore contained available N and total N in the ranges of 18.2 to 44.8 ppm and 0.022 to 0.067 per cent, respectively. All the pedons showed more or less uniform but gradual decrease in content with depth.

Mohan Rao (1988) noticed that surface and sub surface samples of sandy soils of Allur village of Guntur district contained available N in the range of 107 – 311.2 kg ha^{-1} while loamy soils of the same area contained available N to an extent of 169.4 to 395.8 kg ha^{-1}. The red and associated soils of Nellore contained 82.95 kg ha^{-1} available N (Prasuna Rani *et al.*, 1992). Whereas the red and black soils of Giddalur mandal of Guntur district contained available N in the range of 142 to 105 mg kg^{-1} soil (Gurumurthy *et al.*, 1996).

Prasad (1991) recorded that the red soils of left canal area of Polavaram project in East Godavari and Visakhapatnam districts contained 262 ppm of available N (low to medium). However, in certain Alfisols of North coastal zone of Andhra Pradesh, the available N content was around 122 to 295 kg ha^{-1} (Ratnam, 2003).

Lakshmana Murthy (1996) recorded horizonwise distribution of nitrogen in different pedons (Inceptisols) of Rentachintala mandal of Guntur district. Available N was in the range of 56 ppm (B_2 horizon) to 196 ppm (AP horizon) and total N was in the range of 12 ppm (C horizon) to 574 ppm (Ap horizon) respectively. Sailaja (1999) reported that the Alfisols of Rajendranagar, Hyderabad contained total N and available N content of 6.10 and 10.89 per cent in different pedons. Basava Raju (2003) reported that Alfisols of Chandragiri mandal of Guntur district contained total N to an extent of 0.025 to 0.013 per cent in different pedons while low in available N (74.36 to 210.31 kg ha^{-1}).

In turmeric growing Inceptisols of Nizamabad, Adilabad and Karimnagar low to medium available N content (206 to 331 kg ha^{-1}) were recorded (RARS, Jagityal, 1988). Similar values were reported by Vijayakumar (1997) in Northern Telangana turmeric growing soils. Jhansi Rani (2005) also reported that the turmeric growing soils of Guntur district contained available nitrogen contents of 214 to 283 kg ha^{-1}.

2.2 FORMS OF NITROGEN IN SOILS

Nitrogen is present in soil both as organic and inorganic forms. Inorganic N occurs in soils as N_2O, NO and NO_2 which give rise to NH_4, NO_2 and NO_3 ions. The contents of different forms vary with type of soil. The N nutrition of crops is dependant more on N supplying power of the soil for a period of time than on the concentrations of NH_4 and NO_3 at a given time. Though inorganic forms of nitrogen contribute to a small fraction of total nitrogen, these forms play a major role in plant nutrition (Sreenivasa Raju and Narasimham, 1995).

Ammoniacal nitrogen is an important form of N in soil, which is directly absorbed by some plants or nitrified for use by many plants for their nutrition. It is also the first recognisable product in the mineralization of organic nitrogen, which is successively oxidized to nitrite and then nitrate on which most of the plants feed. Generally ammonium ions occur both in exchangeable and non exchangeable forms. Exchangeable NH_4-N frequently falls in the range of 0.01 to 0.1 meq per 100 g soil which corresponds to 1.4 to 14 ppm in soils (Jackson,1967).

NH_4^+, which is fixed between inter layer spaces of expanding minerals viz., montmorillonite, vermiculite, illite, undergoes only slow exchange and is reluctant to get transformed by nitrification. Several studies reported that about 22 – 87.1 per cent of total N in 7 bench mark soil profiles of West Bengal (Sah and Parischa, 1984) and 7 – 24 per cent of total N in forest profiles of North Western Himalayan region (Kaeistha *et al*., 1980) was present as fixed NH_4^+. Similarly, 5 – 54 per cent of total N in several soil groups of West Bengal (Raju and Mukhopadhyay, 1972) was also found as fixed NH_4^+.

Since plants absorb nitrogen from the soil mostly in the form of NO_3^-, except in highly acidic soils, the amount of nitrate produced in a soil as a result of microbial decomposition of soil organic matter has a considerable significance in relation to its crop production power (Acharya and Jain, 1954). Nitrate release from organic matter in soil may be less rapid but is continuous over a long period with as much as 10 per cent of total N converted to the nitrate form. Kaistha *et al*. (1980) observed that soils having greater amount of total N had high content of NO_3-N in Himachal Pradesh soils.

Grewal and Kanwar (1967) reported that the exchangeable NH_4^+ and NO_3^--N constituted 5.0 per cent and 0.1-5.0 per cent of total N (220-1000 ppm), respectively in Punjab soils. Prasad *et al*. (1970) observed that the water soluble NH_4^+ constituted to 2.5 per cent of total N, whereas the exchangeable NH_4^+ constituted 4.3 per cent of total N in certain alluvial soils of Bihar.

The distribution of various forms of N varies significantly due to influence of land form (Goyal and Singh, 1987) and pedogenic development (Beke *et al*., 1995). Walia *et al*. (1998) observed different N forms in some land forms of Bhundelkhand region. They recorded contents of total N, NH_4^+-N, NO_3^--N and available N in cultivated Alfisols (Ultic Haplustalf) of Devagan region as 630, 3.3, 0.1 and 100.2 mg kg^{-1}, respectively and mineral N accounted to 1.8 to 16.5 mg kg^{-1} soil.

In Andhra Pradesh Subba Rao *et al*. (1984) recorded 28– 70 ppm NH_4^+-N and 21.0 – 94.5 ppm NO_3^--N in certain Alfisols. Hulagur and Shinde (1984) reported NH_4^+-N content of 4 ppm in Vertisols of Hyderabad. In general Alfisols have more NO_3^--N than NH_4^+-N.

Sreelatha (1998) analysed different N forms in mesta growing sandy loam soils of Amadalavalasa in Srikakulam district. The contents of total N, available N, NH_4^+-N and NO_3^--N in Alfisols of Amadalavalasa were 1920, 176, 21.8 and 154.7 kg ha^{-1} respectively.

In maize growing Inceptisols of Rajendranagar, Hyderabad the contents of NH_4^+-N and NO_3^--N were found to be 3.79 and 2.2 mg kg^{-1}, respectively (Sharada, 2004).

2.3 POTASSIUM STATUS OF SOILS

Potassium content of Indian soils varies from 0.5 to 3.0 per cent (Tandon and Sekhon, 1988). According to Datta *et al.* (1966), soils containing available potassium from 0 to 45, 45 to 112 and more than 112 ppm were grouped under low, medium and high categories, respectively. Based on the available K status, Sekhon (1990) reported that the Indian soils from 20 per cent of districts fall under low category whereas 42 and 38 per cent of districts were under medium and high categories, respectively. Extensive studies carried out indicated positive response of crops to K fertilizer application (Janakiraman, 1993).

Red and laterite soils, which occupy major portion of Southern India (Sekhon and Subba Rao, 1985) are generally regarded deficient in potassium (Ramanathan and Krishnamurthy, 1978).

In Andhra Pradesh, out of 21 districts, soils belonging to 2, 13 and 6 districts showed low, medium and high available K status, respectively (Ghosh and Hassan, 1976). The red soils belonging to Anantapur, Chittoor and Nellore districts were deficient in K (Raman and Subba Rao, 1979). Turmeric growing Inceptisols in Nizamabad, Adilabad and Karimnagar districts of Northern Telangana were high (318 to 325 kg K_2O ha^{-1}) in available K status (Jhansi Rani, 2005). Vijaya Kumar *et al.* (1997) also reported high available K in red, black and associated soils of Giddalur mandal of Andhra Pradesh. According to Padmaja and Sreenivasa Raju (1999), the mean available K contents in vegetable growing red soils of Ranga Reddy, Mahaboobnagar and Medak districts were 0.32, 0.41 and 0.45 c mol (p^+) kg^{-1}, respectively. Venkateshu (2002) stated that groundnut growing soils of Nellore district contained available K_2O in the range of 82 – 212 kg ha^{-1} with a mean of 116 kg ha^{-1}. Revathi (2003) reported that tomato growing soils of Chittoor district contained available potassium in the range of 108.64 to 414.51 kg ha^{-1} with a mean of 248.18 kg ha^{-1}. Whereas, the available K content of Sivagiri micro watershed of Chittoor district was in the range of 22 to 212 kg ha^{-1} (Thangasamy, 2002).

2.4 FORMS OF POTASSIUM IN SOILS

Potassium is present in both organic and inorganic forms in soils. The organic form is usually less than one per cent of the total potassium. Hence, the status of inorganic potassium occurring in various forms viz., water soluble, exchangeable, non-exchangeable, lattice and total K in different soils is reviewed.

The water soluble potassium is the form taken up by plants easily. It is usually too low to meet the crop requirements during a growing season and depends on replenishment from other fractions (Subramanyeswara Rao and Raj Gopal, 1981). The water soluble K indicates the tendency for release or fixation of potassium in soil (Mahendra Singh and Mittal, 1983). Water soluble K contributed to 0.27 per cent of total K in the coastal alluvial soils of Andhra Pradesh. Whereas in vegetable growing Alfisols of Southern Telangana Zone, this form of K constituted to 0.14 per cent of total K (Padmaja and Sreenivasa Raju, 1999).

The exchangeable K is held by negative charges of organic matter and clay minerals and is readily available to plants. In soils of Maharashtra, the exchangeable K was in the range of 2.0 to 13.2 per cent of total K (Sonar and Patil, 1996).

The exchangeable potassium content increases with increase in clay content and in coastal alluvial soils of Andhra Pradesh, it constituted to 2.0 per cent of total K (Subramanyeswara Rao and Raj Gopal, 1981).

The K fractions of Alfisols of Vittal series (Haplustalf), Hosapura series (Lithic Haplustalf) and Gottipura series (Typic Rhodustalf) of different agroclimatic zones of Southern Karnataka were analysed by Ramagowda and Srikanth (2000). The soils contained water soluble, exchangeable and non exchangeable K contents to an extent of 0.08, 0.20, 0.39 c mol (p^+) kg^{-1} in Vittal series, 0.14, 0.35, 1.05 c mol (p^+) kg^{-1} in Hosapura series, 0.08, 0.09 and 2.03 c mol (p^+) kg^{-1} in Gottipura series. In Narsinghpur area of Cuttack, laterites contained NH_4OAc extractable, exchangeable and total K in the ranges of 70-380, 130-900 and 950 to 1500 mg kg^{-1}, respectively (Pal *et al*., 2001).

Varaprasada Rao (2005) collected samples from 7 pedons in Ramachandrapuram mandal of Chittoor district in Andhra Pradesh. These soils were found to have exchangeable and total K contents ranging from 0.10 to 1.02 and 2750 to 4000 mg kg^{-1}, respectively. In certain Inceptisols of Rentachaintal mandal of Guntur district, the exchangeable K content was in the range of 0.30 to 0.71 c mol (p^+) kg^{-1} (Lakshmanamurthy, 1996).

The non exchangeable K is that part of potassium which is held between adjacent tetrahedral layers of dioctahedral and trioctahedral micas, vermiculites and intergrade clay minerals (Sparks and Huang, 1985). This form of potassium is slowly released during crop growth period. Arbinda and Saroj Kumar (2000) analysed surface soil samples of Kahipura and Susania soil series of West Bengal for non-exchangeable K contents. Soils of Kahipura and Susania series found to have non exchangeable K contents to the extent of 1.43 and 1.69 c mol (p^+) kg^{-1}, respectively.

Soil samples collected from 22 Bench mark soil series from 14 states of India were analysed for 1N HNO_3 extractable K (Srinivasa Rao *et al*., 2000). 1N HNO_3 extractable K contents in Alfisols of Khatki (Uttar Pradesh), Vijayapura (Bangalore), Tyamagondalu (Bangalore) and Doddahhawl (Coimbatore) series were 1300, 120, 320 and 1040 mg kg^{-1}, respectively.

Mineral potassium is a structural constituent of primary and secondary minerals. The different forms of K have a dynamic equilibrium among themselves. In certain, Inceptisols of Maharashtra, the different forms of K viz., water soluble, exchangeable, available, non exchangeable and lattice K constituted to 0.04, 1.39, 1.43, 3.95 and 9.46 per cent of total K, respectively (Kaskar *et al*., 2001).

In Andhra Pradesh, Krishna Reddy (1982) reported that the red and laterite soils of Nellore district showed water soluble, exchangeable, non exchangeable and total K contents in the ranges of 0.11 to 0.17, 0.13 to 0.34, 0.17 to 1.38 and 4.7 to 13.6 c mol (p^+) kg^{-1}, respectively. Whereas, in certain Alfisols of Ranga Reddy, Mahaboobnagar and Medak districts of Southern Telangana Zone of Andhra Pradesh, NH_4OAc extractable, exchangeable, water soluble, 1N HNO_3 extractable and total K contents ranged from 0.103 to 0.92, 0.08 to 0.84, 0.03 to 0.15, 4.41 to 11.8 and 42.3 to 76.2 c mol (p^+) kg^{-1}, respectively (Padmaja and Sreenivasa Raju, 1999).

2.5 N AND K NUTRITION OF MARIGOLD AND OTHER FLOWER CROPS

Response of flowering plants to applied N and K depends on soil nutrient status, N and K requirements of crop and variety. The N and K nutrients of flower crops varies according to their growth stages also. Many soils inspite of their high amounts of available potassium status, show responses of crops markedly to applied potassium because of slow release of unavailable forms of K to available form. Similarly depending on soil type, most of the native available nitrogen is lost through several ways and crop grown on these soils respond to N fertilization.

Several studies on different flower crops indicated that there was significant increase in N, P and K concentration with increase in levels of these nutrients. Increase in N level from 0 to 200 kg ha^{-1} showed an increase in N concentration of marigold from 1.17 to 3.25 per cent (Raja Naik, 2001). Baboo and Singh (2003) also reported an increase in N concentration (0.62%) of marigold at 375 kg N ha^{-1}.

