INTERACTION EFFECTS OF NITROGEN AND POTASSIUM ON SOIL FERTILITY, YIELD, QUALITY AND NUTRIENT UPTAKE BY OKRA (*Abelmoschus esculentus* L.)

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B.Sc. (Ag.)

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(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

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By

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**THESIS SUBMITTED TO THE
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RAJENDRANAGAR, HYDERABAD - 500 030**

2012

DECLARATION

I, **B.NAVEEN KUMAR,** hereby declare that the thesis entitled **"INTERACTION EFFECTS OF NITROGEN AND POTASSIUM ON SOIL FERTILITY, YIELD, QUALITY AND NUTRIENT UPTAKE BY OKRA (*Abelmoschus esculentus* L.)"** submitted to the **Acharya N.G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place: Hyderabad

Date :

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CERTIFICATE

Mr. **B.NAVEEN KUMAR** has satisfactorily prosecuted the course of research and that the thesis entitled **"INTERACTION EFFECTS OF NITROGEN AND POTASSIUM ON SOIL FERTILITY, YIELD, QUALITY AND NUTRIENT UPTAKE BY OKRA (*Abelmoschus esculentus* L.)"** 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 neither the thesis nor its part thereof has been previously submitted by him for a degree of any University.

Date:

(Dr. G. PADMAJA)
Chairperson

CERTIFICATE

This is to certify that the thesis entitled **"INTERACTION EFFECTS OF NITROGEN AND POTASSIUM ON SOIL FERTILITY, YIELD, QUALITY AND NUTRIENT UPTAKE BY OKRA (*Abelmoschus esculentus* L.)"** submitted in partial fulfilment 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 original research work carried out by **Mr. B. NAVEEN KUMAR** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of investigations have been duly acknowledged by the author of the thesis.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
@	:	at the rate of
$^{\circ}C$	:	Degree Celsius
Available K_2O	:	Available Potassium
Available N	:	Available Nitrogen
Available P_2O_5	:	Available Phosphorus
B:C	:	Benefit Cost ratio
c mol (p^+) kg^{-1}	:	Centimoles per kilogram
CD	:	critical difference
CEC	:	Cation exchange capacity
cm	:	centimeter
d Sm^{-1}	:	Desi Siemens per meter
DAS	:	Days after sowing
EC	:	Electrical conductivity
et al.	:	and others
Fig.	:	Figure
g ha^{-1}	:	grams per hectare
g kg^{-1}	:	grams per kilogram
i.e.,	:	that is
K	:	Potassium
kg ha^{-1}	:	kilogram per hectare
kg	:	kilogram
L	:	litre
m ha	:	million hectare
m	:	meter
M	:	molar
m^2	:	square meter
mg kg^{-1}	:	milligrams per kilogram
mg	:	milli gram (s)
ml l^{-1}	:	milli litre per litre
ml	:	milli litre
MOP	:	Muriate of potash
N	:	Nitrogen
NS	:	Not significant
NUE	:	Nitrogen use efficiency
OC	:	Organic carbon
P	:	Phosphorus
pH	:	soil reaction
q	:	quintal
r	:	Correlation coefficient
RBD	:	Randomized block design
Rs.	:	Rupees
SEd$\pm$	:	Standard error difference
SSP	:	Single super phosphate
t ha^{-1}	:	tonnes per hectare
viz.,	:	namely

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ABSTRACT

The present investigation entitled **"Interaction effects of nitrogen and potassium on soil fertility, yield, quality and nutrient uptake by okra (*Abelmoschus esculentus* L.)"** was carried out under field conditions during 2011 in *kharif* season with a view to study the response of okra in terms of yield and nutrient uptake. The transformation of applied N and K into various fractions in relation to their availability was also studied besides monitoring the changes in available nutrient status. The experiment was conducted in randomized block design with factorial concept consisting of sixteen treatment combinations with 4 levels each of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and potassium (0, 30, 60 and 90 kg K_2O ha^{-1}). Nitrogen and potassium were applied as per treatment combinations. The recommended dose of P_2O_5 (60 kg ha^{-1}) was applied uniformly to all the treatments.

The soil (*Alfisol*) under study was sandy loam in texture, slightly alkaline (pH=7.8) in reaction, non saline (0.23 dS m^{-1}) in nature and low in organic carbon (0.48 %), low in available nitrogen (226.8 kg N ha^{-1}), medium in available phosphorus (38.63 kg P_2O_5 ha^{-1}) and potassium (278.5 kg K_2O ha^{-1}).

The effect of different treatments were evaluated in terms of dry matter production (30, 60 and 90 DAS) and okra pod yield. Plant samples were analyzed for their per cent nutrient composition with respect to N, P and K at 30, 60 and at 90 DAS and nutrient uptake was computed. The fresh okra pods were analyzed for ascorbic acid content and dry samples were analyzed for crude protein and crude fibre contents. Soil nutrient status with regard to available N, P_2O_5 and K_2O were also studied at 30, 60 and 90 DAS of okra crop. The soil samples at harvest (90 DAS) were analyzed for inorganic N and K fractions.

The results of the experiment revealed that there was significant increase in dry matter production, nutrient content, uptake and pod yield of okra with increase in levels of N and K. Among the different interactions (N×K), application of 180 kg N ha^{-1} + 90 kg K_2O ha^{-1} (N_3K_3) recorded significantly highest total dry matter production (5152.9 kg ha^{-1}) and pod yield (126.17 q ha^{-1}). However, pod yield was on par with the yield obtained at N_3K_2 (124.83 q ha^{-1}). The nutrient content and uptake of N, P and K by okra plants at all the growth stages viz., 30, 60 and 90 DAS were highest with N_3K_3 combination and the total N and K uptake values found to be 83.83 and 75.19 kg ha^{-1}, respectively.

With regard to quality parameters of okra, application of nitrogen and potassium significantly increased the ascorbic acid and crude protein content. While the levels of nitrogen decreased the crude fibre content and potassium levels increased the crude fibre content. The interactions did not show significant effect on quality of okra pods.

The soil samples analyzed at 30, 60 and at 90 DAS of okra revealed that the effect of levels of nitrogen (N_3), potassium (K_3) and their interactions at higher levels (N_3K_3) were significantly superior over other levels. With regard to changes in soil available nutrient status, it was found that, there was an increase in total nutrient uptake and decrease in soil available N, P and K at 30-60 DAS and 60-90 DAS, which coincide with crucial growth period of crop.

Among the different forms of nitrogen and potassium, both NH_4-N and NO_3-N forms of nitrogen and readily available forms of potassium viz., water soluble K and exchangeable K contributed to pod yield and total N and K uptake, which was evidenced by their significant correlation with these plant parameters.

Though the pod yield recorded at N_3K_3 level was high, the benefit cost ratio in terms of money invested for one kilogram of fertilizer is not economical. Hence, keeping in view the requirement of nutrients viz., N, P and K at different growth stages of okra, nitrogen use efficiency and the net returns, it can be suggested that application of 120 kg N ha^{-1} combined with 60 kg K_2O ha^{-1} i.e., N_2K_2 is optimum for better productivity, quality and economic returns which also reduces the cost on fertilizers applied to okra grown on light textured red sandy loam soils (*Alfisols*).

Chapter-I

INTRODUCTION

Vegetables constitute a substantial part of human diet, supplying some of vital substances required for normal growth and health such as vitamins and minerals. *Okra* (*Abelmoschus esculentus* L.) is one of the most important vegetable crops having nutritional value with respect to vitamin A, B and C, proteins and minerals. It also has medicinal and industrial importance. It is an excellent source of iodine which is useful for control of goitre. Fully matured fruits and stems containing crude fibre are used in paper industry. India is the largest producer of *okra*, commonly known as *bhendi* and commercially cultivated in the states of Andhra Pradesh, Gujarat, Maharashtra, Uttar Pradesh, Tamil Nadu, Punjab, Karnataka and Haryana due to its well adaptability.

The crop is grown over wide range of soils and climatic conditions both in summer and rainy seasons. In India, *Okra* is cultivated in 0.43 million hectares producing 4.54 million tonnes with a productivity of 10.4 t ha^{-1}. In Andhra Pradesh it is grown in an area of 0.2 lakh hectares with a production and productivity of 4.3 lakh tonnes and 5.0 t ha^{-1} (Indiastat, 2010). It occupies an area of 1466 ha in Ranga Reddy district and 1904 ha in Mahaboobnagar district of Andhra Pradesh (Statistical abstract, Andhra Pradesh – 2010).

Nitrogen is an important plant nutrient and is an essential constituent of various metabolically active compounds like amino acids, proteins, nucleic acids, pyrimidines, flavines, purines, nucleoproteins, enzymes, alkaloids etc. (Panda, 2006). It governs the utilization of phosphorus and potassium uptake to an appreciable extent. The crucial role of nitrogen in plant metabolism, its status in soils and its management is an extremely important aspect of crop production.

Potassium is another important plant nutrient that imparts increased vigour and disease resistance to plants. It counteracts harmful effects of excess nitrogen in plants. The response of crop to potassium increases significantly in the presence of nitrogen (Sharma, 1989). Even though the theory of the 'Law of the Minimum' and scientific findings show the interaction between nitrogen and potassium, imbalanced fertilization and ignorance of the importance of potassium often leads to sub-optimal levels of nitrogen use efficiency.

Indiscriminate use of fertilizers and serious imbalances in N and K application are responsible for low yield. Current fertilization rates are insufficient to sustain high yields and to replenish nutrient removal by the crop. Nitrogen and potassium consumption in India during 2010-11 was 16.558 and 3.514 million tonnes (Fertilizer News, 2011), respectively. *Okra* removes 78 kg N, 34 kg P_2O_5 and 110 kg K_2O ha^{-1} to produce an yield of 25 t ha^{-1}. 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. The light textured soils belonging to the order *Alfisols*, which also occur in association with *Entisols* and *Inceptisols*, accounts 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. Among the different forms of potassium viz., water soluble, exchangeable, 1N HNO_3 extractable, non exchangeable and mineral K, the readily available forms constitute 1 to 2 per cent of total K.