The nutrient concentration in marigold (*Tagetes erecta* L.) also varies during different growth stages. Anuradha *et al*. (1988) observed that increasing N levels (0 to 90 kg ha^{-1}) significantly increased the N concentration at 30 DAT (2.67 to 3.05%), 60 DAT (3.02 to 4.06%) and 90 DAT (1.12 to 2.97%). However, a reduction in N concentration in leaves was observed from 60 DAT to 80 DAT. Similar results were also reported by Ravindran *et al*. (1986) in African marigold. They observed that though N levels significantly increased the N concentration in leaves, it decreased at 90 DAT which was attributed to translocation of nutrients to flowers during flowering stage.

Apart from marigold, several other flower crops were studied for their response to N and K fertilization. The N concentration of China aster at 240 kg N ha^{-1} was found to be 4.09 per cent (Geeta Madhuri, 2002).

Studies were conducted on gaillardia (Nagalakshmi, 1998), tuberose (Bankar and Mukhopadhyay, 1990) and gerbera (Dufault *et al*., 1990). Application of 150, 120 and 300 kg ha^{-1} N resulted in highest N concentrations of 5.88, 2.58 and 4.37 per cent, respectively.

Dufault *et al*. (1990) reported an increase in K concentration of gerbera with increase in K application. They also observed a decrease in the leaf N concentration from 1.48 to 1.36 per cent with an increase in K fertilization.

However, Venkataramana Prasad (1989) in his studies on tuberose observed that there was increase in N concentration of leaves at higher levels of K (200 kg K_2O ha^{-1}) application at all the growth stages.

Studies conducted by Joiner and Smith (1962) revealed that there was antagonistic effect between K and P whereas N and P have synergestic effect on P absorption by chrysanthemum.

With regard to optimum nutrient contents for better flower yields. Orlova (1989) reported that the optimum nutrient levels for ensuring the highest yield in rose were 3.5 per cent N, 0.9 per cent P and 1.6 per cent K at bud development stage.

Effect of N levels on P concentration (Anuradha *et al.*, 1988) of marigold grown in Alfisols revealed that with increase in N levels (0 to 90 kg ha^{-1}) there was significant increase in P concentration at 30 DAT (0.168 to 0.310%), 60 DAT (0.521 to 0.931%) and 90 DAT (0.356 to 0.350%). They also reported that P concentration decreased from 60 DAT to 90 DAT. Similar results were also reported by Baboo and Singh (2003) and Rajanaik (2001) for marigold grown on light soils.

Geeta Madhuri (2002) also found significant increase in P concentration with N application in China aster. Also in Tuberose, higher level of applied K (200 kg K_2O ha^{-1}) increased the foliar P concentration at all the growth stages (Venkataramana Prasad, 1989). He also reported high foliar K content with higher level of K application (200 kg K_2O ha^{-1}). Similar results were reported by Bankar and Mukhopadhyay (1990) for tuberose and Default *et al*. (1990) for gerbera.

With regard to interaction effect of N and K in tuberose (Venkataramana Prasad, 1989), highest foliar K concentration was recorded at 200 kg N ha^{-1}. However, further increase in nitrogen levels to 300 and 400 kg N ha^{-1} decreased the K concentration. Similar results were also reported by John and Arora (1978) in carnations. Dufault *et al*. (1990) observed an increase in K concentration (1.34 to 1.61% K) of gerbera with increase in N levels upto 220 kg N ha^{-1}. They also found that, there was a decrease in K concentration with further increase in level of application of nitrogen beyond 220 kg ha^{-1}.

2.6 NUTRIENT UPTAKE BY MARIGOLD AND OTHER FLOWER CROPS

Crop species differ significantly with respect to their nutrient removal from soil and applied sources. The quantity of nutrients removed by crops is influenced by the nutrient availability in soil, the requirement of particular crop and the environment in which the crop is growing. The N and K removals by flowering plants are equal to or higher than cereal crops. Among the flowering crops, bulbous crops remove more nutrients than others. Flowering crops also differ in their nutrient uptake at different growth stages.

As studies pertaining to nutrient removal, uptake and response studies of marigold are meager; the information available on other flower crops is also reviewed.

Hoffman and Komara (1997) conducted pot culture studies on marigold (*Tagetes patula)* and reported that N uptake by 10 plants was 2.31 g and the rate of nutrient utilization from soil was 57.5 per cent of available N. It was also observed that the need for nitrogen was maximum upto 70-75 days, which coincides with flowering stage.

Anuradha *et al*. (1988) observed that there was significant increase in N uptake by marigold (*Tagetes erecta* L.) with increase in levels of applied nitrogen from 0 to 90 kg ha^{-1} when grown on Alfisols of Bapatla. They reported highest values at 90 DAT (199.27 kg ha^{-1}). Similar results were also reported by Chandrasekhar Rao (2002) in African marigold (Cv. Pusa naringe gainda) grown on Alfisols. He also observed an increase in N uptake upto 120 kg ha^{-1} with advancement of age. Though, the increase in N uptake from 30 DAT to 60 DAT was rapid, it was marginal from 60 DAT to 90 DAT and very little from 90 DAT to harvest.

Increase in N uptake by marigold at higher levels of applied N and P was reported by Ingawale (1979) and Nalawadi (1982). Similar results were reported in China aster (Geeta Madhuri, 2002) and helichrysum (Sharana Basappa, 1990). Whereas, Mokashi (1988) reported no significant increase in N uptake by gaillardia with increase in N levels.

However, Nagalakshmi (1998) observed significant increase in the N uptake by gaillardia with increase in N levels (0 to 150 kg ha^{-1}) at 30 DAT (0.35 to 0.081 g $plant^{-1}$), 60 DAT (0.434 to 1.24 g $plant^{-1}$), 90 DAT (0.578 to 1.239 g $plant^{-1}$) and 120 DAT (0.756 to 1.406 g $plant^{-1}$). High uptake values at 60 and 90 DAT show the importance of nutrition at flowering and post bloom stages in this crop. Similar trend was observed by Serra *et al.* (1975) in chrysanthemum.

Jaoual and Cox (1998) conducted studies through solution culture technique to know the preferential uptake of nitrate and ammoniacal forms of nitrogen by marigold (*Tagetes erecta* L.). They found that the uptake of nitrate nitrogen was more than ammoniacal form.

Phosphorus uptake by marigold grown on certain Alfisols was studied by Chandrasekhara Rao *et al.* (2002). There was a significant increase in P uptake with increase in nitrogen upto 120 kg N ha^{-1}. The P uptake values at 30, 60 and 90 DAT were 1.16, 1.73 and 5.07 t ha^{-1}, respectively. Baboo and Singh (2003) also reported significant increase in P uptake by Pusa Basanthi Gainda, with maximum values being recorded at 250 kg N ha^{-1}. Whereas, Joshi *et al*. (2002) reported that P uptake increased with applied N levels upto 150 kg ha^{-1} and further application of 200 kg N ha^{-1} reduced the P uptake at final harvest stage.

Studies on K uptake by marigold in certain Alfisols also revealed that there was an increase in K uptake at different growth stages of crop with increase in N levels upto 120 kg ha^{-1} (Chandrasekhar Rao, 2002). The K uptake values at 30, 60 and 90 DAT were 10.38, 33.0 and 39.58 t ha^{-1}, respectively.

Application of N and P_2O_5 also significantly increased the concentration and uptake of K in marigold. This might be due to the fact that both N and P_2O_5 improved K nutrition and enhanced the uptake of K by the plants. Also the trends showed that, there was maximum uptake of N, P and K at full bloom stage followed by a decline at harvest stage. This reduction was attributed to translocation of nutrients from the leaf and stem to the developing flowers (Anuradha *et al.*, 1988).

Nizzar and Rehalia (1977) observed increasing K uptake by rose plants with corresponding increase in K content in soils.

2.7 RESPONSE OF MARIGOLD TO N AND K FERTILIZATION

Maximisation of flower yield with quality is of prime importance in the cultivation of marigold. This can be achieved through optimum use of fertilizers (Das and Mishra, 2005).

Nutrition plays an important role in improvement of growth and yield of marigold (Anuradha *et al*., 1990). Nitrogen is the major nutrient that is essential for flower production. Several workers reported different levels of nitrogen as optimum for obtaining higher yields depending on soil type and varieties.

Karuppiah and Krishna (2005) conducted an experiment with French marigold grown on sandy clay loam soils at Annamalainagar. They observed that different levels of N significantly influenced the plant growth. Though there was maximum response for dry matter production (34.64 g $plant^{-1}$) at 250 kg N ha^{-1}, the flower yield showed a reduction at this level of N application. Optimum N level for higher flower yield (149.79 q ha^{-1}) was found to be 400 kg N ha^{-1}.

Ritujain and Gupta (2004) reported maximum flower yield (340.8 g $plant^{-1}$) in African marigold (cv. Pusa naringa gainda) at 300 kg N ha^{-1}. Further increase in nitrogen level reduced the yield. Similar results were also reported by Yadav *et al*. (2004) in African marigold grown in Raipur region. They recorded highest flower yield of 141.13 q ha^{-1} at 120 kg N ha^{-1} while there was decrease in flower yield (108.47 q ha^{-1}) at 180 kg N ha^{-1}. Belorkar *et al*. (1992) reported 90 kg N ha^{-1} as optimum for obtaining higher yield in African marigold beyond which, there was reduction in flower yield.

While Acharya and Dashora (2004), from results of their experiment conducted on African marigold (cv. Pusa basanthi gainda) at Udaipur region stated that increase in N application from 50 to 150 kg ha^{-1} resulted in significant increase in the flower production (75.30 to 174.13 q ha^{-1}). Similar favourable effect of applied N on flower yield was reported by many workers.

In African marigold cv. Pusa basanthi gainda grown on clay loams of Udaipur region, maximum flower diameter of 6.06 cm was recorded with 200 kg N ha^{-1} (Acharya and Dashora, 2004). Experiments conducted by Anuradha *et al.* (1990) with African marigold grown on sandy loams of Bapatla indicated that the flower size significantly increased from 5.7 to 7.0 cm with each level of increase in N from 0 to 90 kg ha^{-1}. Similar results were reported by Ritujain and Gupta (2004), Yadav *et al*. (2004) and Das and Mishra (2005) recording maximum flower diameters of 7.45, 7.21 and 8.65 cm, respectively at 150 : 75 kg N and K application in marigold.

Agrawal *et al*. (2002) also stated that application of N and K significantly increased the flower diameter in African marigold grown on

Alfisols of Chattisgarh region. Higher dose of applied N (300 kg ha^{-1}) resulted in higher flower diameter of 8.8 cm. Similarly, increasing K levels (0 to 200 kg K_2O ha^{-1}) significantly increased the flower size from 6.5 to 8.4 cm. But N and K interaction effect was found non significant. Similar results were obtained in pot marigold (*Calendula officinalis L.)* Gontait Subhedu and Chattopadhyay (2004) also recorded highest flower diameter (4.66 cm) at highest level of K (200 kg K_2O ha^{-1}) though N and K interaction effect was found non significant.

2.8 EFFECT OF N AND K ON QUALITY PARAMETERS OF MARIGOLD

In the recent years, the commercial value of marigold increased not only for ornamental flowers but also for the carotenoids and essential oils extracted from flowers and leaves. Though the information on effect of N and K on carotenoids and essential oils is very less, the available literature is reviewed. Recently, orange coloured marigold flowers have emerged as a rich source of carotenoid pigment. The total carotenoid content in marigold flowers ranged from 3 to 5 mg per gram on fresh flower basis (Raghava, 2000). Nutrient supply improves the carotenoid content in marigold (Anand Kumar *et al.*, 2004).

In French marigold grown on sandy clay soils of Annamalainagar, Karuppiah and Krishna (2005) observed that application of 50 kg N ha^{-1} resulted in maximum carotenoid content (0.0079 mg g^{-1}) and it was significantly higher than the content observed at lower levels of N application. Anuradha *et al.* (1990) also reported an increase in carotenoid content with increase in N level upto 60 kg N ha^{-1} and further application (100 kg N ha^{-1}) reduced the carotenoid content in African marigold. Chandrasekar Rao (2002) observed significant increase in the total carotenoid content (mg g^{-1}) of African marigold at 60 kg N ha^{-1} (3.4) compared to 90 kg N ha^{-1} (2.69). Bosma *et al*. (2003), however, did not report significant increase in content of carotenoid pigment in African marigold with N application. Baldwin *et al*. (1993) found that the pigment yield increased with application of nitrogen at 75 kg ha^{-1}.

Hemla Naik *et al*. (2004) also reported the effect of spraying of N and K on carotenoid content of marigold when grown on Alfisols of Dharwad. They observed that additional supply of N and K through DAP and MOP, respectively @ 1 and 2 per cent spray enhanced the carotenoid content.

Several workers reported importance of N and K nutrients in improving the pigmentation in other flower crops.

Maharana and Pradan (1976), in a pot culture experiment with Floribunda rose (cv. Celebration) observed that application of ammonium sulphate (15 g) and potassium sulphate (8.0 g) per plant increased flower colour compared to application of single superphosphate (18.75 g). Among the treatment combinations, N and K combination resulted in more carotenoid content (31.50 ppm) than with other combinations indicating the importance of N and K in rose colour development. However, Nizzar and Rehalia (1977) did not observe any colour variation in rose flowers treated with different N, P and K combinations.

Joiner and Smith (1962) studied the effect of N and K on growth and flowering of chrysanthemum and reported that high N and low K concentration decreased the bloom colour.

Essential oils extracted from marigold plants have commercial importance in several fields. Almost all the species of Tagetes are aromatic and contain essential oils. Tagetes minuta gives maximum yield and superior quality of essential oil (0.2 to 0.35 %) among all the cultivated Tagetes species (Chopra *et al*., 1963). In case of *Tagetes erecta*, all plant parts are weakly aromatic and essential oils obtained from aerial plant parts contain about 0.01 per cent on fresh weight basis. Verma *et al*. (2001) reported that essential oils obtained from flowers of *Tagetes erecta* grown in Kangra valley of Himachal Pradesh contained 0.347 per cent of oil on fresh weight basis. Verma *et al*. (2001) examined oil contents of *Tagetes minuta* flowers collected from different locations and at different stages of maturity. The values ranged from 0.330 to 0.960 per cent. They also stated that soil nutrient status, climatic conditions, season and stage of crop also contributed to this range.

Munnu Singh (2001) reported that application of 0, 100 and 200 kg N ha^{-1} did not show any effect on oil content in *Tagetes minuta* grown on Alfisols of the semi arid tropical climate of South India. The mean values were 0.4, 0.4 and 0.44 per cent at 0, 100 and 200 kg N ha^{-1} levels, respectively.

Whereas, Munnu Singh and Rao (2005) observed significant increase in oil content of *Tagetes minuta* with application of N at 200 kg ha^{-1} as compared to control.

Ram *et al*. (1999) observed highest oil yield with 150 kg N ha^{-1} and application of 225 kg N ha^{-1} reduced the yield due to decreased herb oil content at this level in *Tagetes minuta*.

Several workers have reported N and K effects on essential oil content in other aromatic crops. Khandelwal and Nagda (2005) observed that essential oil content of henna flowers significantly increased with N and K application. Similar results were observed by Bhaskar *et al*. (1998) in scented geranium and rose (Singh and Ramesh, 2000).

Rajeswar Rao and Kailash Singh (1988) reported that the essential oil content of *Mentha arvensis* in the first harvest was not affected by N levels but in the second harvest, application of 60 kg N ha^{-1} had significantly increased the oil content over control. However, Singh (1989) stated that the oil content decreased with increasing N levels in the Japanese mint as compared to control. Singh *et al*. (1992) also reported similar results in Japanese mint. Whereas, the effect of N and K on oil content of Japanese mint was found non significant (Singh *et al*., 1973).

CHAPTER III

MATERIAL AND METHODS

A field experiment entitled "Nitrogen and Potassium requirement and their effect on flower yield and quality of marigold (*Tagetes erecta* L.) grown on Alfisols" was conducted at Students' Farm, College of Agriculture, Rajendranagar, Hyderabad during *kharif*, 2005 – 2006.

3.1 CLIMATIC CONDITIONS

Rajendranagar is situated at an altitude of 542.6 meters above mean sea level. It is located at 18.5^{o} N latitude and 77.5^{o} E longitude. The weekly mean meteorological data during the crop period are furnished in table1.

The mean maximum and minimum temperatures, total rainfall, wind speed and evaporation during the experimental period were 29.4^{o}C, 19.3^{o}C, 901.4 mm, 4.1 km h^{-1} and 3.2 mm, respectively.

3.2 SOIL SAMPLING

The soil samples collected (0-15 cm depth) at different stages of crop growth were shade dried, powdered with wooden pestle and mortar and passed through a 2 mm sieve. The soil samples were then stored in labelled cloth bags and were used for laboratory analysis.

3.3 METHODS OF SOIL ANALYSIS

The initial soil sample collected form the experimental site was analysed for its salient characteristics following standard procedures as outlined in the references cited below :

Soil Character	References
A. Physical	
i) Mechanical composition(%)	International pipette method (Page *et al*., 1982)
B. Physico – chemical	
i) p^H (1:2.5 soil: water suspension)	Jackson (1967)
ii) Electrical conductivity (1:2.5 soil water extract)	Jackson (1967)
C. Chemical	
i) Organic carbon (%)	Walkley and Black (1934)
ii) Cation exchange capacity (c mol (p+) kg^{-1})	Bower *et al*. (1952)
iii) Forms of nitrogen (kg ha^{-1})	
a) Available nitrogen	Alkaline permanganate method (Subbiah and Asija, 1956)
b) Ammoniacal nitrogen	Bremner (1965)
c) Nitrate nitrogen	Bremner (1965)
d) Total nitrogen	Bremner (1965)
iv) Available phosphorus	Ascorbic acid method (Watanabe and Olsen, 1965)

Soil Character	References
v) Forms of potassium (c mol (p+) kg^{-1})	
a) Water soluble potassium (1:5 soil : water extract)	Jackson (1967)
b) Neutral normal ammonium acetate extractable potassium	Hanway and Heidal (1956)
c) Exchangeable potassium	Jackson (1967)
d) Boiling 1 N HNO_3 extractable potassium	Wood and Deturk (1941)
e) Non – exchangeable potassium (difference of 1N HNO_3 extractable K and NH_4OAc extractable K)	Wood and Deturk (1941)
f) Total potassium	Page *et al*. (1982)

3.4 FIELD EXPERIMENT

A field experiment was conducted with African marigold (Var. Pusa naringa gainda) during *kharif*, 2005–06 at Students' Farm, College of Agriculture, Rajendranagar, Hyderabad with sixteen treatment combinations laid out in a Factorial Randomised Block Design, each treatment being replicated thrice (Fig. 1). The details of treatment combinations are as follows:

T_1 : N_oK_o	T_5 : N_1K_o	T_9 : N_2K_o	T_{13} : N_3K_o
T_2 : N_oK_1	T_6 : N_1K_1	T_{10} : N_2K_1	T_{14} : N_3K_1
T_3 : N_oK_2	T_7 : N_1K_2	T_{11} : N_2K_2	T_{15} : N_3K_2
T_4 : N_oK_3	T_8 : N_1K_3	T_{12} : N_2K_3	T_{16} : N_3K_3

Fig 1 : Layout of Field Experiment

N

R_1	R_2	R_3
T_1	T_{12}	T_{14}
T_3	T_8	T_4
T_5	T_{14}	T_6
T_9	T_6	T_8
T_7	T_{15}	T_{16}
T_{11}	T_4	T_{12}
T_{16}	T_1	T_{10}
T_2	T_3	T_{13}
T_{13}	T_5	T_2
T_{10}	T_9	T_{11}
T_4	T_7	T_{15}
T_{15}	T_{11}	T_7
T_6	T_{16}	T_9
T_{14}	T_{10}	T_5
T_8	T_2	T_3
T_{12}	T_{13}	T_1

3 m

4.0 m

Legend : **Levels of nitrogen (kg ha^{-1})**

N_o : 0
N_1 : 40
N_2 : 80
N_3 : 120

Levels of potassium (kg K_2O ha^{-1})

K_o : 0
K_1 : 40
K_2 : 60
K_3 : 80

Plot size : 4x3 m
Design : FRBD
Replications : 3
Spacing : 40 cm x 30 cm

3.5 CULTIVATION DETAILS

The details of operations carried out from sowing to harvest of marigold crop are furnished in table 2.

Table 2: Calendar of operations during crop period

S.No	Name of operation	Date of operation
1.	Raising of nursery	27 – 8 – 2005
2.	Preparatory cultivation	
i)	Ploughing	23 – 09 – 2005
ii)	Leveling	24 – 09 – 2005
3.	Lay out	25 – 09 – 2005
4.	Transplanting	26 – 09 – 2005
5.	Fertilizer application (Basal)	26 – 09 – 2005
6.	Pinching	28 – 10 – 2005
7.	1^{st} top dressing $¼^{th}$ N and $¼^{th}$ K_2O	29 – 10 – 2005
8.	Foliar spray of 0.2% $ZnSO_4$	15 – 11 –2005
9.	2^{nd} top dressing $¼^{th}$ N and $¼^{th}$ K_2O	27 – 11 - 2005
10.	Intercultural operations	
i.	Hand weeding	Three times at 20 days interval (i.e., 20,40 and 60 DAT)
ii.	Earthing up	30 – 10 – 2005
11.	Irrigations	Weekly intervals

12. Harvesting

Total no. of pickings	:	Seven
First picking		26 – 12 – 05
Second picking		2 – 1 – 2006
Third picking		14 – 1 – 2006
Fourth picking		21 – 1 – 2006
Fifth picking		28 – 1 – 2006
Sixth picking		5 – 2 – 2006
Seventh picking		12 – 2 – 2006

3.5.1 Raising nursery

Marigold seeds were sown on raised nursery bed in rows at a distance of 5 cm from row to row and covered with soil and watered regularly to ensure proper germination. The variety Pusa naringa gainda was sown at a seed rate of 0.2 kg ha^{-1}.

3.5.2 Preparatory cultivation

The experimental field was ploughed thrice with tractor drawn plough followed by harrowing and leveling with a wooden plank.

3.5.3 Transplanting

Thirty days old seedlings of marigold were transplanted at a spacing of 40 cm x 30 cm on flat beds.

3.5.4 Fertilizer application

Nitrogen and potassium were applied as per treatment combinations along with recommended dose of phosphorus (80 kg P_2O_5 ha^{-1}). Entire quantity of phosphorus and half doses of nitrogen and potassium were applied as basal in the form of urea, single superphosphate and muriate of potash. Remaining half of N and K_2O were applied in two equal splits at 30 and 60 days after transplanting. A single foliar spray of zinc through $ZnSO_4$ @ 0.2 percent was done at 15 days after first top dressing.

3.5.5 Irrigation schedule

Irrigations were given at weekly intervals depending on soil moisture and weather conditions. A total of 13 irrigations were given to the crop during its growth period in the field.

3.5.6 Inter cultivation

The crop was kept weed free throughout the cropping period and earthing up of the plants was done at 30 days after transplanting.

3.5.7 Pinching / Tipping

Pinching was done at 30 days after transplanting to remove apical dominance and promote more number of side shoots.

3.5.8 Plant Protection

The crop was not affected by any pest or disease. Hence, there was no necessity of applying pesticides and fungicides to the crop.

3.5.9 Harvesting

First flower picking was done at 90 days after transplanting. Subsequent 6 pickings were done at weekly intervals and fresh weights of flowers were recorded (q ha^{-1}). Size of the flowers was also measured as it is one of the yield attributing factors.

3.5.10 Collection of plant and soil samples

Plant and soil samples were collected from each treatment at 2 stages viz., 60 days after transplanting and after final harvest. Fresh and dry weights of plant samples were recorded and processed samples were analysed for total N, P and K concentrations to compute N, P and K uptake (kg ha^{-1}) by marigold crop.

The soil samples collected at these stages were analysed for different forms of nitrogen (available, ammoniacal and nitrate nitrogen) and potassium (water soluble, exchangeable, 1N HNO_3 extractable, non-exchangeable and total K). The soil samples were also analysed for available phosphorus at these stages.

3.5.11 Plant analysis

The plant samples were air dried followed by oven drying at 60^{o}C till constant weights were obtained. The oven dried material was finely ground, digested (Piper *et al*., 1966) and used for analysing N, P and K concentrations (per cent).

3.5.12 Quality parameters

Fresh flower and leaf samples collected at final harvest were analysed for total carotenoids and essential oil content, respectively.

3.5.12.1 Total carotenoids

Total carotenoids were estimated by the procedure given by Zakaria *et al* (1964).

Saponication

One gram homogenous sample was taken in a 100 ml conical flask and dissolved in 10 ml of working alcoholic KOH solution, which was prepared freshly before analysis. The conical flask was incubated at 37^{o}C for 20 minutes and the contents of the flask were transferred to a separating funnel for extraction with intermittant shaking.

Extraction of total carotenoids

The saponicated mixture was extracted with petroleum ether. Each extraction was done by using 50 ml of solvent. After each extraction, the upper solvent layer was transferred back to the funnel for extraction.

The process was repeated until a clear white layer was obtained indicating complete extraction. The pooled petroleum ether layer was poured back into the separating funnel after discarding the lower layer and washed thrice with distilled water. The washed solvent was dispensed into a conical flask and 20 – 30 g of anhydrous sodium sulfate was added to remove the excess water.

The solvent was transferred to 100 ml measuring jar and volume was measured. Optical density of the solution was measured at a wave length of 450 nm using UV visible spectro photometer and expressed as mg g^{-1} on fresh weight basis.

3.5.12.2 Essential oil content (%)

One kg fresh foliage was collected treatmentwise and essential oil was extracted for 3 hours by steam distillation of each sample using modified clavengers type apparatus and expressed in percent (Guenther, 1972).

3.6 STATISTICAL ANALYSIS

The data on various parameters were subjected to statistical analysis following the standard method for analysis of variance prescribed for Factorial Randomized Block Design (Panse and Sukhatme, 1978).

CHAPTER IV

RESULTS

In order to study the effect of nitrogen and potassium on yield and quality of African marigold (*Tagetes erecta* L.) grown on Alfisol, a field experiment was conducted at Students' Farm, College of Agriculture, Rajendranagar during *kharif* 2005-06. The results obtained on yield and from analysis of soil and plant samples at different growth stages besides other parameters are presented in this chapter.

4.1 SALIENT CHARACTERISTICS OF SOIL

The initial soil sample collected from the experimental site was analysed for salient characteristics and data are furnished in Table 3.

The soil under study was slightly alkaline but non-saline and is sandy loam in texture. The contents of organic carbon and available phosphorus were 0.5 per cent and 36 kg P_2O_5 ha^{-1}, respectively. The soil was also analysed for different forms of nitrogen and potassium. The available, ammoniacal and nitrate nitrogen contents were 22.0, 18.0 and 28.7 (kg ha^{-1}), respectively (Table 3). Water soluble, ammonium acetate extractable, exchangeable, 1N HNO_3 extractable, non exchangeable and total K contents, (c mol (p^+) kg^{-1}) were 0.045, 0.25, 0.205, 4.3, 4.05 and 50.2, respectively. The cation exchange capacity was 16.8 c mol (p^+) kg^{-1}.

4.2 DRY MATTER PRODUCTION, CONCENTRATIONS AND UPTAKE AT 60 DAT

The data on effect of different levels of nitrogen (0, 40, 80 and 120 kg ha^{-1}) and potassium (0, 40, 60 and 80 kg K_2O ha^{-1}) on dry mater production, N, P and K concentration and uptake by African marigold (*Tagetes erecta*) at 60 DAT are given in Table 4, 5 and 6 and are shown in Figure 2 and 3.