Little information is available on the interaction effects of nitrogen and potassium on yield and quality of *okra*. Hence, keeping in view the facts, an experiment entitled **"Interaction effects of nitrogen and potassium on soil fertility, yield, quality and nutrient uptake by *Okra (Abelmoschus esculentus L.)*** is planned with the following objectives.

OBJECTIVES:

1. To study the interaction effects of nitrogen and potassium on yield and quality of *okra*.
2. To know the response of *okra* to the different levels of nitrogen and potassium at different growth stages of crop.

3. To suggest the optimum combination of nitrogen and potassium for *okra*.
4. To know the changes in soil available nitrogen and potassium at different growth stages.
5. To know the benefit-cost ratio of different treatment combinations.

Chapter – II

REVIEW OF LITERATURE

Increased use of the fertilizer nitrogen is probably the most important single factor that has enabled the crop production to increase significantly in recent years. Nitrogen is an essential constituent of various metabolically active compounds of cell like amino acids, proteins, nucleic acids, pyrimidines, flavines, purines, nucleoproteins, enzymes, alkaloids and plays an important role in plant metabolism. The critical role of nitrogen in plant metabolism, its availability in soils and the management is an extremely important aspect of crop production.

Though potassium is not a constituent of any plant structure or compound, it plays a vital role in enzyme activation, water regulations, translocation of assimilates, photosynthesis, protein and starch synthesis. Potassium is also known as ‘Quality element’ because of its influence on size, shape, color, taste and shelf life of fruits.

Keeping in view the above facts, response of okra and other vegetable crops to nitrogen and potassium application in *Alfisols* and other soils have been reviewed under the following sub heads:

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 Effect of nitrogen and potassium on soil fertility status

2.6 Response of okra and other vegetable crops to nitrogen and potassium application

2.7 Nutrient use efficiency

2.1 Nitrogen status of soils

Nitrogen deficiency in Indian soils is almost universal and with the adoption of modern technology of intensive cropping with high yielding varieties, there is a considerable pressure on soil to supply nitrogen. Hence, medium to high yields cannot be obtained anywhere without adequate N application (Tiwari, 2002).

Mostara (2002) compiled the data of 3.65 million samples analyzed during 1997-99 and reported that 63, 42 and 13 per cent of the samples were low, 26, 38 and 37 per cent were medium and 11, 20 and 50 per cent samples were high in available N, P_2O_5 and K_2O, respectively. Soils having low organic matter content were in general consistently been depleted of their nitrogen reserves due to continuous cultivation of crops for many centuries, which was evident from soil test data.

Sailaja (1999) reported that the *Alfisols* of Rajendranagar, Hyderabad contained total N and available N contents to an extent of 6.10 and 10.89 per cent, respectively 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 the available N content of these soils found to be low (74.36 to 210.31 kg ha $^{-1}$).

The red soils of left canal area of Polavaram project in East Godavari and Visakhapatnam districts contained 262 ppm of available N. Where as in certain *Alfisols* of North coastal zone of Andhra Pradesh, the available N content was around 122 to 295 kg ha $^{-1}$ (Prasad, 1991).

2.2 Forms of nitrogen in soils

Nitrogen is present in soil both as organic and inorganic forms. Inorganic N occurs in soils as NH_4^+, NO_2 and NO_3-N. The contents of different forms vary with type of soil. The N nutrition of crops is dependent more on N supplying power of the soil for a period of time than on the contents 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 recognizable product in the mineralization of organic nitrogen, which is successively oxidized to nitrite and 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 100 g^{-1} soil which corresponds to 1.4 to 14 ppm in soils (Jackson, 1967).

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, Rao *et al*. (1984) recorded 28-70 ppm NH_4^+-N and 21.0 to 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 and NH_4^+-N.

Sreelatha (1998) analyzed different N forms in 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 *Inceptisols* of Rajendranagar, Hyderabad the contents of NH_4^+-N and NO_3^--N 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 where as 42 and 38 per cent of districts 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.

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).

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. While the tomato growing soils of Chittor district contained available K_2O in the range of 108.6 to 414.5 kg ha^{-1} (Revathi, 2003). Where as, 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 water soluble, exchangeable, non-exchangeable, lattice and total K in different soils.

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 analyzed for different forms of potassium. 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 range of 70-380, 130-900 and 950-1500 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 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).

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, 0.3 to 0.15, 4.41 to 11.8 and 42.3 to76.2 c mol (p^+) kg^{-1}, respectively (Padmaja and Sreenivasa Raju, 1999).

Soil samples collected from 22 Bench mark soil series from 14 states of India were analyzed 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.

2.5 Effect of levels of nitrogen and potassium on soil fertility status

The available nutrients in the soil are greatly influenced by the nature and age of crops, microbial activity, enzymatic transformations and application of organic manures and inorganic fertilizers. Under the intensive system of agriculture, marked changes in the soil fertility are likely to occur due to high cropping intensity with high yielding varieties and high levels of nutrient input. The information regarding the effect of application of fertilizers on available nutrient status of soils has been reported by several workers.

Sharma *et al*. (2003) conducted an experiment with onion in sandy loam soil, reported an increase in the contents of available N, P and K significantly with the increasing levels of applied NPK. Highest available N (224 kg ha^{-1}), P (26.2 kg ha^{-1}) and K (217 kg ha^{-1}) was recorded with 150% NPK + 20 tonnes FYM ha^{-1} as compared to control. Sharma *et al*. (2005) also observed an increase in the contents of available N, P and K to the tune of 44.7, 136.3 and 38.6% respectively over their initial status through the application of 150% NPK + 20 tonnes FYM ha^{-1} in braccoli.

Progressive increase in the available K was noticed with the increase in the dose of potassium (Duraisami and Mani, 2002) in loamy sand soils in which the tomato was grown. The highest availability of K (209.5 kg ha^{-1}) was recorded at 80 kg K_2O ha^{-1} as against only 181.8 kg K ha^{-1} at control.

Mondal *et al*. (2007) observed that the available N, P and K contents in soil increased significantly in the treatments that received recommended dose of NPK along with FYM. The mean available N, P and K status found to be 142, 22.3 and 206 kg ha^{-1} in treatments receiving N, P_2O_5, and K_2O at the rate of 120, 100 and 100 kg ha^{-1}, respectively along with 10 t FYM ha^{-1}.

Correlation studies also revealed that the K uptake and removal of K from fixed forms showed positive correlations indicating that this pool has a vital role to play in potassium nutrition of crops (Hariprakasa Rao and Subramanian, 1991).

Bharadwaj *et al.* (2010) observed the changes in the available macronutrients in soil after the harvest of Pea and they recorded an increase in available N, P and K significantly with the increasing levels of applied NPK. Highest available N (334.9 kg ha^{-1}), P (42.80 kg ha^{-1}) and K (265.56 kg ha^{-1}) were recorded with 100% NPK over control.

Byju *et al*. (2002) conducted a field experiment with sweet potato in a clayey soil and they recorded significantly higher value of available (water soluble + exchangeable) K (89.21 mg kg^{-1}) at 75 kg K ha^{-1} compared to 25 and 50 kg K ha^{-1}.

Prabhakar Reddy *et al.* (2010) carried out field experiment on a sandy loam soil during kharif (onion) and rabi (radish) seasons and they found an increase in the exchangeable NH_4^+-N (37.76 to 43.82 mg kg^{-1}) and NO_3-N (10.99 to 14.80 mg kg^{-1}) after the harvest of onion crop as the levels of nitrogen increased from 0 to 120 kg N ha^{-1}. Similar results were found after the harvest of radish crop.

Duraisami *et al.* (2001) in their study on sandy clay loam soil registered the progressive increase in NH_4-N and NO_3-N with successive increase in the level of nitrogen applied to the sorghum crop. The available N and inorganic nitrogen fractions showed positive correlation with N uptake.

Padmaja and Sreenivasa Raju (1999) conducted a field experiment on an *Alfisol* to study the response of brinjal with 4 levels of potassium (0, 10, 20 and 40 kg K_2O ha^{-1}) and they reported the increase in different forms of K in soil with the increase in the applied level after the harvest of crop. Highest contents of water soluble, ammonium acetate extractable, exchangeable potassium and 1N HNO_3 K were recorded as 0.073, 0.28, 0.21 and 7.45 c mol. (p^+) Kg^{-1} respectively by application of highest dose of potassium (40 kg K_2O ha^{-1}). Similar results were obtained by Anjaiah (2002)

2.6 Response of okra and other crops to nitrogen and potassium application

2.6.1 Dry matter production

Plant growth is predominantly influenced by climate, water and nutrients. The success of crop depends on the vegetative growth, harvesting of solar radiation, photosynthesis and finally proper translocation from source to the sink. Dry matter yield is often used as a measure of growth. The effect of nitrogen was assessed in terms of the percentage increase or decrease in the dry matter production. The relevant literature pertaining to the effect of nitrogen and potassium on dry matter production of okra and other crops has been reviewed here under.

Chauhan and Gupta (1973) conducted experiment in sandy loam soil and they found that the dry matter production of okra increased with increasing levels of N from 22.5 to 67.5 kg ha^{-1} and K_2O from 0 to 22.5 kg ha^{-1}. Nitrogen being a major constituent of chlorophyll resulted in increased photosynthesis. However, with increased levels of P_2O_5 from 22.5 to 45.0 kg ha^{-1}, the dry matter production did not show any significant effect.

The dry matter production in okra was significantly influenced by increasing levels of nitrogen from 0 to 180 kg N ha^{-1} at all the three stages of crop growth. Maximum dry matter production (27.46 g, 30.66 g and 28.28 g $plant^{-1}$ at 30, 60 and 90 DAS respectively) was recorded with nitrogen at 180 kg N ha^{-1} (Rao, 1981). In some of the studies the response was recorded upto 200 kg N ha^{-1} (Venugopal, 1981).

Paramasivan *et al*. (2005) reported that dry matter production in okra increased (5.97 to 7.18 t ha^{-1}) with the increase in the level of nitrogen (0 to 60 kg ha^{-1}) and also they observed the increase in the dry matter production from 6.57 to 7.61 t ha^{-1} with the increase in the level of potassium from 0 to 45 kg ha^{-1}.