The results revealed that there was significant increase in dry matter production (Table 4), N and P concentrations with increasing levels of nitrogen from N_0 to N_3, recording highest values of 4528.3 kg ha^{-1}, 1.75 and 0.61 per cent, respectively. Whereas, the effect of N levels on K concentration was found non-significant.

With regard to effect of levels of K, similar trend was observed with P and K concentrations recording the highest values of 0.55 and 1.52 per cent, respectively at K_3 level (Table 5). However dry matter production and N content were not affected significantly with application of different levels of K.

The interaction effects of different levels of N and K on dry matter production and N concentration were found non significant, the highest values of 4511.6 kg ha^{-1} and 1.78 per cent being recorded at N_3K_3 while lowest were at N_0K_0. With regard to P concentration, there was no significant variation at lower levels of N and K whereas at higher values of N and K, there was significant increase in P concentration. The highest P concentration (0.63 %) was recorded at N_3K_3, which was on par with N_3K_2 (0.62 %). The interaction (N x K) effect on K content of marigold was found non significant at 60 DAT.

Increase in levels of N application also increased the N and K uptake significantly, the highest values of 81.7 and 56.7 kg ha^{-1} being recorded at 120 kg N ha^{-1} level, respectively (Table 6).

With regard to effect of K levels on N and P uptake, it was non significant. Whereas, K uptake increased significantly with increase in levels of K from K_0 (24.75 kg ha^{-1}) to K_3 (37.80 kg ha^{-1}). However, K uptake at K_1 and K_2 levels was on par with each other (31.75 and 32.84 kg ha^{-1}).

The interaction effect (N x K) of levels on N and P uptake was found non significant, while the effect was significant on K uptake by marigold. Among the different combinations of N and K, highest K uptake was recorded at N_3K_3 (71.28 kg ha^{-1}) followed by N_3K_2 (61.98 kg ha^{-1}); the lowest K uptake (5.95 kg ha^{-1}) being recorded at N_0K_0 (Table 6).

4.3 CONTENTS OF DIFFERENT FORMS OF NITROGEN IN SOIL AT 60 DAT

The contents (kg ha^{-1}) of available, ammoniacal and nitrate nitrogen in soil at 60 DAT are presented in Table 7.

With increasing levels of applied N, there was significant increase in available (272.5 kg ha^{-1}), ammoniacal (27.1 kg ha^{-1}) and nitrate nitrogen (60.5 kg ha^{-1}), the highest values being recorded at N_3 level.

Similar trend was observed with available and nitrate nitrogen contents with application of potassium. There was significant increase in contents of these two forms due to increase in levels of application of K from K_0 to K_3.

With regard to ammoniacal nitrogen, there was significant increase in content from K_0 to K_2 level and the levels K_2 (21.7 kg ha^{-1}) and K_3 (22 kg ha^{-1}) were on par with each other.

The interaction (N x K) effect revealed that the contents (kg ha^{-1}) of available nitrogen (276.3), ammoniacal nitrogen (29.5) and nitrate nitrogen (62.0) were highest at N_3K_3 level. However, the values at N_3K_3 were on par with those values recorded at N_3K_2 and were significantly superior to other combinations (Table 7). It was also found that there was no significant variation among contents of these three forms of nitrogen due to increase in level of potassium in combination with any level of nitrogen.

4.4 CONTENTS OF DIFFERENT FORMS OF POTASSIUM IN SOIL AT 60 DAT

The contents of different forms of potassium viz., water soluble, NH_4OAc extractable and exchangeable K at 60 DAT of marigold crop are given in Table 8.

There was a significant increase in contents of water soluble, NH_4OAc extractable and exchangeable K at K_3 level, the values (c mol (p^+) kg^{-1}) of which were 0.062, 0.263 and 0.200, respectively.

The effect of levels of nitrogen on contents of water soluble K was non significant while the contents of available and exchangeable K increased significantly from N_0 to N_1 but significantly decreased from N_1 to N_3 level. The values of available and exchangeable K were 0.237 and 0.188 c mol (p^+) kg^{-1}, respectively at N_1 level (Table 8).

The combined application of different levels of N and K gave significantly highest (0.064 c mol (p^+) kg^{-1}) and lowest (0.039 c mol (p^+) kg^{-1}) values of water soluble K at N_3K_3 and N_0K_0, respectively (Table 8). However, no much variation was observed among other treatments. In case of contents of available and exchangeable K, there was a significant increase from N_0 to N_1 followed by significant decrease from N_1 to N_3 at any combinations with levels of K. The highest contents of available K (0.295 c mol (p^+) kg^{-1}) and exchangeable K (0.233 c mol (p^+) kg^{-1}) were recorded in N_1K_3 treatment (Table 8).

The contents of slowly available forms of potassium viz., non exchangeable and total K were given in Table 9.

There was a significant increase in contents of 1N HNO_3 extractable, non exchangeable and total K from K_0 to K_3 level recording 5.74, 5.47 and 53 c mol (p^+) kg^{-1}, respectively at K_3 level.

The contents of 1N HNO_3 extractable K and non exchangeable K were significantly increased upto N_3 level (5.29 and 5.07 c mol (p^+) kg^{-1}, respectively). Whereas, the total K content was not effected by level of N application (Table 9).

The interaction effect (N x K) on 1N HNO_3 extractable, non exchangeable and total K content was significant. The 1N HNO_3 extractable K and total K contents were highest (5.71 and 56.4 c mol (p^+) kg^{-1}) at N_3K_3 level. However, there was no significant variation among other treatment combinations. In case of non exchangeable K highest values were recorded at N_1K_3 (5.79 c mol (p^+) kg^{-1}) while lowest contents were obtained at N_1K_0 (3.95 c mol (p^+) kg^{-1}) as furnished in Table 9.

4.5 DRY MATTER PRODUCTION, CONCENTRATIONS AND UPTAKE AT HARVEST

The data on dry matter production, N, P and K concentrations and nutrient uptake by marigold at harvest are given in Tables 10, 11 and 12, respectively.

The results revealed that there was significant increase in dry matter production (Table 10), N and P concentrations with increasing levels of nitrogen from 0 to 120 kg ha^{-1}, recording highest values of 9438.6 kg ha^{-1}, 2.16 per cent and 0.90 per cent, respectively. However, the effect of levels of nitrogen on K concentration of marigold was not found significant (Fig. 4 and 5).

There was significant increase in dry matter production with application of potassium upto K_1 level. The values recorded from K_1 (5187.1 kg ha^{-1}) to K_3 (5105.5 kg ha^{-1}) were, however, on par with each other (Table 10). Also the effect of K levels on N concentration of marigold plants was not significant whereas P and K concentration increased significantly from K_0 to K_3 levels

(Fig. 6 to 9); highest values (0.88 % and 1.81 %) being recorded at K_3 (Table 11).

The interaction effect of levels of N and K on dry matter production and N and K concentrations was not found significant. However, higher levels of N and K increased the P concentration significantly. Highest P concentrations of 0.95 per cent was recorded at N_3K_3 which lowest (0.70 %) was observed at N_0K_0.

The data on N, P and K uptake by marigold (whole plant) at final harvest are presented in Table 12.

There was a significant increase in N, P and K uptake with increase in levels of nitrogen. The highest values of 200.4, 85.32 and 143.6 kg ha^{-1} were recorded at N_3 level, respectively.

It was found that the levels of K did not significantly influence N uptake. While P uptake was significantly increased upto K_3 level (46.78 kg ha^{-1}) which was on par with that of K_2 level (44.60 kg ha^{-1}) and K_1 level (44.15 kg ha^{-1}).

Also with increase in K levels, there was significant increase in K uptake recording highest (92.83 kg ha^{-1}) and lowest (38.80 kg ha^{-1}) values at K_3 and K_0 levels, respectively (Table 12). However, the uptake at K_3 was on par with the uptake recorded at K_2 (89.36 kg ha^{-1}).

The interaction affect (N x K) revealed that there was no significant effect on N uptake (Fig. 10). However there was significant effect on P and K uptake. With regard to P uptake highest value was recorded at N_3K_2

(88.27 kg ha^{-1}) and was on par with that of N_3K_3 (89.28 kg ha^{-1}). Similarly highest and lowest values of K uptake were recorded at N_0K_0 (16.38 kg ha^{-1}) and N_3K_3 (180.44 kg ha^{-1}) with significant variation among other treatment combinations (Figs. 11 and 12).

4.6 CONTENTS OF FORMS OF NITROGEN IN SOIL AT HARVEST

The contents of different forms of nitrogen viz., available, ammoniacal and nitrate nitrogen at harvest of marigold were given in Table 13.

There was a significant increase in available, ammoniacal and nitrate nitrogen contents from N_0 to N_3. The values of these forms at N_3 level were 225.6, 13.5 and 37.8 kg ha^{-1}, respectively (Table 13).

Similar results were found with k levels, showing significant increase in available, ammoniacal and nitrate nitrogen contents with increase in K from K_0 to K_3 recording highest values of 146.1, 10.9 and 30.8 kg ha^{-1}, respectively at K_3. However, the nitrate nitrogen recorded at K_3 was on par with K_2 (30.0 kg ha^{-1}).

The interaction effect also showed a significant increase in available nitrogen content at all the levels of N application, highest (233.9 kg ha^{-1}) and lowest (63.0 kg ha^{-1}) values being recorded at N_3K_3 and N_0K_0 (Table 13). Similar trend was observed with ammoniacal nitrogen recording highest (15.3 kg ha^{-1}) and lowest (5.7 kg ha^{-1}) values at N_3K_3 and N_0K_0. However, there was no significant variation among other treatment combinations. Also the interaction (N x K) effect found to be non significant on nitrate nitrogen content.

4.7 CONTENTS OF FORMS OF POTASSIUM IN SOIL AT HARVEST

The contents (c mol (p^+) kg^{-1}) of different forms of K viz., water soluble, available, exchangeable, 1N HNO_3 extractable, non-exchangeable and total potassium in soil at harvest of marigold were given in Tables 14 and 15.

The effect of levels of N, K_2O and N x K on water soluble K content was non significant. While K levels showed significant effect on available and exchangeable forms of K recording 0.245 and 0.191 c mol (p^+) kg^{-1}, respectively at K_3 level.

With regard to N levels, they showed non significant effect on available and exchangeable forms of K. While the combined effect of levels of N and K indicated that there was significant effect on available and exchangeable forms of K. The highest values of these two forms were recorded at N_1K_3 (0.252 and 0.195 c mol (p^+) kg-1).

The contents of 1N HNO_3 extractable, non exchangeable and total K are given in table 15. The effects of levels of K and N x K were found significant for 1N HNO_3 extractable and non exchangeable forms while the effects were found non significant with N levels. Similarly, there were no significant effects of N levels and N x K on total K content. Highest values of 1N HNO_3 extractable (5.31 c mol (p^+) kg-1) and non exchangeable forms (5.06 c mol (p^+)

kg^{-1}) were recorded at K_3 level. In case of total K content, a significant increase was observed upto K_2 (50.0 c mol (p^+) kg^{-1}) and was on par with K_3 (Table 15).

The interaction effect of levels of N and K revealed that 1N HNO_3 extractable K and non exchangeable K contents were significantly increased from K_0 to K_2 level at all the levels of N application. However, with increasing levels of N, there was not much variation at any level of K application. Highest contents of 1N HNO_3 extractable and non-exchangeable K i.e. 5.38 and 5.20 c mol (p^+) kg^{-1} were recorded at N_2K_3 and N_0K_3 levels, respectively (Table 15).

4.8 EFFECT OF LEVELS OF N AND K ON AVAILABLE PHOSPHORUS IN SOIL AT 60 DAT AND AT HARVEST

Available phosphorus contents at 60 DAT and at harvesting stages of marigold are given in table 16.

The N and K levels significantly influenced the available phosphorus contents both at 60 DAT and at harvest. At 60 DAT, available phosphorus content (kg P_2O_5 ha^{-1}) was more at N_0 level (56 kg ha^{-1}). Increasing levels of N significantly decreased content of the available P_2O_5. Also there was no significant variation in this content at N_1, N_2 and N_3 levels (Table 16). Similar trends were observed even at harvesting stage recording the highest mean values at N_1 (45.2 kg P_2O_5 ha^{-1}) and K_2 levels (42.1 kg P_2O_5 ha^{-1}).

Interaction effect of N and K on available P_2O_5 content was also significant. The highest value was recorded at N_0K_0 (57.1 kg ha^{-1}) while the lowest value was obtained at N_3K_3 (51.3 kg ha^{-1}) which was on par with N_3K_2

(52.6 kg ha^{-1}) and N_1K_1 (51.2 kg ha^{-1}) at 60 DAT. At harvesting stage, similar trends were seen with highest value at N_1K_2 (46.1 kg P_2O_5 ha^{-1}) followed by N_1K_0 (46.0) and N_1K_1 (44.8 kg ha^{-1}) as given in table 16.

4.9 FLOWER SIZE AND YIELD OF MARIGOLD

The data on effect of different levels of nitrogen (0, 40, 80 and 120 kg ha^{-1}), potassium (0, 40, 60 and 80 kg K_2O ha^{-1}) and their interaction (N x K) on flower size and yield of African marigold are given in Table 17.

Different N levels significantly increased the flower yield and diameter from N_0 to N_3 recording highest flower yield (137.6 q ha^{-1}) and flower size (6.8 cm) at N_3 level.

Similar results were observed with increase in K levels from K_0 to K_3. The mean flower yield and size of flower at K_3 level were 115.9 q ha^{-1} and 6.2 cm (Table 17).