Rani and Jose (2009) conducted a pot culture experiment with sandy clay soil at the College of Horticulture, Kerala Agricultural University using okra as the test crop. They reported that higher dry matter production (1105 kg ha^{-1}) was obtained with 30 kg K_2O ha^{-1} over control and 15 kg K_2O ha^{-1} but further increase resulted in decrease in the dry matter production. This may be due to the dilution effect by the high K levels.

Balle Gowda *et al*. (2002) recorded significantly higher total dry matter (5817 kg ha^{-1}) with the application of 175:125:100 kg NPK ha^{-1} over the treatments which received 125:75:60 kg NPK ha^{-1} and 150:100:75 kg NPK ha^{-1} in *okra* grown in sandy loam soil. The increase in the dry matter is attributed to the better mineral nutrition.

Sharma *et al*. (2011) conducted a field experiment to know the influence of different fertilizer levels on dry matter production of okra in sandy loam soil at Vegetable Research Farm, JNKVV and concluded that application of 80:60:60 NPK kg ha^{-1} resulted in highest total dry matter production (40.3 q ha^{-1}), which was significantly superior over 40:30:30 NPK kg ha^{-1} and 60:45:45 NPK kg ha^{-1}.

In a study on sandy loam soil at Solan (Himachal Pradesh), it was observed that the dry matter content of bell pepper increased with increasing rates of nitrogen and maximum dry matter (5.14 per cent) was recorded from the plots provided with 160 kg N per ha (Manchanda and Bhopal Singh, 1987).

2.6.2 Yield

Fruit yield is a function of yield attributes which are significantly and favourably influenced by the application of nitrogen and potassium. In general, the fruit yield of okra increased significantly with increasing levels of nutrient application. The relevant literature pertaining to the effect of nitrogen and potassium on fruit yield of okra has been reviewed hereunder.

Verma *et al*. (1974) in a trial with okra cv. Pusa Sawani in sandy loam soil, obtained higher pod yields with nitrogen applied at the rate of 150 kg ha^{-1}. Whereas Gupta and Rao (1979) found a significant increase in pod yield upto 100 kg N ha^{-1}. Further increase in nitrogen level did not affect the okra fruit yield significantly.

From a field experiment conducted in sandy loam soil by Birbal *et al*. (1995) it was found that application of 100 kg N ha^{-1} significantly increased bhendi fruit yield to an extent of 65.6 and 22.0 per cent over control and 50 kg N ha^{-1}.

Naik *et al*. (1996) carried out experiment on sandy loam soil of IIHR, Bangalore with three levels of nitrogen (100, 150 and 200 kg ha^{-1}) and observed that application of 200 kg N ha^{-1} increased the brinjal fruit yield (170 q ha^{-1}) over 100 kg ha^{-1} (162 q ha^{-1}). This was due to the superior yield components like fruit weight and number of fruits per plant.

Ambare *et al*. (2005) in their study on the effect of nitrogen on growth and yield of okra in clay loam soil, reported that increasing levels of nitrogen increased the fruit yield per hectare. Highest fruit yield (98.44 q ha^{-1}) was obtained with the application of 100 kg N ha^{-1}. This was due to the impact of application of nitrogenous fertilizer which resulted in better growth, increase in number of branches and fruits per plant.

Firoz (2009) conducted a field trial with okra with four levels of nitrogen (60, 80, 100 and 120 kg ha^{-1}). They reported the highest fruit yield with the application of 100 kg N ha^{-1} and the yield produced at 120 kg N ha^{-1} was on par with the 100 kg N ha^{-1}.

Akanbi *et al*. (2010) in their study on okra in *alfisol* observed that the fresh fruit yield was highly significantly influenced by N application. Fruit yield increased with increase in N level reaching peak with the highest N level (75 kg N ha^{-1}). Fresh fruit yields obtained with 75 kg N ha^{-1} was 18.75 % higher than control (0 kg N ha^{-1}). Similar results were also obtained by Singh *et al*. (2010).

Hariprakasa Rao and Subramanian (1991) conducted a field trial in sandy loam soil with six levels of potassium and they reported the increase in the yield of okra (11.7 to 18.5 t ha^{-1}) with the increase in the level of potassium (0 to 200 kg ha^{-1}).

Rani and Jose (2009) also found that increase in the level of potassium increased the fruit yield of okra. Highest fruit yield (7297 kg ha^{-1}) was recorded at 30 kg K_2O ha^{-1} over control and 15 kg K_2O ha^{-1}.

As the information pertaining to response of okra to potassium is very meagre, other supporting vegetable crops information was reviewed.

Kanaujia *et al*. (1998) conducted field experiment with peas at vegetable research farm, Nauni on a well-drained loamy soil with 4 levels of potassium (0, 30, 60 and 90 kg ha^{-1}). The results showed significantly higher green pod yield of 104.2 kg ha^{-1} at 60 kg K_2O ha^{-1}. This was due to either direct or indirect involvement of potassium in major plant processes like photosynthesis, respiration, enzyme activation and carbohydrate metabolism.

Majumdar *et al*. (2000) conducted field experiment during 1994 and 1995 in loamy sand soil with different levels of potassium (0, 30, 60 and 90 kg K_2O ha^{-1}). They observed that increasing levels of potassium significantly influenced the fruit yield of tomato and chilli and maximum fruit yield of tomato (525.33 q ha^{-1}) and chilli (168.20 q ha^{-1}) were observed under 90 kg K_2O ha^{-1} when compared with remaining K levels was due to its superiority over other levels of K in respect of availability of potassium.

Singh and Verma (2001) studied the response of onion to the different levels of potassium (0, 40, 80, 120 and 160 kg ha^{-1}) on sandy loam soil. The data revealed that the application of potassium @ 120 kg ha^{-1} recorded the higher bulb yield.

The interaction effects of nitrogen and potassium on yield of vegetables also showed significant effect on the yield of okra.

Mishra and Pandey (1987) conducted experiment in highly calcareous soil at vegetable research farm, Pusa with four levels of nitrogen (0, 40, 80 and 120 kg N ha^{-1}) and four levels of potassium (0, 40, 80 and 120 kg N ha^{-1}) and observed that combined application of 80 kg N ha^{-1} and 40 kg K_2O ha^{-1} recorded higher okra yield of 15.47 q ha^{-1}.

Mani and Ramanathan (1980) conducted a field experiment to study the influence of varying levels N and K fertilizers on the yield of bhendi fruits on a red sandy loam soil. The yield of bhendi fruits significantly increased with application of nitrogen. Application of potassium also increased the yield of bhendi fruits. Interaction studies revealed that the combined application of 80 kg N ha^{-1} with either 30 kg K_2O ha^{-1} or 60 kg K_2O ha^{-1} registered higher yield of bhendi fruits. Application of 90:45:45 kg N: P_2O_5: K_2O ha^{-1} also resulted higher fruit yield of 99.24 q ha^{-1} (Choudhary *et al*., 2011).

2.6.3 Nutrient content

A study on nutrition of bhendi in sand culture revealed that an increase in the level of nitrogen in the nutrient solution resulted in increased nitrogen content in shoot. Highest level of nitrogen (1050 ppm) resulted in higher nitrogen content (3.10%) and increased nitrogen supply also increased the K content in plants (Chhonkar and Singh, 1963).

Singh (1979) reported that leaf nitrogen content increased (1.61% to 3.98%) with increase in the nitrogen levels (0 to 150 kg ha^{-1}). But the K content increased up to 75 kg N ha^{-1} and decreased with increasing nitrogen level, showing that higher doses of nitrogen had adverse effect on potassium content in okra.

Rao (1981) found that nitrogen content in bhendi increased with increase in the level of nitrogen from 0 to 180 kg ha^{-1} at all the three stages of sampling viz., 30, 60 and 90 DAS. Among nitrogen levels, maximum N content was obtained with the highest dose of 180 kg N ha^{-1}. The maximum N content at 30, 60 and 90 DAS were 2.93, 2.03 and 1.54 per cent, respectively. Higher nitrogen content during initial stages may be attributed due to vigorous vegetative growth during first month.

Hariprakasa Rao and Subramanian (1991) studied the effect of six levels of potassium on okra cv. Pusa Sawani and reported highest concentration of potassium in both shoot (3.23%) and fruit (5.80%) at 200 kg K_2O per ha. Higher nutrient content in fruits as compared to that of plants at harvesting was due to the translocation of nutrients from source (shoot) to sink (fruit). Similar results were reported with nitrogen by Muhammad *et al*. (1993).

Balle Gowda *et al*. (2002) reported higher accumulation of N, P and K with increase in fertilizer levels. Highest content of N(2.72%), P(0.63%) and K(3.65%) in okra leaves was observed at higher dose of fertilizers (175:125:100 kg NPK ha^{-1}) over the treatment which received 150:100:75 kg NPK ha^{-1}. This may be attributed to the more availability of nutrients in the soil.

Vachhani and Patel (1993) conducted experiment during rabi season and reported that potassium application (50 to 150 kg ha^{-1}) enhanced the contents of N (1.22 to 1.46 %) and K (0.88 to 1.26%) in onion bulbs significantly.

Subbiah and Raniperumal (1994) studied the effect of five levels of nitrogen and three levels of potassium on tomato on sandy loam soil. The results indicated that, combined application of nitrogen and potassium significantly increased the nitrogen concentration of tomato fruits. It was also reported that combined application of 80 kg N ha^{-1} and 100 kg K_2O ha^{-1} recorded high K content in fruits.

Application of increasing doses of nitrogen (0 to 120 kg ha^{-1}) significantly increased the N content (2.13 to 2.62%) and K content (2.29 to 2.35%) in potato tubers. Increasing doses of potassium (0 to 100 kg ha^{-1}) also increased N content (2.13 to 2.59%) and K content (2.20 to 2.41%). Maximum N content (2.99%) and K content (2.47%) was recorded when 120 kg ha^{-1} N was applied along with 100 kg K ha^{-1} (Gyanendra *et al*., 2002). This is attributed to the synergistic effect between N and K. A significant increase in N uptake by cucumber was recorded at highest level of N (120 kg ha^{-1}) application (Umamaheswarappa *et al*., 2006).

Anjaiah *et al.* (2005) studied the effect of levels of potassium on soil available potassium at different growth stages of carrot in *Alfisol* and reported that the soil available K increased from 0-30, 30-60 and 60-90 DAS with increase in levels of potassium, which in turn reflected in increase in K content, uptake and carrot yield.

Kanazawa *et al.* (1991) reported that the nutrients are concentrated in leaves and shoot during vegetative and flowering stage and later transported to edible fruits and roots.

Olaniyi *et al*. (2010) conducted a field experiment with okra in sandy loam soil and they noticed the highest N (1.79%), P (0.27%) and K (0.52%) in okra fruits with the application of 200 kg NPK ha^{-1} over control and 150 kg NPK ha^{-1}.

Sharma *et al*. (2011) also observed the effect of different levels of fertilizers on nutrient content in okra fruits and they reported the highest N (2.96%), P (0.57%) and K (3.92%) content in okra fruits at highest dose of fertilizers (80:60:60 NPK kg ha^{-1}).

2.6.4 Nutrient uptake

Nutrient uptake is the total amount of nutrients taken up by a crop during the crop growth period. The uptake values, provides a reliable estimate of the nutrient requirements under varying soil and climatic situations. In general, the uptake of N, P, and K by okra significantly increased with increasing levels of application of nutrients through fertilizers.

The nutrient uptake by plants increases with increase in the duration of crop. However, there will be translocation of nutrients from source (shoot) to sink (fruits/pods).

Irene Velthamoni and Balakrishnan (1990) reported the N uptake by bhendi grown in sandy loam soil increased from 14.1 to 22.8 kg ha^{-1} and 54.4 to 67.0 kg ha^{-1}, respectively at 40 and 80 DAS. Similarly potassium uptake also increased from 10.8 to 14.5 and 32.4 to 38.5 kg ha^{-1} at 40 and 80 DAS, respectively. The increase was mainly due to higher concentration of available soil nitrogen and increased plant dry matter production.

Balle Gowda *et al*. (2002) also observed significantly higher values of total uptake of N (101.27 kg ha^{-1}), P (24.31 kg ha^{-1}) and K (141.87 kg ha^{-1}) by okra with 175:125:100 kg NPK ha^{-1} over the treatments which received 125:75:60 kg NPK ha^{-1} and 150:100:75 kg NPK ha^{-1} in *okra*. This increased total uptake may be attributed due to cumulative effect of increased dry matter production and nutrient content.

Dademal *et al*. (2004) reported the increase in total N and K uptake by okra grown in clay loam soil with increased fertilizer levels. Higher total N uptake of 19.2, 452.5 and 580.3 mg plant^{-1} and K uptake of 20.7, 490.5 and 475.4 mg plant^{-1} were noticed at 30, 75,105 DAS, respectively with fertilizer combination of 150 kg N, 75 kg K_2O and 75 kg P_2O_5 ha^{-1}.

Rani and Jose (2009) studied the effect of four levels of potassium (0, 15, 30 and 45 kg K_2O ha^{-1}) on okra. The results indicated that, with increasing rate of K application, there was significant increase in K uptake. Highest potassium uptake (14.245 kg ha^{-1}) was found with the application of 45 kg K_2O ha^{-1}.

Choudhary *et al*. (2011) studied the effect of N:P:K on nutrient uptake by okra in loamy sand soil. Application of 60:30:30 N:P:K kg ha^{-1} significantly enhanced the nitrogen, phosphorus and potassium uptake by okra. The per cent increase over control found to be 63.79, 58.52 and 58.89, respectively. Similar results were also reported by Sharma *et al*. (2011) with application of 80:60:60 NPK kg ha^{-1}.

Results pertaining to other vegetable crops also revealed that there was significant increase in N, P and K uptake by onion (Ashok kumar *et al*., 2001), potato (Gyanendra *et al*., 2002) and peas (Brar *et al*., 2004).

Anjaiah *et al*. (2005) studied the effect of different levels of potassium (0, 40, 80 and 120 kg ha^{-1}) on carrot grown on an *Alfisol*. The total K content (8.35%), uptake (262.75 kg ha^{-1}), and root yield (17.59 t ha^{-1}) recorded at 120 kg K_2O ha^{-1} was highest but found to be on par with the values recorded at 80 kg K_2O ha^{-1} level indicating luxury consumption of potassium at higher levels.

Hari *et al.* (2007) reported significantly higher uptake of nitrogen and potassium (99.38 and 171.25 kg ha^{-1}) at higher level of potassium (90 kg ha^{-1}) by paprika plants grown in red sandy loam soil. Similarly the higher uptake of nitrogen and potassium (92.94 and 161.30 kg ha^{-1}) was noticed at higher level of nitrogen (150 kg ha^{-1}). They also reported that among the interaction treatments, the combined application of highest level of N (150 kg ha^{-1}) and K (90 kg ha^{-1}) recorded the higher uptake of nitrogen (137.13 kg ha^{-1}) and potassium (207.79 kg ha^{-1}).

2.6.5 Quality.

The fruit quality is an integrated effect of nutritional, physiological and biochemical factors. Fruit quality is an important parameter which fetches good market price to the farmer.

Mani and Ramanathan (1981) reported that increased levels of nitrogen application (0 to 80 kg ha^{-1}) decreased the crude fibre content (14.52% to 12.91%). whereas, the content increased (13.57% to 13.64%) with potassium application in *okra* fruits. Increase in the level of N resulted an increase in the succulence and decreased the crude fibre content. Increase in the level of K application increased the crude fibre content on account of its specific role in strengthening the cell wall. With regard to the protein content, it showed an increase with increasing levels of nitrogen from 80 to 120 kg N ha^{-1} (Pandey, 1994).

Irene Velthamoni and Balakrishnan (1990) conducted a field experiment in sandy loam soil with 3 levels of nitrogen (25, 40 and 50 kg ha^{-1}). They also reported a decrease in crude fibre content and increase in ascorbic acid content in okra fruits with increasing levels of nitrogen. Lowest crude fibre content (12.6%) and highest ascorbic acid content (17.5 mg 100 g^{-1}) were obtained with the application of 50 kg N ha^{-1}. However, Singh (1979) noticed highest crude fibre content (22.10%) at higher level of nitrogen (150 kg ha^{-1}).

Nitrogen plays an important role in improving ascorbic acid content due to the enhancement of enzymatic activities for amino acid synthesis. Potassium also improves the ascorbic acid content due to the close relationship between carbohydrate metabolism and the formation of ascorbic acid.

Results pertaining to other vegetable crops revealed that, with increasing levels of N and K there was a significant increase in ascorbic acid content of potato (Vijaya Lakshmi *et al*., 2011), tomato (Majumdar *et al*., 2000), palak (Bhore *et al*., 2005) and brinjal (Thakre *et al*., 2005).

In a nutritional study on chilli cv. K-2 with different levels of nitrogen, Shibhila Mary and Balakrishnan (1990) reported significant increase in ascorbic acid content with increasing levels of nitrogen and potassium. The interaction effect of N X K resulted in highest ascorbic acid content of 103.26 mg 100 g^{-1} in chilli.

Nitrogen plays a major role in improving the crude protein content of vegetables by its direct involvement in photosynthesis.

Pandey and Dubey (1996) conducted field experiments on okra with four levels of nitrogen (0, 60, 120 and 180 kg ha^{-1}) and they reported an increase in crude protein content with increasing levels of nitrogen from 0 to 120 kg ha^{-1}.

Other vegetable crops like potato (Sud *et al*., 1999) and amaranthus (Samlind Sujin and Sam Ruban, 2007) also showed an increase in the crude protein content with increasing levels of nitrogen application.

2.7 Nutrient use efficiency :

Increase in nutrient use efficiency is the consequence of enhanced nutrient uptake, dry matter production and in turn the yield, which is expressed as kg grain/ pod yield per kg of nutrient added through fertilizer.

Application of K influences nitrogen use efficiency. In maize, NUE varied from 21.1 to 53.3 with increasing levels of nitrogen (Ladha *et al*., 2005). However, higher levels of N and K decreased the nitrogen use efficiency.

Chapter – III

MATERIAL AND METHODS

The present investigation entitled **"Interaction effects of nitrogen and potassium on soil fertility, yield, quality and nutrient uptake by okra"** was carried out under field conditions during *kharif*, 2011. The details of the research work carried out, methodologies adopted and materials used in these investigations are as follows.

3.1 Location of the Experimental Site

The field experiment was conducted at Student's Farm, College of Agriculture, Rajendranagar, Hyderabad. The farm is geographically situated at $77^0$85' East longitude and $18^0$59' North latitude and at an altitude of 542.6 m above mean sea level. The climate of Hyderabad is tropical semi-arid.

3.1.1 Characteristics of the experimental site

The experiment was conducted in a sandy loam soil (*Alfisol*). The initial soil sample was collected prior to the layout of the experiment at 0-15 cm depth and analyzed for physical, physico-chemical and chemical properties following standard analytical methods. The salient soil characteristics of the experimental site was given in table 3.1

3.1.2 Methods of soil analysis

The initial soil sample and soil samples collected at different growth stages of the crop were analyzed for physical, physico-chemical and chemical properties following standard procedures as given below.