Among all the treatment combinations, significantly highest flower yield was recorded at N_3 K_3 (141.89 q ha^{-1}). However, it was on par with N_3K_2 (140.0 q ha^{-1}), N_2 K_3 (139.5 q ha^{-1}) and N_2K_2 (137.9 q ha^{-1}), but significantly superior to all other treatment combinations (Fig. 13). Similar trends were observed with flower diameter also, with highest flower size at N_3K_3 (7.2 cm) followed by N_2K_2 (6.9 cm) and N_3K_1 (6.6 cm).

Treatmentwise flower yield recorded at different pickings are given in Appendix I.

4.10 QUALITY PARAMETERS

Marigold fresh flower samples were analysed for total carotenoids while leaf samples were analysed for essential oil at peak flowering stage (Fourth picking). The data on these quality parameters on fresh weight basis are given in Table 18.

There was a significant increase in total carotenoid content of flowers from N_0 to N_2 (2.78 to 3.43 mg g^{-1}). Further increase in N levels to N_3 significantly decreased the carotenoids content from 3.03 to 2.98 mg g^{-1}.

With respect to K levels, content of total carotenoids increased significantly from 2.97 to 3.10 mg g^{-1} fresh weight with the application of K at 0 to 60 kg ha^{-1}. Total carotenoid content at 80 kg ha^{-1} (3.10 mg g^{-1}) was on par with that at K_2 level (3.10 mg g^{-1}).

A significant interaction (N x K) effect was also noticed on total carotenoid content. Highest carotenoid content (3.54 mg g^{-1}) was recorded at N_2K_3 while the lowest (2.70 mg g^{-1}) was observed at N_0K_0.

With regard to essential oil content in leaves of marigold, though there was slight variation in oil content, the effects of levels of N, K and N x K were not found significant (Table 18).

CHAPTER V

DISCUSSION

Marigold is an important flower crop as it is gaining lot of commercial importance in recent years. Though nutrition of marigold plays a significant role in improving flower yield and quality, it is being neglected cultivating the crop under improper management and poor fertility conditions. To suggest optimum N and K fertilization for marigold especially when grown on Alfisols of Southern Telangana Zone of Andhra Pradesh, the present investigation was carried out during *kharif*, 2005 with four levels of nitrogen (0, 40, 80 and 120 kg N ha^{-1}) and potassium (0, 40, 60 and 80 kg K_2O ha^{-1}) as these two nutrients in general contribute to growth and development of crop and quality of its flowers.

5.1 SALIENT CHARACTERISTICS OF EXPERIMENTAL SOIL

The experimental soil was slightly alkaline (pH 7.2), non saline (0.11 d Sm^{-1}) and is sandy loam in texture. The red soil under study was poor in fertility status with low available N (220 kg ha^{-1}), medium available potassium (198 kg K_2O ha^{-1}) and phosphorus (36.0 kg P_2O_5 ha^{-1}). The content of organic carbon (0.5 %) and cation exchange capacity (16.8 c mol (p^+) kg^{-1}) of soil were also found low (Table 3).

Among the different forms of nitrogen, nitrate nitrogen was more (28.7 kg ha^{-1}) than that of ammoniacal nitrogen (18.0 kg ha^{-1}). Alfisols in general have more nitrate nitrogen than ammoniacal nitrogen as compared to Vertisols (Sreenivasa Raju and Narasimham, 1995).

With regard to different forms of potassium, the contents of water soluble, exchangeable, ammonium acetate extractable, 1N HNO_3 extractable, non exchangeable and total K were found to be 0.045, 0.205, 0.25, 4.3, 4.05 and 50.2 c mol (p^+) kg^{-1}, respectively indicating low K status of experimental soil (Table 3).

Based on initial nutrient status, it was found that the Alfisol under study has poor fertility status and crops grown on these soils need balanced fertilization for improvement of growth and yield.

5.2 RESPONSE OF MARIGOLD TO DIFFERENT LEVELS OF NITROGEN AND POTASSIUM

The results revealed that, with increase in levels of nitrogen (No to N_3) there was significant increase in dry matter production, concentration and uptake.

With regard to dry matter production, nitrogen played a significant role in increasing mean dry matter yield from N_0 (2135 kg ha^{-1}) to N_3 (9438 kg ha^{-1}); the per cent increase being 342.0 (Table 10). This might be due to more vegetative growth with high N fertilization (120 kg N ha^{-1}), which inturn contributed to increase in dry matter production. Similar results were also reported by Baboo and Singh (2003) and Halepyati *et al*. (2001) for marigold grown on red soils.

Similarly, the N content and uptake by marigold also increased significantly at different growth stages with increase in N levels from N_0 to N_3. At higher level of N fertilizer application, the availability of nitrogen to marigold was high, which inturn contributed to high N content (2.16 %) and total N uptake (200.4 kg ha^{-1}). Also with increase in levels of nitrogen, there was significant increase in P concentration (0.90 %), K concentration (1.51 %) and total P and K uptake (Table 12). This can be attributed to better growth and development of marigold plants at higher N fertilization, which inturn contributed to increase in concentration and uptake (Anuradha *et al.*, 1988).

With regard to K levels, the effect on dry matter production was non significant. However, with increase in level of K fertilization from K_0 to K_3, there was significant increase in K concentration (1.81 %) and K uptake (92.83 kg ha^{-1}), the per cent increase being 123.4 and 139.25, respectively. Similar results were also reported by Agrawal *et al*. (2002). They found the response of marigold even upto 200 kg K_2O ha^{-1}.

The trends on effect of levels of N and K at 60 DAT and at harvest revealed that there was increase in dry matter production, concentration and uptake of N and K with increase in duration of crop specifically at higher level of N and K applications. This indicated that the requirement of nutrients increased with advancement in growth, which inturn contributed to higher flower yield and also improvement in quality.

5.3 EFFECT OF LEVELS OF N AND K ON FLOWER YIELD OF MARIGOLD

There was significant increase in flower yield (137.6 q ha^{-1}) of marigold with increase in nitrogen application from 0 to 120 kg N ha^{-1}; the increase being 71.35 per cent. However, the effect of K levels on flower yield was only 11.12 per cent due to increase in dose from 0 to 80 kg K_2O ha^{-1}. Similar trend was observed with flower size, which is an yield attributing factor. The flower size was significantly highest at N_3 (6.8 cm) followed by K_3 (6.2 cm).

The influence of N on flower yield was very significant because, this nutrient plays an important role in transport of metabolites for growth and development (Marschner, 1983), which inturn is responsible for more uptake of nutrients and increase in flower size and yield.

Though the individual effect of potassium on flower yield was not much, the interaction effect of N x K was found to significantly contribute to increase in flower size and yield. Highest fresh flower yield of 141.8 q ha^{-1} was recorded at N_3K_3 while the lowest was observed at N_0K_0 (77.6 q ha^{-1}). Among the different treatment combinations, N_3K_3 was found to be the best, followed by N_3K_2 (140 q ha^{-1}), N_2K_3 (139.5 q ha^{-1}) and N_2K_2 (137.9 q ha^{-1}). However, when the increase in yield (per cent) was considered, it was 0.35 (N_2K_3 to N_3K_2), 1.28 (N_3 K_2 to N_3K_3) and 1.64 (N_2 K_3 to N_3 K_3) indicating that application of 120 kg N along with 80 kg K_2O ha^{-1} (N_3K_3) is optimum for obtaining better flower yield.

5.4 EFFECT OF LEVELS OF N AND K ON QUALITY PARAMETERS OF MARIGOLD

Since, the quality parameters viz., carotenoids and essential oils extracted from flowers and leaves of marigold have commercial value, an attempt was made to know the effect of N and K nutrition on these quality parameters in view of the very little work done on these aspects.

The results revealed that there was significant increase in carotenoid content of flowers upto N_2 (3.43 mg g^{-1}) as further increase resulted in a decrease at N_3 level (2.98 mg g^{-1}). Similarly, the carotenoid content showed an increase upto K_2 (3.1 mg g^{-1}), which was on par with that recorded at K_3 level.

Among the different treatment combinations, N_2K_3 recorded significantly highest carotenoid content (3.54 mg g^{-1}) followed by N_2 K_2 (3.43 mg g^{-1}). Similar results were reported by Anuradha *et al*. (1990) indicating high carotenoid content at 60 kg N ha^{-1} followed by a decrease at higher level.

With regard to essential oil content, the effect of levels of N, K and also the interaction effect was found non significant. Variations in essential oil content with different varieties were reported by workers. According to Raghava (2000), among the different species of marigold, *Tagetes erecta*, which was selected for the present study, has very less essential oil content of 0.01 % while the highest oil content was recorded in *Tagetes minuta* (0.20 to 0.35 %) followed by *Tagetes patula* (0.14 %). This might be the reason for non significant effect of N and K nutrients on essential oil content. However, this species i.e. *Tagetes erecta* (cv. *Pusa naringa gainda*), which is commercially cultivated around Hyderabad, is rich in carotenoids. Hence, for commercial extraction of essential oils, *Tagetes minuta* appears to be the best.

5.5 CHANGES IN FORMS OF N AND K IN SOIL AND THEIR DEPLETION BY MARIGOLD AT 60 DAT AND AT HARVEST

As nutrition of marigold plays an important role in its growth, development, improvement in quality and flower yield there can be changes with soil fertility. Further, it is possible that the crop depletes the nutrients from soil. Hence, the soils collected at different growth stages viz., 60 DAT (flower initiation) and at 100 DAT were analysed for different forms of N and K to know the extent of change in contents of these forms due to nutrient uptake by marigold at these stages.

The contents of different forms of inorganic nitrogen viz., available, ammoniacal and nitrate nitrogen significantly increased from N_0 to N_3 at both stages of crop growth period; the increase being 46.5, 59.4 and 132.6 per cent (60 DAT) and 223.5, 107.6 and 62.3 per cent (100 DAT), respectively. Among the different forms of nitrogen, the ammoniacal and nitrate nitrogen appear to have contributed to N concentration and uptake. The changes in forms of N also revealed that there was decrease in all the three forms from 60 DAT to harvest (100 DAT) as was shown in Table 19. It was also noticed that at higher levels of N application (N_2 and N_3), there was build up in different forms of N upto 60 DAT. Later on there was decrease in all these forms of nitrogen even at higher levels of N application (Table 19) indicating that the crop has removed nitrogen to a greater extent (200.4 kg N ha^{-1}) to meet its requirements at peak growth and flowering stages.

With regard to forms of potassium, there was significant increase in all forms with increase in potassium application form K_0 to K_3 at two growth stages (Tables 8, 9, 14 and 15).

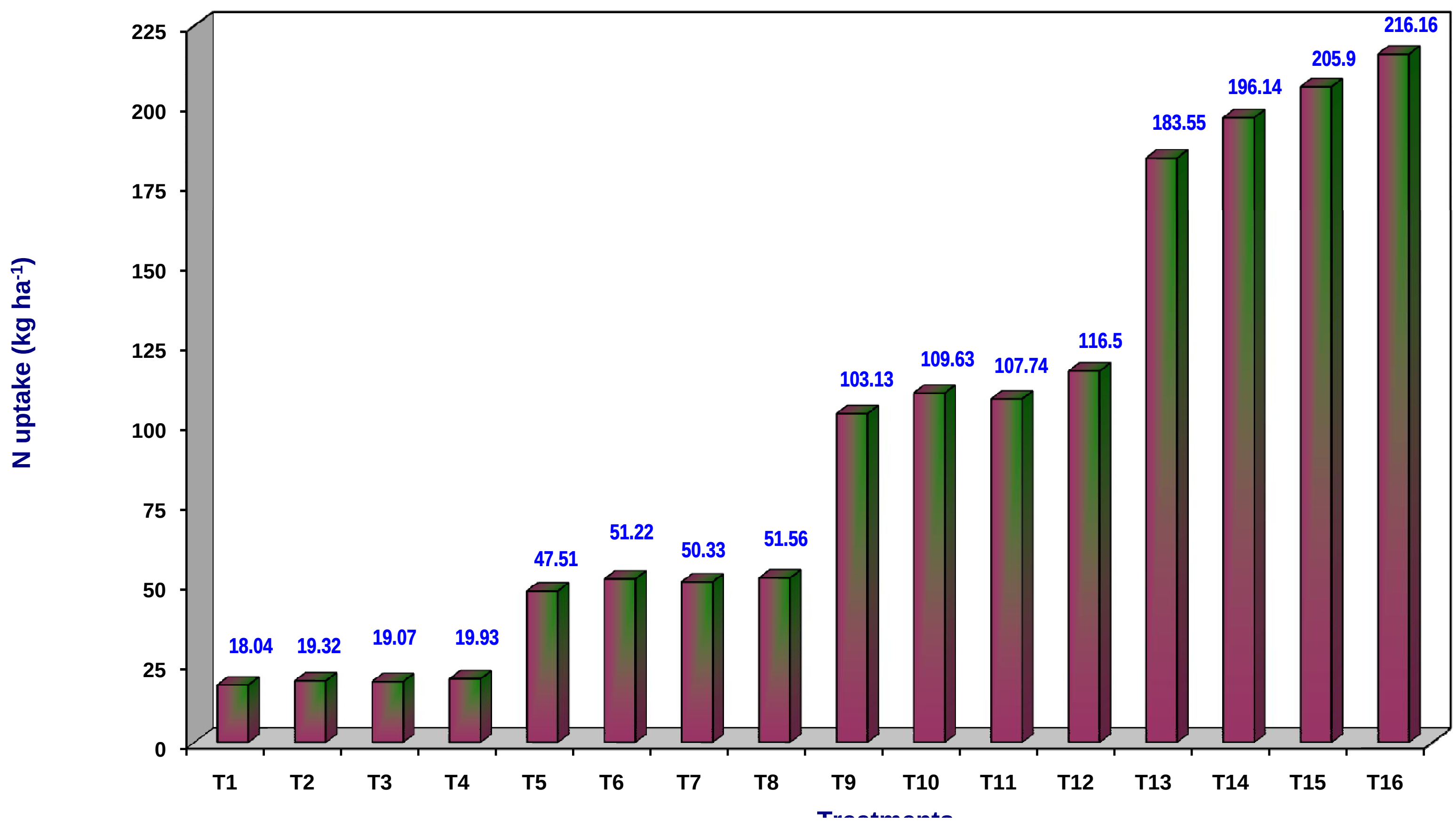
The changes in contents of forms of potassium in soil at different growth stages revealed that the crop utilized the easily available forms of K at initial stages (60 DAT) viz., water soluble, NH_4OAc extractable and exchangeable K (Table 19). Whereas, at later stages, the slowly available forms of K *viz*., 1N HNO_3 extractable and non exchangeable K would have contributed to K uptake (92.8 kg K_2O ha^{-1}) by marigold to meet its K requirement.