	Soil characters	Method of analysis
I)	**Physical properties**	
a)	Mechanical composition	Kanwar and Chopra (1976)
II)	**Physico-chemical properties**	
a)	Soil reaction (pH) (1:2.5 soil : water suspension)	Glass electrode pH meter, Model DI-707 (Jackson, 1973)

b)	Electrical conductivity (1:2.5 soil : water extract)	Conductivity bridge, DI-909 (Jackson, 1973)
III)	**Chemical properties**	
1)	Organic carbon (g kg^{-1})	Wet digestion method (Walkley and Black, 1934)
2)	Available nutrients	
a)	Nitrogen (kg N ha^{-1})	Alkaline permanganate method (Subbaiah and Asija, 1956)
b)	Phosphorus (kg P_2O_5 ha^{-1})	Olsen's method (Olsen *et al*., 1954)
c)	Potassium (kg K_2O ha^{-1})	1N NH_4OAC method Jackson (1973)
3)	Nitrogen fractions (mg kg^{-1})	
a)	Ammoniacal –N	Bremner (1965)
b)	Nitrate –N	Bremner (1965)
4)	Potassium fractions (mg kg^{-1})	
a)	Water soluble – K	Page *et al*. (1982)
b)	Exchangeable – K	Page *et al*.(1982)
c)	1N HNO_3-K	Page *et al*. (1982)

Table 3.1. Salient soil characteristics of the experimental site

S No.	Soil characters	Value
I)	**Physical properties**	
a)	Mechanical composition	
	i) Sand (%)	64.4
	ii) Silt (%)	20.0
	iii) Clay (%)	15.6
	iv) Textural class	Sandy loam
II)	**Physico-chemical properties**	
a)	Soil reaction (pH) (1:2.5 soil : water suspension)	7.8
b)	Electrical conductivity (1:2.5 soil : water extract) (dS m^{-1})	0.23
III)	**Chemical properties**	
1)	**Organic carbon (%)**	0.48
2)	**Cation exchange capacity (c mol (p^+) kg^{-1})**	16.6
3)	**Available nutrients (kg ha^{-1})**	
a)	Nitrogen (kg ha^{-1})	226.8
b)	Phosphorus (kg P_2O_5 ha^{-1})	38.63
c)	Potassium (kg K_2O ha^{-1})	278.5
4)	**Nitrogen fractions (mg kg^{-1})**	
a)	Ammoniacal N	37.42
b)	Nitrate N	20.31
5)	**Potassium fractions (mg kg^{-1})**	
a)	Water soluble – K	7.85
b)	Exchangeable – K	116.48
c)	1 N HNO_3 – K	1223.04

3.1.3 Weather during the crop growth period

The weather parameters were collected from the meteorological observatory located at Agricultural Research Institute, Rajendranagar, Hyderabad. The weather data during the crop season is presented in table 3.2.

3.2 Field Experiment

The field experiment was laid out in Randomized Block Design with factorial concept taking two factors and 16 treatment combinations, each replicated thrice. The layout plan is depicted in fig.3.1.

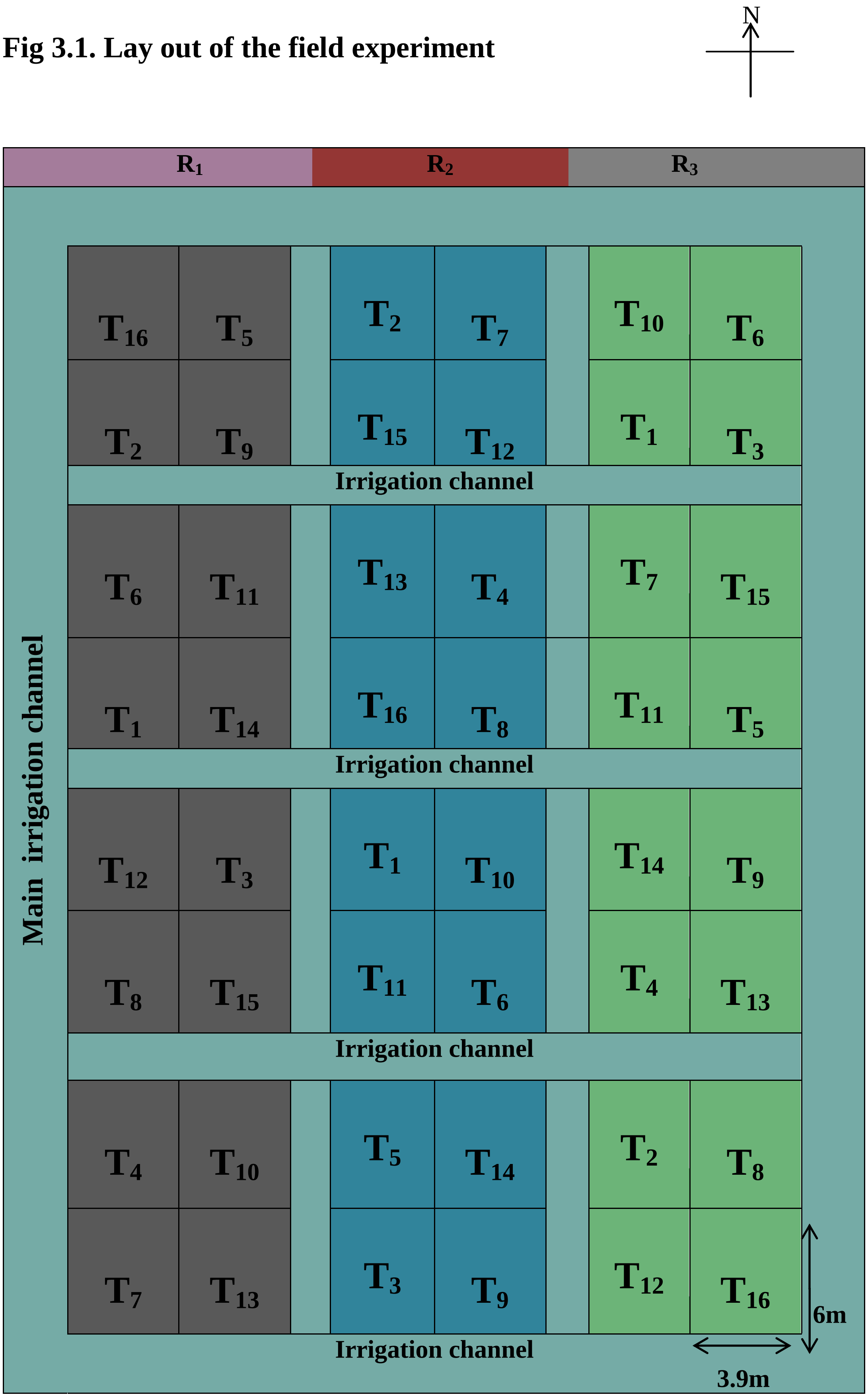
3.2.1 Crop details

Crop	Bhendi/ okra
Variety	*Arka anamika*
Season	*Kharif* (2011)
Duration	90-95 days
Seed rate	10-12 kg ha^{-1}
Spacing	60 cm x 30 cm
plot size	6 m x 3.9 m
Planting pattern	Ridge and furrow
Treatments	16
Replications	3
Design	RBD with factorial concept
Recommended dose of fertilizers	120:60:60 N-P_2O_5-K_2O kg ha^{-1}

3.2.2 Treatment details

Factor I: Levels of nitrogen (kg N ha^{-1}):	N_0	N_1	N_2	N_3
	0	60	120	180
Factor II: Levels of potassium (kg K_2O ha^{-1}):	K_0	K_1	K_2	K_3
	0	30	60	90

Fig 3.1. Lay out of the field experiment



Treatment combinations (F1 X F2)

T_1 :	N_0K_0	T_5 :	N_1K_0	T_9 :	N_2K_0	T_{13} :	N_3K_0
T_2 :	N_0K_1	T_6 :	N_1K_1	T_{10} :	N_2K_1	T_{14} :	N_3K_1
T_3 :	N_0K_2	T_7 :	N_1K_2	T_{11} :	N_2K_2	T_{15} :	N_3K_2
T_4 :	N_0K_3	T_8 :	N_1K_3	T_{12} :	N_2K_3	T_{16} :	N_3K_3

3.2.3 Calendar of operations

The details of the calendar of operations carried out from sowing to harvest of okra crop were furnished below:

S.No.	Name of the operation		Date of the operation
1.	Field preparation	-	15-7-2011
2.	Herbicide spraying	-	16-7-2011
3.	Layout	-	19-7-2011
4.	Sowing	-	20-7-2011
5.	Fertilizer application (basal)	-	20-7-2011
6.	Gap filling	-	28-7-2011
7.	1st Top dressing of N and K fertilizers	-	22-8-2011
8.	2nd Top dressing of fertilizers	-	06-09-2011
9.	Plant protection	-	17-08-2011 & 05-09-2011
10.	Weeding	-	05, 06, 21-08-2011 & 22-08-2011
11.	Earthing up	-	09-09-2011
12.	Irrigations	-	As per requirement
13.	Harvesting	-	10-09-2011 to 25-10-2011

3.2.4 Cultivation details

3.2.4.1 Field preparation

The experimental field was ploughed with tractor drawn disc plough followed by two ploughings with cultivator and the clods were broken with rotavator. The field was uniformly levelled.

3.2.4.2 Fertilizer application

A basal dose of 60 kg P_2O_5 ha^{-1} was applied to all the treatment plots. Nitrogen and potassium were applied in the form of urea and muriate of potash, in 3 splits as per treatment combinations. Phosphorus was applied in the form of single super phosphate.

3.2.4.3 Irrigation

First irrigation was given immediately after sowing of *okra* seeds while subsequent irrigations were given depending on moisture and weather conditions. A total of only 3 irrigations were given to the *okra* crop because of frequent rains during the crop growth period.

3.2.4.4 Cultural practices

Gap filling was done a week after sowing. Hand weeding was done twice at 15 and 30 days after sowing and earthing up was done to prevent lodging.

3.2.4.5 Plant Protection

Necessary plant protection measures were adopted as and when required for the control of common insect pests and diseases of *okra* during the experimental period. Dimethoate was sprayed @ 2ml l^{-1} to control the sucking pests at vegetative stage (27 DAS) and chlorpyriphos was sprayed @ 2.5ml l^{-1} to control the sucking pests and borers at flowering stage (45 DAS).

3.2.4.6 Harvesting

Okra fruits were picked in the morning hours when they are still tender. A total of 15 pickings were taken at 2 days interval and yield was recorded.

3.3 Data Collected

3.3.1 Soil analysis

Apart from the analysis of initial soil sample for different soil properties, the soil samples collected at different growth stages of the crop viz., 30, 60 and 90 DAS were analyzed for available N and K_2O. The soil samples collected at harvest were also analyzed for inorganic nitrogen (NH_4^+-N and NO_3-N) and potassium fractions (Water soluble-K, Exchangeable -K and 1N HNO_3- K) as per the methods given under 3.1.2.

3.3.2 Plant analysis

Plant samples collected at 30, 60 and 90 DAS were oven dried at 65^0 C. The dried samples were powdered and analyzed for per cent N, P and K contents by adopting the standard procedures (Piper, 1966).

The dry matter production (kg ha^{-1}) was also recorded to compute nutrient uptake at different growth stages.

$$\text{N uptake (kg ha}^{-1}\text{)} = \frac{\text{N content (\%) x Dry matter production (kg ha}^{-1}\text{)}}{100}$$

$$\text{P uptake (kg ha}^{-1}\text{)} = \frac{\text{P content (\%) x Dry matter production (kg ha}^{-1}\text{)}}{100}$$

$$\text{K uptake (kg ha}^{-1}\text{)} = \frac{\text{K content (\%) x Dry matter production (kg ha}^{-1}\text{)}}{100}$$

3.3.3 Fruit analysis

Ascorbic acid

Ascorbic acid (vitamin C) content of okra fruit was analyzed by dichlorophenol indophenol dye method as given below and expressed in mg 100 g^{-1} (Ranganna, 1994).

Reagents

1. 3% Metaphosphoric acid: Prepared by dissolving the sticks or pellets of metaphosphoric acid in glass distilled water.
2. Ascorbic acid standard: 100 mg of L-ascorbic acid was taken, dissolved and made up to 100ml with 3% metaphosphoric acid (1mg = 0.1 mg of ascorbic acid).

3. Dye solution: 50 mg of the sodium salt of 2, 6-dichlorophenol-indophenol was dissolved in approximately 150 ml of hot glass distilled water containing 42 mg of sodium bicarbonate. Cooled and diluted with glass distilled water to 200ml.

Procedure

Standardization of Dye

5ml of standard ascorbic acid solution was taken and 5ml of HPO_3 was added. Microburette was filled with the dye and then titrated with the dye solution to a pink colour which should persist for 15 sec. Dye factor was determined, i.e. mg of ascorbic acid per ml of the dye, using the formula:

$$\text{Dye factor} = \frac{0.5}{\text{Titre value}}$$

Sample analysis

10 g of the sample was taken, blended with 3% HPO_3 and made up to 100 ml with HPO_3. Filtered through filter paper. An aliquot (10 ml) of the HPO_3 extract of the sample was taken and titrated with the standard dye to a pink end-point which should persist for at least 15 sec.

Calculation

The ascorbic acid content of the sample was calculated using the following formula:

$$\text{mg of ascorbic acid per 100g of the sample} = \frac{\text{Titre value} \times \text{dye factor} \times \text{volume made up} \times 100}{\text{Aliquot taken} \times \text{Wt of sample (g)}}$$

Crude fibre content (%)

Fibre content of the okra fruit was estimated as per the procedure outlined by Ranganna (1961).

Crude fibre is the organic fraction left after the sequential extraction with solution of 1.25 per cent H_2SO_4 and 1.25 per cent NaOH.

Pod samples collected from five tagged plants in each treatmental plot were collected at 7th picking, oven dried at 65 ^{0}C and 1 g of oven dried sample was weighed in a beaker and 200 ml of 1.25 per cent sulphuric acid was added and placed on a pre-heated hot plate of digestion apparatus. It was digested for 30 minutes by rotating the beaker periodically, at the end of the digestion period, the mixture was filtered through a muslin cloth and the residue was washed with water till it was free from acid. The material was then transferred to the same beaker and 200 ml of 1.25 per cent NaOH was added and placed on the hot plate for 30 minutes and filtered through muslin cloth. The residue was washed with water till it was free from alkali. It was then transferred to a crucible, heated over night at 80-100 ^{0}C and weighed (W_1). The crucible was kept over a low flame till all the material was completely charred and was kept in a muffle furnace at 600 ^{0}C for 30 minutes, cooled and weighed (W_2).

$$\text{Crude fibre (per cent)} = \frac{W_1 - W_2}{\text{Weight of the sample (g)}} \times 100$$

W_1 = Weight of crucible with samples before ashing (g).

W_2 = Weight of crucible with samples after ashing (g).

Crude protein content

Crude protein content was calculated by multiplying per cent nitrogen in fruits with a factor 6.25.

$$\text{Crude protein} = \text{Nitrogen \%} \times 6.25$$

Nitrogen use efficiency (NUE)

Nitrogen use efficiency (Ladha *et al*., 2005) was calculated by using the following formula:

$$\text{NUE} = \frac{\text{Difference in pod yield (kg) between the treatments}}{\text{Difference in added N fertilizer (kg)}}$$

For example: NUE at N_{120} is calculated as follows

$$NUE = \frac{\text{Pod yield (kg) at } N_{120} - \text{Pod yield (kg) at } N_{60}}{\text{Difference in added N fertilizer (kg) i.e., 120-60}}$$

The nitrogen use efficiency was calculated taking the difference in pod yield with increasing levels of N application. NUE at N_{60} was calculated by taking difference between yield at N_{60} and control (N_0).

Fruit yield

Fresh okra fruit yield was recorded treatment wise at 2 days intervals. A total of 15 pickings were taken.

3.4 Benefit-Cost Ratio

The benefit cost ratios were computed through partial budgeting technique by taking into consideration the additional cost incurred due to imposition of the treatments and the additional returns realized. Benefit Cost Ratio was calculated using the formula

$$\text{Benefit Cost Ratio} = \frac{\text{Net returns (Rs ha}^{-1}\text{)}}{\text{Total cost of cultivation (Rs ha}^{-1}\text{)}}$$

For example: Benefit Cost Ratio at $N_{60}K_{30}$ is calculated as follows

Net returns (Rs ha^{-1}) and Total cost of cultivation (Rs ha^{-1}) at $N_{60}K_{30}$ is 35726.31 and 41757, respectively.

$$\text{Benefit Cost Ratio} = 35726.31 / 41757 = 0.86$$

3.5 Statistical Analysis

The data on various parameters was statistically analyzed following the method of analysis of variance for factorial randomized block design and the significance was tested by ‘F’ test (Snedecor and Cochron, 1967). Critical difference for examining treatment means and their significance was calculated at 5 per cent level of probability.

Table 3.2. Weekly mean meteorological data during crop growth period

Standard Week	Period	Temperature (°C)		Mean Temp. (°C)	Relative humidity (%)		Rain fall (mm)	Rainy days	Sun shine (Hrs.)	Wind speed (km hr^{-1})	Evapo ration (mm)
		MAX.	MIN.		I	II					
26	25-01 JULY	35.0	24.2	29.6	75	44	9.6	1	1.5	15.2	5.9
27	02-08	31.3	22.4	26.9	91	64	89.0	4	2.5	9.1	4.5
28	09-15	30.7	22.6	26.7	84	64	38.8	2	5.6	14.5	5.2
29	16-22	31.6	23.3	27.4	82	59	15.0	1	5.2	14.8	5.0
30	23-29	30.6	21.9	26.2	93	65	48.2	4	5.2	8.3	4.3
31	30-05 AUGUST	29.5	22.6	26.1	87	65	10.4	1	3.2	12.1	4.6
32	06-12	31.4	23.3	27.3	90	63	1.8	0	4.9	11.1	5.0
33	13-19	31.7	23.2	27.4	89	76	11.0	2	6.2	7.7	5.2
34	20-26	30.2	22.2	26.2	95	73	106.6	3	3.5	3.7	3.5
35	27-02 SEPTEMBER	27.7	22.1	24.9	89	80	61.5	5	1.5	10.0	3.4
36	03-09	29.7	22.2	26.0	90	79	30.6	2	5.2	9.1	2.7
37	10-16	31.3	22.5	26.9	89	74	0.0	0	6.2	4.1	2.9
38	17-23	30.5	22.4	26.4	83	69	12.0	1	5.0	5.8	2.8
39	24-30	31.7	20.7	26.2	88	74	3.5	1	6.5	2.9	2.9
40	01-07 OCTOBER	32.4	20.5	26.4	89	74	8.2	1	6.8	1.9	2.7
41	08-14	32.0	21.1	26.5	91	64	28.5	2	5.5	1.9	2.7
42	15-21	32.9	19.9	26.4	90	67	1.0	0	8.2	2.0	2.8
43	22-28	31.7	19.9	25.8	91	76	10.2	1	7.1	4.1	2.8
44	29-04 NOVEMBER	29.5	19.7	24.6	91	61	27.5	1	4.4	3.1	2.4

Chapter IV

RESULTS AND DISCUSSION

The present experiment entitled **"Interaction effects of nitrogen and potassium on soil fertility, yield, quality and nutrient uptake by okra (*Abelmoschus esculentus* L.)"** was carried out during *kharif*, 2011 season on a sandy loam soil at Student's Farm, College of Agriculture, Rajendranagar, Hyderabad. The effect of different levels of nitrogen, potassium and their interactions on dry matter production, yield, nutrient uptake, quality parameters, soil available nutrient status and distribution of N and K fractions were studied under field conditions. The results of investigation are presented and discussed with relevant references in this chapter.

4.1. Response of okra to different levels of nitrogen, potassium and their interactions at different growth stages

4.1.1 Dry matter production

4.1.2 Nutrient content

4.1.3 Nutrient uptake

4.1.4 Pod yield

4.1.5 Quality parameters

4.2 Nitrogen use efficiency

4.3 Effect of different levels of nitrogen, potassium and their interactions on soil nutrient status at different growth stages of okra

4.3.1 Available nutrient status

4.3.2 Nitrogen fractions

4.3.3 Potassium fractions

4.4 Correlation studies

4.5 Effect of different levels of nitrogen and potassium on benefit cost ratio

Salient soil characteristics of the experimental site

The initial soil sample collected from experimental field was analyzed for physical, physico-chemical and chemical properties. The data pertaining to salient soil characteristics were presented in table 3.1.

The soil was sandy loam in texture, slightly alkaline (7.8 pH) in reaction, non saline (0.23 dS m^{-1}), low in organic carbon (0.48 per cent) and available nitrogen (226.8 kg N ha^{-1}), medium in available phosphorus (38.63 kg P_2O_5 ha^{-1}) and potassium (278.5 kg K_2O ha^{-1}).