It was also noticed that at higher levels of N and K applications, the soil fertility status also increased and the soil supported the nutrient demand of marigold (Tables 19 and 20). This is not possible with insufficient and lower levels of fertilization.

Even the interaction effect of N x K revealed that there was significant increase in contents of all forms of N and K at higher levels of N and K fertilization (N_3K_3) to marigold crop.

From the study it was found that marigold is a heavy feeder of N, P and K nutrients viz., 216.1, 89.3 and 180.4 kg ha^{-1}, respectively and it responds to fertilization especially when grown on light textured soils like Alfisol.

According to Agrawal *et al*. (2002) and Gavhane *et al.* (2004), the marigold responded even upto 300 kg N ha^{-1} and 150 kg K_2O ha^{-1} when the crop was grown on light textured sandy loam soils showing luxury consumption of N and K at higher levels. Hence, the present study on marigold suggests to recommend 120 and 80 kg ha^{-1} N and K_2O (N_3 K_3) along with 80 kg P_2O_5 ha^{-1} for better growth, improvement in quality and flower yield. Further, it was observed that it is useful for maintaining soil fertility status also to support cultivation of marigold crop.


N uptake (kg ha-1)
0
25
50
75
100
125
150
175
200
225
18.04
19.32
19.07
19.93
47.51
51.22
50.33
51.56
103.13
109.63
107.74
116.5
183.55
196.14
205.9
216.16
T1
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T13
T14
T15
T16

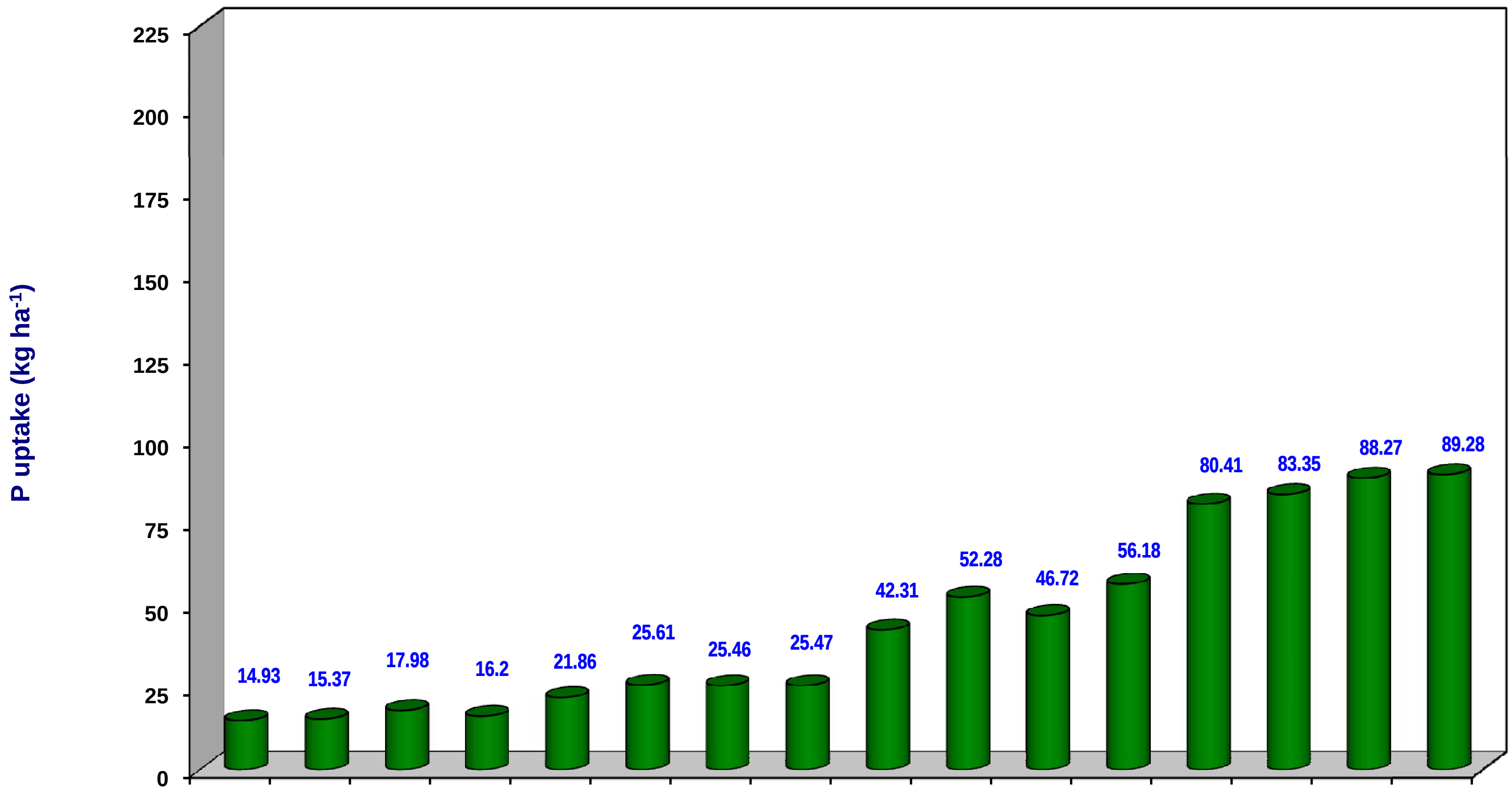
P uptake (kg ha-1)
225
200
175
150
125
100
75
50
25
0
14.93
15.37
17.98
16.2
21.86
25.61
25.46
25.47
42.31
52.28
46.72
56.18
80.41
83.35
88.27
89.28

Table 1: Weekly mean meteorological data during crop growth period

Standard Week	PERIOD	TEMPERATURE (^oC) MAX.	MIN.	R.H. (%) I	II	RAIN-FALL (mm)	RAINY DAYS	SUN-SHINE (hrs.)	WIND SPEED (km/hr)	EVAPO-RATION (mm)	MEAN TEMP. (^oC)
27	02-08 JULY'05	32.8	24.3	83	62	35.2	1	4.9	11.0	5.2	28.6
28	09-15	28.4	23.4	96	74	134.6	2	1.9	5.5	3.0	25.9
29	16-22	32.0	24.1	90	71	35.4	2	6.3	4.2	2.6	28.1
30	23-29	26.5	22.7	91	86	83.1	4	0.8	9.0	2.1	24.6
31	30-05 AUG	29.5	23.7	86	70	11.8	2	1.4	9.6	3.2	26.6
32	06-12	29.9	23.4	85	60	10.4	2	4.2	7.9	3.8	26.7
33	13-19	29.8	23.0	92	71	54.1	4	4.5	6.2	3.6	26.4
34	20-26	29.2	23.2	87	65	2.4	0	4.3	4.6	3.5	26.2
35	27-02 SEP	32.4	22.8	93	57	65.4	3	6.6	2.2	3.7	27.6
36	03-09	30.5	23.4	96	68	110.2	6	5.5	2.3	3.5	27.0
37	10-16	29.3	23.2	88	68	5.6	0	1.0	5.8	3.2	26.2
38	17-23	27.9	22.6	89	74	71.4	2	3.9	8.0	4.1	25.3
39	24-30	30.0	22.2	93	60	30.0	2	6.2	3.0	3.8	26.1
40	01-07 OCT	32.5	22.3	87	45	0.0	0	8.1	1.6	4.3	27.4
41	08-14	31.2	21.2	87	55	30.6	3	6.2	3.7	4.3	26.2
42	15-21	28.0	22.5	97	68	76.9	5	3.1	3.1	2.9	25.2
43	22-28	29.5	21.3	91	64	30.6	2	5.4	2.1	3.2	25.4
44	29-04 NOV	26.9	20.1	94	71	113.7	2	2.8	2.3	2.7	23.5
45	05-11	28.5	15.2	87	71	0.0	0	9.3	2.4	3.2	21.9
46	12-18	29.3	11.4	80	28	0.0	0	9.9	2.0	3.5	20.3
47	19-25	29.2	14.1	85	35	0.0	0	8.4	2.1	3.4	21.7
48	26-02 DEC	28.4	13.5	87	38	0.0	0	8.0	2.3	2.8	21.0
49	03-09	29.1	15.0	79	30	0.0	0	7.5	2.5	3.4	22.1
50	10-16	28.8	11.3	81	28	0.0	0	9.3	1.8	3.0	20.1
51	17-23	28.4	14.7	92	44	0.0	0	8.3	2.1	2.1	21.5
52	24-31	27.3	11.3	87	30	0.0	0	8.8	2.2	2.1	19.3
1	01-07 JAN'06	27.2	11.1	89	37	0.0	0	9.3	2.4	2.4	19.2
2	08-14	29.4	14.6	92	41	0.0	0	8.9	2.1	2.4	22.0
	Total	**822.1**	**541.6**	**2481**	**1571**	**901.4**	**42**	**165.1**	**114.3**	**90.9**	**681.8**
	Mean	**29.4**	**19.3**	**89**	**56**	**-**	**-**	**5.9**	**4.1**	**3.2**	**24.4**

CHAPTER VI

SUMMARY

Among the various agricultural inputs, fertilizers contribute maximum to agricultural production. Nitrogen and potassium are the major nutrients required for growth and development of plants. However, due to continuous cropping and use of high yielding varieties, there is depletion of these nutrients from soil. Moreover, light textured red soils like Alfisols are poor in fertility status and crops grown on this respond to N, P and K fertilization. Hence, there is a need to apply them through fertilizers, based on crop requirement and soil fertility status.

Nitrogen and potassium application is essential for many flower crops as their uptake of N and K is equal to or higher than that of cereals. Marigold though is a heavy feeder of nutrients, is commonly grown on light textured soils around Hyderabad. Further, this flower crop is gaining importance day by day, due to commercial value of carotenoids and essential oils extracted from flowers and leaves, respectively. However, not much work was done on this crop with regard to nutrition, optimum doses of fertilization, quality aspects etc.

With a view to find out optimum doses and N and K for obtaining high flower yield with good quality, a field experiment entitled "Nitrogen and potassium requirement and their effect on flower yield and quality of African marigold (*Tagetes erecta*) grown on Alfisol" was conducted at Students' Farm, College of Agriculture, Rajendranagar, Hyderabad during *kharif* 2005-06. The experiment was laid out in a factorial RBD with four levels each of nitrogen (0, 40, 80 and 120 kg ha^{-1}) and potassium (0, 40, 60 and 80 kg K_2O ha^{-1}) with 16 treatment combinations, each replicated thrice. Nitrogen and potassium were applied as per treatments along with an uniform dose of phosphorus at 80 kg P_2O_5 ha^{-1}. Entire quantity of phosphorus and half of nitrogen and potassium were applied as basal in the form of single superphosphate, urea and muriate of potash, respectively. Rest of N and K was applied in two equal splits at 30 and 60 DAT. The soil and plant samples were collected at 60 DAT and at harvest (100 DAT). Dry matter production of plants was recorded and the plant samples were analysed for N, P and K contents to compute the N, P and K uptake. Data on flower yield and flower size were also recorded. Fresh flowers and leaves collected at harvest were analysed for total carotenoids (mg g^{-1}) and essential oil content, respectively. Soil samples collected at 60 DAT and at harvest were analysed for different forms of N and K and also for available phosphorus (kg P_2O_5 ha^{-1}).

The results obtained from the field experiment are summarized below :

The experimental soil is light textured (sandy loam) with slightly alkaline reaction but was non saline. The soil was low in organic carbon (0.5 %) and available nitrogen (220 kg ha^{-1}), medium in available potassium (198 kg K_2O ha^{-1}) and available phosphorus (36.0 kg P_2O_5 ha^{-1}) indicating that the soil, in general, was poor in fertility status. The contents of ammoniacal and nitrate nitrogen were 18.0 and 28.7 kg ha^{-1}, respectively. The contents of water soluble,

NH_4OAc extractable, exchangeable, 1N HNO_3 extractable, non exchangeable and total K were 0.045, 0.205, 0.25, 4.3, 4.05 and 50.2 c mol (p^+) kg^{-1}, respectively indicating low N and K status of experimental soil.

Dry matter production concentrations of N, P, K and their uptake were found significantly increased with advancement in age of crop. Dry matter production increased by 342.01 % from N_0 (2135 kg ha^{-1}) to N_3 (9438 kg ha^{-1}) due to application of 120 kg N ha^{-1}. Similar trends were observed with N concentration and uptake; the percent increase being 135.9 and 949.4 from N_0 to N_3 level. Also concentration of P (0.90 %) and its uptake (85.32 kg P_2O_5 ha^{-1}) were increased significantly at both stages with increase in level of N. However, K uptake increased significantly from 10.73 to 56.72 kg ha^{-1} (60 DAT) and 30.85 to 143.6 kg ha^{-1} (harvest) due to application of N at 120 kg ha^{-1} against control (N_0).

With regard to effect of levels of K on concentration and uptake of potassium, significant increase was noticed in these two parameters both at 60 DAT and at harvest. The K concentration and uptake were 1.52 per cent and 37 kg ha^{-1} at 60 DAT and 1.81 per cent and 92.83 kg ha^{-1} at harvest, respectively. There was also significant increase in P uptake from 16.1 to 85.3 kg ha^{-1} from N_0 to N_3 level.