The soil was analyzed for different inorganic fractions (mg kg^{-1}) of nitrogen and potassium (Table 3.1). Ammoniacal and nitrate nitrogen contents were found to be 37.42 and 20.31 mg kg^{-1}, respectively. Among the potassium fractions, water soluble K and exchangeable K found to be 7.85 and 116.48 mg kg^{-1}. The fixed form of K_2O viz., 1N HNO_3 extractable K was 1223.04 mg kg^{-1}.

4.1 Response of okra to different levels of nitrogen, potassium and their interactions at different growth stages

The effects of different treatments were evaluated in terms of dry matter production, per cent nutrient content and uptake at 30, 60 and 90 days after sowing.

4.1.1 Dry Matter Production

The data pertaining to dry matter production of okra plant and pod (edible part) at different growth stages viz., 30, 60 and 90 DAS were furnished in table 4.1 and 4.2. The effect of different levels of nitrogen, potassium and their interactions found to have significant effect on dry matter production of okra plants at all the growth stages (Table 4.1and 4.2). In general, dry matter production increased with increase in age of the crop.

Among the nitrogen levels, N_3 (180 kg ha^{-1}) has recorded significantly highest plant dry matter production viz., 1125.7, 2086.1 and 3281.9 kg ha^{-1} at 30, 60 and 90 DAS, respectively and the lowest value was recorded at N_0 level. The per cent increase being 114.95, 136.89 and 95.95 over N_0 at 30, 60 and 90 DAS, respectively. Similarly, application of potassium @ 90 kg ha^{-1} (K_3) has recorded highest plant dry matter production at 30 (966.0 kg ha^{-1}), 60 (1660.0 kg ha^{-1}) and at 90 DAS (2716.3 kg ha^{-1}) and the extent of increase was 41.13, 33.77 and 24.97 per cent over control at 30, 60 and 90 DAS, respectively.

With regard to interaction effects, N_3K_3 has recorded significantly highest plant dry matter production at 30 DAS (1243.9 kg ha^{-1}), 60 DAS (2274.4 kg ha^{-1}) and at 90 DAS (3467.4 kg ha^{-1}) while the lowest value was recorded at N_0K_0 at all the stages of crop growth period. However at 30 DAS, N_3K_3 (1243.9 kg ha^{-1}) was on par with N_3K_2 (1232.9 kg ha^{-1}) and N_2K_3 (1042.1 kg ha^{-1}) was on par with N_2K_2 (975.5 kg ha^{-1}) and significantly superior over other interaction effects.

Dry matter production of pod was significantly influenced by different levels of nitrogen, potassium and their interactions (Table 4.2).

The results revealed that with increase in levels of N application, significantly highest pod dry matter production of 1600.5 kg ha^{-1} was recorded at 180 kg N ha^{-1} (N_3) at harvest (90 DAS) and the extent of increase was 49.08 per cent over control (N_0). Among the potassium levels, K_3 (90 kg K_2O ha^{-1}) has recorded significantly highest pod dry matter yield of 1518.0 kg ha^{-1} at 90 DAS followed by K_2, K_1 and K_0 (Table 4.2), the per cent increase being 27.34 over control (K_0).

The interaction effects of N x K also influenced the pod dry matter production significantly (Table 4.2), recording the highest dry matter production of 1685.5 kg ha^{-1} at N_3K_3, while the lowest was recorded with control (N_0K_0). However the values recorded at N_3K_3 was on par with N_3K_2 level.

Total dry matter production

Data pertaining to total dry matter production of okra (plants + pods) at harvest were presented in table 4.3 and shown in figure 4.1. It was significantly influenced by levels of nitrogen, potassium and their interactions at harvest.

Among the different nitrogen levels, 180 kg N ha^{-1} (N_3) has recorded significantly highest total dry matter production (4882.5 kg ha^{-1}) which was significantly superior over N_2 (4145.9 kg ha^{-1}), N_1 (3515.7 kg ha^{-1}) and N_0 (2748.5 kg ha^{-1}).

With regard to potassium levels, K_3 (90 kg ha^{-1}) has recorded significantly highest total dry matter production (4234.3 kg ha^{-1}) followed by K_2 (3963.9 kg ha^{-1}), K_1 (3728.7 kg ha^{-1}) and K_0 (3365.6 kg ha^{-1}).

The interaction effects also found to be significant. Among the interactions, application of nitrogen @ 180 kg ha^{-1} (N_3) along with potassium @ 90 kg ha^{-1} (K_3) has recorded significantly highest total dry matter production (5152.9 kg ha^{-1}) while the lowest was recorded at N_0K_0 (2322.3 kg ha^{-1}).

4.1.2 Plant Nutrient Content

Okra plant samples were analyzed for their per cent N, P and K contents in plant at 30, 60 and 90 DAS and for N and K content in pod at harvest (90 DAS). Data pertaining to nutrient content of okra plant and pod were shown in tables 4.4 to 4.9.

Nitrogen

The nitrogen content in plant decreased as the age of the plant increased. The data pertaining to nitrogen content of okra plants at different stages of crop growth are presented in table 4.4 and 4.5.

Among the different nitrogen levels, the highest N content was recorded at N_3, which was significantly superior over lower levels at 30, 60 and at 90 DAS. The values ranged from 2.00 to 2.81, 1.61 to 2.23 and 1.05 to 1.47 per cent at 30, 60 and at 90 DAS, respectively.

With regard to levels of potassium, application of 90 kg K_2O ha^{-1} (K_3) recorded highest plant N content at 90 DAS (1.31 per cent) but was on par with K_2 and significantly superior over K_1 and K_0. However, at 30 and 60 DAS it was found to be non significant. The interaction effect of nitrogen and potassium did not show any significant effect on N content of okra plants at 30, 60 and at 90 DAS.

The data pertaining to nitrogen content of okra pods at 90 DAS were presented in table 4.5. The N content in okra pods was significantly influenced by levels of nitrogen, potassium and their interactions.

Nitrogen content increased significantly with increase in levels of nitrogen from N_0 to N_3 and the values ranged from 1.35 to 1.79 per cent. Among the potassium levels, the highest N content was recorded with application of potassium @ 90 kg K_2O ha^{-1} (K_3) and was significantly superior over K_2, K_1 and K_0 (Table 4.5).

Among the interaction effects, N_3K_3 recorded higher N content which was significantly higher over rest of the treatments. However, N_2K_3 and N_2K_2 were on par with each other.

Phosphorus

The data pertaining to P content of okra plant is given in tables 4.6. Among the nitrogen levels, application of N @ 180 kg N ha^{-1} (N_3) showed higher P content at 30, 60 and 90 DAS and significantly higher over N_2, N_1 and N_0 (Table 4.6).

Application of different levels of potassium and their interaction with nitrogen did not show significant effect on P content of okra plant at all the stages of crop growth. The data pertaining to P content of okra plant at 30, 60 and 90 DAS are given in table 4.6.

Potassium

The results pertaining to K content of okra plants and pods were presented in tables 4.7 and 4.8. The potassium content in okra plants decreased with the age of the crop. It was significantly influenced by levels of nitrogen, potassium and their interactions at all the stages of crop growth (Table 4.7 and 4.8).

Among the nitrogen levels, application of nitrogen @ 180 kg ha^{-1} (N_3) has recorded highest K content (2.09, 1.59 and 1.37 per cent) at 30, 60 and at 90 DAS which was significantly superior over other levels of N.

With regard to potassium levels, K_3 recorded significantly highest K content followed by K_2, K_1 and K_0 at 60 and 90 DAS. However at 30 DAS K_3 was on par with K_2 and significantly superior over K_1 and K_0. The contents ranged from 1.70 to 2.07, 1.36 to 1.56 and 1.18 to 1.37 per cent at 30, 60 and 90 DAS, respectively.

With regard to interaction effects, the treatment N_3K_3 recorded significantly highest plant K content (2.33 per cent) at 30 DAS while the lowest was recorded with control (1.64

per cent). At 60 DAS maximum K content (1.67%) was recorded with N_3K_3. However, at 30 DAS, the treatments N_3K_3 (2.33 per cent) and N_3K_2 (2.31 per cent), N_2K_3 (2.18 per cent) and N_2K_2 (2.15 per cent) were on par with each other whereas at 90 DAS, N_3K_3 (1.41 per cent) was on par with N_3K_2 (1.40 per cent) and superior over other interactions (Table 4.8).

Potassium content of okra pods was significantly influenced by nitrogen and potassium levels and their interactions (Table 4.8).

Among the nitrogen levels, N_3 recorded highest K content (1.50 per cent) at 90 DAS and was significantly superior over N_2, N_1 and N_0. In case of potassium levels, K_3 recorded highest K content which was significantly superior over K_2, K_1 and K_0.

Among the interaction effects, the treatment N_3K_3 recorded significantly highest K content in pods (1.56 per cent) while the lowest was recorded under control (N_0K_0). However, N_3K_3 (1.56 per cent) and N_3K_2 (1.54 per cent) were on par with each other and significantly superior over other interaction effects.

Total nutrient content

The total N and K contents in okra (plants + pods) at harvest was analyzed and the results were given in table 4.9. The effect of levels of nitrogen and potassium found to be significant with regard to total content of N and K and their interactions found to be significant with regard to total K content.

There was significant increase in total N and K contents (per cent) with application of 180 kg N ha^{-1}(N_3), the values of which found to be 3.25 and 2.87 per cent, respectively (Table 4.9).

Among the potassium levels, application of 90 kg K_2O ha^{-1} (K_3) has recorded highest K content (2.86 per cent) which was significantly superior over lower levels. With regard to influence of N content, K_3 (2.95 per cent) was on par with K_2 (2.91 per cent) and significantly higher over lower levels.

With regard to interaction effects, N_3K_3 has recorded significantly highest total K (2.97 per cent) contents, while the lowest content was recorded under control. However N_3K_3 was on par with N_3K_2 and significantly superior over rest of the treatment combinations where as the interaction effect of nitrogen and potassium did not show any significant effect on total N content.

4.1.3 Nutrient uptake

Nutrient uptake was computed using the values of percent nutrient contents and dry matter production at different growth stages. The data on nutrient uptake were presented in tables 4.10 to 4.15 and depicted in figures 4.2 and 4.3.