Interaction effect revealed that highest levels of N and K significantly resulted in highest dry matter production at N_3K_3 (9398.3 kg ha^{-1}). The

K uptake also showed significant increase at this level recording 71.28 kg ha^{-1} and 180.44 kg ha^{-1} at 60 DAT and at harvest, respectively.

The effect of N and K levels was found significant in increasing flower yield. Highest flower yield of 137.6 q ha^{-1} (71.35 % increase over N_0) was recorded at N_3 while at K_3 the flower yield was 115.9 q ha^{-1} (11.12 %, increase over K_0). Among the treatment combinations N_3K_3 recorded highest flower yield (141.8 q ha^{-1}) followed by N_3K_2 (140 q ha^{-1}) and N_2K_3 (139.5 q ha^{-1}).

With regard to quality parameters, essential oil content was not significantly influenced by N and K levels, whereas carotenoid content increased upto N_2 (3.43 mg g^{-1}) and K_2 levels (3.1 mg g^{-1}). At 120 kg N ha^{-1}, there was a decrease carotenoid content (2.98 mg g^{-1}). Among the treatments, the carotenoid content was more in N_2K_3 (3.54 mg g^{-1}) than at N_3K_3 level (2.91 mg g^{-1}).

From the study, it was found that marigold is a heavy feeder of nutrient and removed 216.1, 89.2 and 180.4 kg N, P_2O_5 and K_2O ha^{-1} respectively.

To find out the depletion of different forms of N and K and their contribution to growth, development, yield and quality, the soils collected at 60 DAT and at final harvest were analysed for different forms of N and K besides available P_2O_5.

The results indicated that there was significant effect of N levels on available, ammoniacal, and nitrate nitrogen increasing the contents by 46.5, 59.4 and 132.6 per cent increase from N_0 to N_3 at 60 DAT and 223.0, 107.6 and

62.2 per cent increase at harvest (100 DAT) indicating that ammoniacal and nitrate nitrogen contributed to N content and uptake. There was also a decrease in all forms with advancement in crop growth.

The data on changes in different forms of K indicated depletion of easily available forms at 60 DAT. Later on by harvest, the depletion of slowly available forms were more than at 60 DAT. This indicates the existence of dynamic equilibrium among different forms of K in soil. There was significant increase in different forms of K with increase in K levels form K_0 to K_3 also. Even the interaction effect of N x K revealed that there was significant increase in all forms of N and K at higher levels (N_3K_3) and contributed to nutrition of marigold.

It can be concluded that application of 120 kg N, 80 kg P_2O_5 and 80 kg K_2O ha^{-1} is optimum for better growth, development, increase in flower yield and quality of marigold (*Tagetes erecta*) when grown on light textured Alfisol. For commercial flower production and also for carotenoids extraction, marigold variety Pusa naringa gainda can be recommended to farmers around Hyderabad and Ranga Reddy districts.

Future line of work

- There is a need to work out variations among species for extraction of essential oils *viz.*, *Tagetes minuta*, *Tagetes patula* etc. for making proper recommendations.
- The actual biochemical components present in essential oil of marigold *viz.*, dihydrotagetone, tagetone and ocimenone need to be analysed in detail for suggesting the commercial value of essential oil.
- Similar studies have to be conducted with other nutrients such as S and micronutrients to know the interaction effects on improving the yield and quality of marigold flowers.

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The pattern of “Literature Cited” presented above is in accordance with the “Guidelines” for thesis presentation for Acharya N. G. Ranga Agricultural University, Hyderabad.

Appendix I

Flower yield of marigold at different pickings

Treatment	Yield at different pickings (q ha^{-1})							Total yield (q ha^{-1})
	I	II	III	IV	V	VI	VII	
T_1	7.0	37.0	17.6	6.0	1.0			77.6
T_2	8.0	38.0	20.1	7.0	1.0			81.1
T_3	10.4	39.0	19.0	8.0	1.0			80.4
T_4	10.0	40.0	20.0	11.3	1.0			82.3
T_5	13.0	45.0	22.0	12.5	0.3			92.8
T_6	14.0	44.5	22.5	12.5	0.5			94.0
T_7	13.5	46.9	24.0	12.0	0.5			96.9
T_8	15.0	47.0	25.0	13.1	0.5			100.6
T_9	18.5	50.0	29.0	17.0	1.5	0.5		113.5
T_{10}	21.0	54.0	33.0	15.5	1.6	0.5		125.8
T_{11}	20.5	58.4	36.0	16.0	7.0	0.1		138.0
T_{12}	20.5	58.4	36.3	17.0	7.0	0.3		139.5
T_{13}	20.0	58.2	35.0	15.0	4.0	1.0	0.1	133.3
T_{14}	20.5	58.3	35.5	15.5	4.5	1.0	0.1	135.4
T_{15}	21.5	60.0	36.0	16.0	6.4	1.0	0.1	140.0
T_{16}	22.0	60.5	36.5	16.3	6.4	1.0	0.1	140.8

Table 3 : Salient characteristics of experimental soil

S.No.	Soil properties	Value
1.	pH (1:2 soil : water suspension)	7.2
2.	EC (1:2 soil : water extract) (dSm^{-1})	0.11
3.	Mechanical composition (%)	
	Coarse sand	39.6
	Fine sand	23.2
	Silt	22.6
	Clay	14.6
	Textural class	Sandy loam
4.	Organic carbon (%)	0.5
5.	Cation exchange capacity (c mol (p^+) kg^{-1})	16.8
6.	**Forms of nitrogen (kg ha^{-1})**	
	a. Available nitrogen	220.0
	b. Ammoniacal nitrogen	18.0
	c. Nitrate nitrogen	28.7
7.	Available phosphorus (kg P_2O_5 ha^{-1})	36.0
8.	**Forms of potassium (c mol (p^+) kg^{-1})**	
	a. Water soluble K	0.045
	b. Ammonium acetate extractable K	0.25
	c. Exchangeable K	0.205
	d. Boiling 1 N HNO_3 extractable K	4.30
	e. Non exchangeable K	4.05
	f. Total K	50.2

Table 4 : Effect of levels of nitrogen and potassium on dry matter production of marigold at 60 DAT

Levels (kg ha^{-1})	Dry matter production (kg ha^{-1})				
	K_0	**K_1**	**K_2**	**K_3**	**Mean**
N_0	916.0	971.3	999.3	875.3	940.5
N_1	1491.0	1561.3	1374.0	1499.0	1481.3
N_2	2707.0	2873.3	3373.0	2929.0	2970.5
N_3	4789.3	4439.3	4373.0	4511.6	4528.3
Mean	2475.8	2461.3	2529.8	2453.7	

	SEd (±)	**CD (0.05)**
N levels	126.4211	258.1518
K levels	126.4211	NS
N x K	252.8421	NS

Table 10 : Effect of N and K levels on dry matter production of marigold at harvest

Levels (kg ha^{-1})	Dry matter production (kg ha^{-1})				
	K_0	K_1	K_2	K_3	Mean
N_0	2074.0	2196.0	2193.0	2077.0	2135.0
N_1	2915.0	3123.3	2995.3	3033.0	3016.6
N_2	5289.0	5622.3	5497.0	5914.0	5580.5
N_3	8740.6	9807.0	9808.6	9398.3	9438.6
Mean	4754.6	5187.11	5123.5	5105.5	

	SEd ($\pm$)	CD (0.05)
N levels	146.31	298.78
K levels	146.31	298.78
N x K	292.63	NS

Table 19 : Changes in contents of forms of nitrogen in soil at different growth stages of marigold

Levels of N (kg ha^{-1})	Changes in content (per cent increase / decrease)	
	0-60 DAT	**60-100 DAT**
	Available N	
0	15.45 (D)	166.85 (D)
40	3.77 (D)	91.59 (D)
80	12.3 (I)	76.24 (D)
120	23.86 (I)	20.78 (D)
	Ammoniacal N	
0	5.55 (D)	161.5 (D)
40	6.11 (D)	83.98 (D)
80	18.8 (I)	84.73 (D)
120	50.5 (I)	87.98 (D)
	Nitrate N	
0	9.40 (D)	11.58 (D)
40	54.35 (I)	66.54 (D)
80	79.44 (I)	66.12 (D)
120	110.80 (I)	158.87 (D)

I – Increase; D – Depletion

Initial status (kg ha^{-1}) : Available N – 220.0
Ammoniacal N – 18.0
Nitrate- N – 28.7

Table 20 : Changes in contents of forms of potassium in soil at different growth stages of marigold

Levels of K_2O (kg ha^{-1})	Changes in content (per cent increase / decrease)	
	0-60 DAT	**60-100 DAT**
	Water soluble K	
0	17.77 (D)	37.83 (D)
40	0 (I)	26.66 (D)
60	8.88 (I)	10.20 (D)
80	37.77 (I)	12.90 (D)
	NH_4O Ac extractable	
0	46.4 (D)	7.46 (D)
40	12.0 (D)	19.09 (D)
60	1.2 (D)	7.28 (D)
80	5.2 (I)	6.84 (D)
	Exchangeable K	
0	52.65 (D)	22.68 (D)
40	15.11 (D)	16.66 (D)
60	3.9 (D)	6.09 (D)
80	2.43 (D)	4.5 (D)
	1N HNO_3 extractable K	
0	3.48 (I)	12.80 (D)
40	11.16 (I)	7.53 (D)
60	28.59 (I)	7.41 (D)
80	33.48 (I)	7.49 (D)
	Non exchangeable K	
0	6.41 (I)	12.99 (D)
40	12.59 (I)	7.54 (D)
60	30.56 (I)	7.38 (D)
80	35.05 (I)	7.49 (D)
	Total K	
0	6.96 (I)	5.35 (D)
40	3.61 (I)	5.38 (D)
60	2.85 (I)	3.28 (D)
80	5.32 (I)	3.96 (D)

I – Increase; D - Depletion

Initial status (c mol (p^+) kg^{-1}) :
Water soluble K – 0.045
NH_4OAc extractable – 0.25
Exchangeable K – 0.205
1N HNO_3 extractable K – 4.30
Non exchangeable K – 4.05
Total K – 50.2

Table 5 : Effect of levels of N and K on N, P and K concentrations of African marigold at 60 DAT

Levels (kg ha^{-1})	Concentration (%)														
	Nitrogen					Phosphorus					Potassium				
	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean
N_0	6.72	0.72	0.73	0.74	0.72	0.45	0.46	0.47	0.47	0.46	0.65	1.19	1.25	1.48	1.14
N_1	1.18	1.19	1.21	1.22	1.20	0.49	0.49	0.50	0.51	0.49	0.71	1.20	1.26	1.50	1.16
N_2	1.49	1.50	1.55	1.55	1.52	0.53	0.58	0.58	0.59	0.57	1.72	1.21	1.30	1.52	1.18
N_3	1.72	1.74	1.75	1.78	1.75	0.60	0.62	0.62	0.63	0.61	0.75	1.23	1.32	1.58	1.22
Mean	1.27	1.28	1.31	1.32		0.51	0.53	0.54	0.55		0.70	1.20	1.28	1.52	

	Nitrogen SEd (±)	Nitrogen CD (0.05)	Phosphorus SEd (±)	Phosphorus CD (0.05)	Potassium SEd (±)	Potassium CD (0.05)
N levels	0.042	0.086	0.004	0.008	0.054	NS
K levels	0.042	NS	0.004	0.008	0.054	0.111
N x K	0.172	NS	0.008	0.016	0.222	NS

Table 16 : Effect of levels of N and K on available phosphorus (kg P_2O_5 ha^{-1}) in soil at 60 DAT and at harvest

Levels (kg ha^{-1})	Content of available P (kg P_2O_5 ha^{-1})									
	At 60 DAT					At harvest				
	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean
N_0	57.1	56.2	54.8	55.9	56.0	43.1	43.7	39.8	35.5	40.5
N_1	53.1	51.2	53.4	56.8	52.1	46.0	44.8	46.1	44.2	45.2
N_2	57.1	53.0	56.7	54.3	55.2	40.3	40.4	42.5	41.0	41.0
N_3	52.3	55.3	52.6	51.3	52.8	35.2	34.2	40.1	37.5	36.7
Mean	54.9	53.9	54.3	53.0		41.1	40.7	42.1	39.5	

	At 60 DAT SEd (±)	At 60 DAT CD (0.05)	At harvest SEd (±)	At harvest CD (0.05)
N levels	0.4924	1.0054	0.3215	0.6565
K levels	0.4924	1.0054	0.3215	0.6566
N x K	0.9847	2.0108	0.6431	1.3132

Table 17 : Effect of N and K levels on flower size and yield of marigold at harvest

Levels (kg ha^{-1})	Flower diameter (cm)					Fresh flower yield (q ha^{-1})				
	K_0	**K_1**	**K_2**	**K_3**	**Mean**	**K_0**	**K_1**	**K_2**	**K_3**	**Mean**
N_0	4.7	5.0	5.3	5.5	5.1	77.6	81.1	80.4	82.3	80.3
N_1	5.4	5.6	5.7	5.8	5.6	92.8	94.0	96.9	100.6	96.1
N_2	6.0	6.1	6.2	6.4	6.2	113.5	125.8	137.9	139.5	129.1
N_3	6.4	6.6	6.9	7.2	6.8	133.3	135.4	140.0	141.8	137.6
Mean	5.6	5.8	6.0	6.2		104.3	109.0	113.8	115.9	

	Flower diameter SEd (±)	Flower diameter CD (0.05)	Fresh flower yield SEd (±)	Fresh flower yield CD (0.05)
N levels	0.068	0.139	1.436	2.937
K levels	0.068	0.139	1.436	2.937
N x K	0.124	0.279	2.035	5.864

Table 18 : Effect of levels of N and K on total cariotenoids and essential oil content at harvest

Levels	Total carotenoid content ($mg\ g^{-1}$ fresh wt^{-1})					Essential oil content (%)				
	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean
N_0	2.7	276	2.80	2.85	2.78	0.0249	0.0285	0.0295	0.0321	0.0287
N_1	2.45	2.92	2.99	3.12	2.99	0.0250	0.0287	0.0297	0.0323	0.0289
N_2	2.36	3.39	3.43	3.54	3.43	0.0237	0.0263	0.0267	0.0333	0.0275
N_3	2.87	2.98	3.17	2.91	2.98	0.0333	0.0347	0.0417	0.0427	0.0381
Mean	2.97	3.01	3.10	3.10		0.0267	0.0295	0.0319	0.0351	

	SEd (±)	CD (0.05)	SEd (±)	CD (0.05)
N levels	0.0579	0.1183	0.0009	NS
K levels	0.0579	0.1183	0.0009	NS
N x K	0.1159	0.2366	0.0019	NS

Table 6 : Effect of levels of N and K on N, P and K uptake by marigold at 60 DAT

Levels (kg ha^{-1})	Uptake (kg ha^{-1})														
	Nitrogen					Phosphorus					Potassium				
	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean
N_0	6.59	6.99	7.29	6.47	6.83	4.12	4.46	4.69	4.11	4.34	5.95	11.55	12.49	12.95	10.73
N_1	17.59	18.57	16.62	18.28	17.76	7.30	7.65	6.87	7.64	7.36	10.58	18.73	17.31	22.48	17.27
N_2	40.33	43.09	52.28	45.39	45.27	14.34	16.66	19.56	17.28	16.96	46.56	34.76	83.85	44.52	42.42
N_3	82.37	87.68	76.52	80.30	81.7	28.73	31.24	27.11	28.41	28.87	35.91	57.72	61.98	71.28	56.72
Mean	36.72	39.08	38.1	37.61		13.6	15.0	14.55	14.36		24.75	30.69	33.90	37.80	

	Nitrogen SEd (±)	Nitrogen CD (0.05)	Phosphorus SEd (±)	Phosphorus CD (0.05)	Potassium SEd (±)	Potassium CD (0.05)
N levels	3.773	7.705	0.1726	NS	2.254	4.602
K levels	3.773	NS	0.1726	NS	2.254	4.602
N x K	15.41	NS	0.345	NS	3.205	9.050

Table 7 : Effect of levels of N and K on contents of different forms of nitrogen in soil at 60 DAT

Levels (kg ha^{-1})	Content (kg ha^{-1})														
	Available nitrogen					Ammoniacal nitrogen					Nitrate nitrogen				
	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean
N_0	188.6	189.5	187.6	189.0	186	16.2	17.0	17.6	17.1	17.0	25.8	29	23.5	26.8	26.0
N_1	223.5	228.2	228.4	232.7	228.3	18.5	19.0	19.3	19.6	19.1	48.0	43.8	43.8	41.5	44.3
N_2	242.2	243.0	249.1	254.2	247.1	20.2	21.6	21.9	21.9	21.4	45.9	52.0	52.1	56.0	51.5
N_3	268.2	271.3	273.9	276.3	272.5	24.6	26.1	28.1	29.5	27.1	59.9	58.5	61.6	62.0	60.5
Mean	230.8	233	234.7	238		19.9	20.9	21.7	22.0		44.9	45.8	45.2	46.5	

	SEd (±)	CD (0.05)	SEd (±)	CD (0.05)	SEd (±)	CD (0.05)
N levels	1.0009	2.043	0.365	0.749	0.665	1.358
K levels	1.0009	2.043	0.365	0.747	0.665	1.358
N x K	2.0019	4.087	0.731	1.494	1.330	2.717

Table 8 : Effect of levels of N and K on forms of potassium in soil at 60 DAT (water soluble, exchangeable and available K)

Levels (kg ha^{-1})	Contents (cmol (p^+) kg^{-1})														
	Water soluble potassium					Available potassium					Exchangeable potassium				
	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean
N_0	0.039	0.046	0.051	0.062	0.049	0.130	0.190	0.210	0.226	0.189	0.091	0.144	0.159	0.164	0.139
N_1	0.033	0.049	0.051	0.062	0.048	0.143	0.252	0.258	0.295	0.237	0.110	0.203	0.207	0.233	0.188
N_2	0.038	0.042	0.046	0.063	0.047	0.137	0.223	0.261	0.268	0.224	0.099	0.181	0.215	0.205	0.175
N_3	0.038	0.046	0.051	0.064	0.049	0.128	0.217	0.260	0.264	0.217	0.090	0.171	0.209	0.200	0.155
Mean	0.037	0.045	0.049	0.062		0.134	0.220	0.247	0.263		0.097	0.174	0.197	0.200	

	Water soluble potassium SEd (±)	Water soluble potassium CD (0.05)	Available potassium SEd (±)	Available potassium CD (0.05)	Exchangeable potassium SEd (±)	Exchangeable potassium CD (0.05)
N levels	0.0007	NS	0.0003	0.0007	0.0008	0.0016
K levels	0.0007	0.0014	0.0003	0.0007	0.0008	0.0016
N x K	0.0014	0.0029	0.0007	0.0013	0.0016	0.0033

Table 9: Effect of levels of N and K on different forms of potassium in soil at 60 DAT (HNO_3 extractable, non exchangeable and total K)

Levels (kg ha^{-1})	Contents (cmol (p$^+$) kg^{-1})														
	1N HNO_3 extractable K					Non exchangeable K					Total K				
	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean
N_0	4.11	4.31	5.58	5.61	4.90	3.98	4.12	5.37	5.38	4.71	49.1	50.1	51.2	51.3	50.4
N_1	4.10	4.63	5.54	6.09	5.09	3.95	4.37	5.28	5.79	4.84	46.3	49.0	50.3	52.3	49.5
N_2	4.78	5.14	5.43	5.55	5.22	4.64	4.91	5.16	5.28	4.99	46.2	49.2	49.8	52.2	49.3
N_3	4.81	5.06	5.58	5.71	5.29	4.68	4.84	5.32	5.44	5.07	45.1	45.0	55.5	56.4	50.5
Mean	4.45	4.78	5.53	5.74		4.31	4.56	5.28	5.47		46.7	48.3	51.7	53.0	

	SEd (±)	CD (0.05)	SEd (±)	CD (0.05)	SEd (±)	CD (0.05)
N levels	0.0296	0.0605	0.0045	0.0091	0.674	NS
K levels	0.0296	0.0605	0.0045	0.0091	0.674	1.374
N x K	0.0593	0.1210	0.0089	0.0182	1.346	2.749

Table 11 : Effect of levels of nitrogen and potassium on N, P and K concentration of marigold at harvest

Levels (kg ha^{-1})	Concentration (%)														
	Nitrogen					Phosphorus					Potassium				
	K_0	**K_1**	**K_2**	**K_3**	**Mean**	**K_0**	**K_1**	**K_2**	**K_3**	**Mean**	**K_0**	**K_1**	**K_2**	**K_3**	**Mean**
N_0	0.87	0.88	0.87	0.96	0.89	0.70	0.72	0.82	0.78	0.75	0.79	1.47	1.64	1.82	1.43
N_1	1.63	1.64	1.68	1.70	1.66	0.75	0.82	0.85	0.84	0.81	0.83	1.43	1.76	1.87	1.47
N_2	1.95	1.95	1.96	1.97	1.95	0.80	0.93	0.85	0.95	0.88	0.78	1.52	1.75	1.63	1.42
N_3	2.10	2.00	2.10	2.30	2.16	0.92	0.85	0.90	0.95	0.90	0.84	1.51	1.76	1.92	1.51
Mean	1.63	1.63	1.66	1.73		0.79	0.83	0.85	0.88		0.81	1.48	1.73	1.81	

	Nitrogen SEd (±)	Nitrogen CD (0.05)	Phosphorus SEd (±)	Phosphorus CD (0.05)	Potassium SEd (±)	Potassium CD (0.05)
N levels	0.041	0.0856	0.0035	0.0071	0.054	NS
K levels	0.041	NS	0.0035	0.0071	0.054	0.110
N x K	0.171	NS	0.0070	0.0142	0.221	NS

Table 12 : Effect of levels of N and K on N, P and K uptake by marigold at harvest

Levels (kg ha^{-1})	Uptake (kg ha^{-1})														
	Nitrogen					Phosphorus					Potassium				
	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean
N_0	18.04	19.32	19.07	19.93	19.09	14.93	15.37	17.98	16.20	16.12	16.38	33.28	35.96	37.80	30.85
N_1	47.51	51.22	50.32	51.56	50.15	21.86	25.61	25.46	25.47	24.6	24.19	44.66	52.71	56.71	44.56
N_2	103.13	109.63	107.79	116.5	109.25	42.31	52.28	46.72	56.18	49.37	41.25	85.45	96.19	96.39	79.82
N_3	103.55	196.14	205.9	216.16	200.4	80.41	83.35	88.27	89.28	85.32	73.41	148.08	172.6	180.44	143.6
Mean	88.05	94.07	95.75	101.03		39.8	44.15	44.60	46.78		38.80	77.86	89.36	92.83	

	Nitrogen SEd (±)	Nitrogen CD (0.05)	Phosphorus SEd (±)	Phosphorus CD (0.05)	Potassium SEd (±)	Potassium CD (0.05)
N levels	4.053	8.277	0.7872	1.6074	3.798	7.756
K levels	4.053	NS	0.7872	1.60704	3.798	7.756
N x K	16.554	NS	1.5743	3.2148	7.597	15.313

Table 13 : Effect of levels of N and K on content of forms of nitrogen at harvest

Levels (kg ha^{-1})	Contents (kg ha^{-1})														
	Available nitrogen					Ammonical nitrogen					Nitrate nitrogen				
	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean
N_0	63.0	67.9	71.9	75.9	69.7	5.7	6.0	6.9	7.4	6.5	22.5	23.0	23.7	24.0	23.3
N_1	105.4	120.7	124.9	126.4	119.3	7.6	8.0	7.9	8.4	8.0	25.2	25.7	27.2	28.3	26.6
N_2	132.1	135.7	145.0	148.1	140.2	9.2	9.45	10.4	12.5	10.4	30.2	30.4	31.1	32.3	31.0
N_3	218.1	223.0	227.6	233.9	225.6	12.2	12.6	14.0	15.3	13.5	36.8	37.7	38.1	38.8	37.8
Mean	129.7	136.8	142.3	146.1		8.7	9.0	9.8	10.9		28.7	29.2	30.0	30.8	

	Available nitrogen SEd (±)	Available nitrogen CD (0.05)	Ammonical nitrogen SEd (±)	Ammonical nitrogen CD (0.05)	Nitrate nitrogen SEd (±)	Nitrate nitrogen CD (0.05)
N levels	0.8243	1.6833	0.1394	0.2847	0.5274	1.0769
K levels	0.8243	1.6833	0.1394	0.2847	0.5274	1.0769
N x K	1.6487	3.3665	0.2788	0.5694	2.1538	NS

Table 14 : Effect of levels of N and K on contents of different forms of potassium (c mol (p^+) kg^{-1}) in soil at harvest (water soluble, available and exchangeable K)

Levels (kg ha^{-1})	Content (c mol (p^+) kg^{-1})														
	Water soluble K					Available K					Exchangeable K				
	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean
N_0	0.022	0.031	0.043	0.052	0.037	0.122	0.163	0.240	0.240	0.191	0.100	0.132	0.197	0.188	0.154
N_1	0.016	0.032	0.045	0.057	0.037	0.124	0.188	0.230	0.252	0.198	0.108	0.157	0.185	0.195	0.161
N_2	0.028	0.036	0.043	0.056	0.040	0.127	0.174	0.209	0.247	0.189	0.099	0.138	0.166	0.191	0.148
N_3	0.028	0.035	0.045	0.050	0.039	0.123	0.188	0.237	0.241	0.197	0.095	0.153	0.192	0.191	0.157
Mean	0.023	0.033	0.044	0.054		0.124	0.178	0.229	0.245		0.100	0.145	0.185	0.191	

	Water soluble K SEd (±)	Water soluble K CD (0.05)	Available K SEd (±)	Available K CD (0.05)	Exchangeable K SEd (±)	Exchangeable K CD (0.05)
N levels	0.0314	NS	0.0004	NS	0.0005	NS
K levels	0.0314	NS	0.0004	0.0009	0.0005	0.0010
N x K	0.0628	NS	0.0004	0.0017	0.0009	0.0019

Table 15 : Effect of levels of N and K on contents of different forms of potassium (c mol (p^+) kg^{-1}) in soil at harvest (1 N HNO_3 extractable, non exchangeable and total K)

Levels (kg ha^{-1})	Content (c mol (p^+) kg^{-1})														
	1N HNO_3 extractable K					Non exchangeable K					Total K				
	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean	K_0	K_1	K_2	K_3	Mean
N_0	3.73	4.18	5.26	5.44	4.65	3.61	4.01	5.02	5.20	4.46	47.3	44.3	48.8	50.4	47.7
N_1	3.53	4.38	5.19	5.24	4.58	3.40	4.19	4.96	4.98	4.38	42.9	45.1	49.5	50.4	47.0
N_2	4.11	4.52	5.05	5.38	4.76	3.98	4.34	4.84	5.13	4.57	43.1	47.2	50.2	50.8	47.8
N_3	4.15	4.61	5.00	5.21	4.74	4.02	4.42	4.76	4.96	4.54	43.7	46.1	51.4	51.9	48.3
Mean	3.88	4.42	5.125	5.31		3.75	4.24	4.89	5.06		44.2	45.7	50.0	50.9	

	SEd (±)	CD (0.05)	SEd (±)	CD (0.05)	SEd (±)	CD (0.05)
N levels	0.0358	NS	0.0035	NS	0.9659	NS
K levels	0.0358	0.0673	0.0035	0.0072	0.9659	1.9724
N x K	0.0716	0.1463	0.0071	0.0144	3.9448	NS