Nitrogen

In general, with increase in age of the crop there was an increase in N uptake by okra plants. Application of nitrogen and potassium had significant influence on N uptake at all the stages of crop growth (Table 4.10 and 4.11).

Among the nitrogen levels, application of nitrogen @ 180 kg ha^{-1} (N_3) recorded highest N uptake viz., 31.73, 46.61 and 48.19 kg ha^{-1} at 30, 60, and 90 DAS, respectively. These values were significantly superior over other levels of N application.

Among the potassium levels, application of potassium @ 90 kg ha^{-1} (K_3) has recorded highest N uptake at 30 (23.86 kg ha^{-1}), 60 (32.59 kg ha^{-1}) and 90 DAS (36.54 kg ha^{-1}) which was found to be significantly superior over $K_{2,}$ K_1 and K_0 (Table 4.10 and 4.11). Interaction effect of nitrogen and potassium did not show any significant effect on N uptake.

The okra pods were also analyzed for their N uptake at harvest (90 DAS) and presented in table 4.11. The results revealed that N uptake was significantly influenced by application of nitrogen and potassium.

Among the nitrogen levels, application of nitrogen @ 180 kg ha^{-1} (N_3) recorded significantly highest N uptake by pods (28.61 kg ha^{-1}) followed by N_2, N_1 and N_0. Among the potassium levels, K_3 recorded highest N uptake of 25.13 kg ha^{-1} which was significantly superior over all other K levels.

The N uptake by pods of okra was also influenced by interaction effect of N_3K_3 and recorded significantly highest value (31.69 kg ha^{-1}) while the lowest value was recorded under control (Table 4.11).

Phosphorus

The P uptake by okra plants increased upto 60 DAS and then decreased at 90 DAS. P uptake increased with increase in levels of nitrogen and potassium and at all the stages of crop growth, the values of which are given in table 4.12.

Application of 180 kg N ha^{-1} (N_3) significantly increased P uptake by okra plants compared to lower nitrogen levels (N_2, N_1 and N_0) at all the growth stages. The values ranged from 2.50 to 6.96, 6.14 to 17.31 and 4.62 to 11.83 kg ha^{-1} at 30, 60 and 90 DAS, respectively.

With regard to effect of levels of potassium on P uptake, application of potassium @ 90 kg ha^{-1} (K_3) recorded highest P uptake (5.38, 12.98 and 8.98 kg ha^{-1} at 30, 60 and 90 DAS, respectively) followed by K_2, K_1 and K_0 at all the stages of crop growth.

Among the interaction effects at 30 DAS, application of nitrogen @ 180 kg N ha^{-1} (N_3) along with potassium @ 90 kg ha^{-1} (K_3) has recorded highest P uptake (7.88 kg ha^{-1} which was superior over rest of the treatment combinations. However, it was on par with N_3K_2. At 60 and 90 DAS, interaction between nitrogen and potassium did not show any significant effect on P uptake.

Potassium

The values of K uptake by okra revealed that there was an increase in K uptake with the age of the crop growth. It was significantly influenced by levels of nitrogen, potassium and their interactions at all the crop growth stages (Table 4.13 and 4.14).

Among the nitrogen levels, the maximum K uptake was recorded at 30 (15.44 kg ha^{-1}), 60 (33.26 kg ha^{-1}) and 90 DAS (44.95 kg ha^{-1}) when 180 kg N ha^{-1} (N_3) was applied. While the lowest values of 6.15, 11.91 and 19.54 kg ha^{-1} was recorded without N application (N_0).

The data pertaining to effect of potassium levels revealed that application of 90 kg ha^{-1} (K_3) recorded significantly highest K uptake of 13.27, 26.29 and 37.31 kg ha^{-1} at 30, 60 and 90 DAS, respectively followed by K_2, K_1 and K_0.

The interaction effects revealed that the K uptake values recorded at N_3K_3 was significantly superior over other treatment combinations at 60 and 90 DAS, however at 30 DAS N_3K_3 and N_3K_2 ,N_2K_0 and N_2K_1 were on par with each other and lowest values being recorded under control (N_0K_0). The values ranged from 4.13 to 17.54, 8.55 to 37.99 and 14.66 to 48.90 kg ha^{-1} at 30, 60 and 90 DAS, respectively (Table 4.13 and 4.14).

Potassium uptake by pods of okra at 90 DAS was significantly influenced by nitrogen and potassium levels and their interactions (Table 4.14).

Application of nitrogen @ 180 kg N ha^{-1} (N_3) recorded significantly highest K uptake (24.10 kg ha^{-1}) while the lowest values were recorded with N_0. Among the potassium levels, K uptake by okra pods was highest at K_3 (22.81 kg ha^{-1}) followed by K_2, K_1 and K_0 and the increase was significantly superior over lower levels.

The interaction effects revealed that the K uptake was significantly higher when the crop received 180 kg N and 90 kg K_2O ha^{-1} (N_3K_3) compared to the other treatment combinations. However, the values recorded at N_3K_3 (26.29 kg ha^{-1}) was on par with N_3K_2 (25.72 kg ha^{-1}) and lowest values were recorded at control N_0K_0 (9.99 kg ha^{-1}).

Total nutrient uptake

The total nutrient uptake by okra (plants + pods) at harvest was computed and the results are given in table 4.15. The effect of levels of nitrogen and potassium found to be significant with regard to total uptake of N (Fig 4.2) and K (Fig 4.3).

There was significant increase in total N and K uptake (kg ha^{-1}) with application of 180 kg N ha^{-1}(N_3), the values of which found to be 76.80 and 69.04 kg ha^{-1}, respectively (Table 4.15). Among the potassium levels, application of 90 kg K_2O ha^{-1} (K_3) has recorded highest nutrient uptake viz., 61.67 (N), and 60.12 (K) kg ha^{-1} followed by K_2, K_1 and K_0. The per cent increase in total N and K uptake at N_3 level was 138.29 and 106.64 per cent over N_0, respectively. The total N and K uptake at K_3 level increased to an extent of 34.77 and 42.84 per cent over K_0, respectively.

With regard to interaction effects, N_3K_3 has recorded significantly highest K (75.19 kg ha^{-1}) uptake while the lowest uptake was recorded under control. With regard to total N uptake, interaction between nitrogen and potassium did not show any significant effect.

4.1.4 Okra pod yield

The results revealed that there was significant increase in okra pod yield with application of different levels of nitrogen and potassium. The interaction effects were also significant. The pod yield (q ha^{-1}) of okra recorded on fresh weight basis were presented in table 4.16 and depicted in figure 4.4.

Application of nitrogen @ 180 kg N ha^{-1} (N_3) has recorded highest pod yield (110.53 q ha^{-1}), which was significantly superior over N_2 (98.69 q ha^{-1}), N_1 (81.60 q ha^{-1}) and N_0 (65.71 q ha^{-1}). Among the potassium levels, application of potassium @ 90 kg ha^{-1} (K_3) has recorded highest pod yield (104.10 q ha^{-1}) which was superior over lower levels and the lowest value being recorded at K_0 (71.75 q ha^{-1}). The pod yield increased to an extent of 24.18 (60 kg N ha^{-1}), 50.19 (120 kg N ha^{-1}) and 68.21 per cent (180 kg N ha^{-1}) as compared to control. Similarly, K application increased the pod yield by 14.55, 37.28 and 45.09 per cent at 30, 60 and 90 kg K_2O ha^{-1}, respectively over no K application.

Among the interactions, N_3K_3 has recorded the highest pod yield (126.17 q ha^{-1}). However, it was on par with the yield recorded at N_3K_2 (124.83 q ha^{-1}) and the yield at N_2K_3 (112.63 q ha^{-1}) was on par with N_2K_2 (109.27 q ha^{-1}) significantly superior over other interactions.

Results pertaining to response of okra to levels of N, K and their interactions, revealed that, with increase in levels of N and K, there was significant increase in dry matter production of crop. Nitrogen being a constituent of chlorophyll resulted in increased photosynthesis which ultimately accelerated the growth (Chauhan and Gupta, 1973). Similar increase in dry matter production of okra with increasing levels of nitrogen and potassium were reported by Paramasivan *et al.* (2005) and Rani and Jose (2009). Okra has indeterminate growth and the vegetative growth was noticed with increase in age of the crop. Apart from the physiological behaviour of the crop, split application of N and K also had the influence on growth and development of the crop even upto 90 DAS, which was responsible for increase in dry matter production of the crop. Also split application of N and K in light textured soils improves the use efficiency through minimizing the leaching losses and efficient utilization by the crop (Singh and Verma, 2001).

With regard to nutrient contents in okra, the percent N and K contents in okra plants decreased from 30 to 90 DAS. Among the three stages, nitrogen content was highest at 30 DAS and it was decreased with progressive increase in plant growth. Higher dose of basal nitrogen applied, efficient root absorption and vigorous vegetative growth during initial stages especially during the first month, might be responsible for greater nitrogen content at 30 DAS. As the plant entered reproductive phase in the subsequent months (pod formation), there was translocation of nitrogen and potassium from plants to pods there by decreasing the nitrogen content in plants (Rao, 1981). Potassium concentration at 60 and 90 DAS also followed the similar trend as that of N due to active vegetative growth and consequent dilution effect (Hariprakash Rao and Subramanian, 1991). Similar results were also reported by Padmaja and Sreenivasa Raju (1999) in brinjal and Sweet potato crops.

Among the interactions, N_3K_3 has recorded highest K content in plants at all the growth stages due to synergistic effect of these nutrients while the lowest was recorded at N_0K_0.

Okra is also heavy feeder of nutrients and requires nitrogen and potassium for vegetative growth, flowering and pod formation. With increase in the levels of nitrogen and potassium there was significant increase in total N and K uptake. Similar results were also reported by Balle Gowda *et al*. (2002) and Sharma *et al*. (2011).

The interaction effects showed highest total K uptake (75.19 kg ha^{-1}) at N_3K_3 level. The uptake values were computed based on nutrient contents and dry matter production of plants and pods, which was responsible for increase in nutrient uptake by plants at different growth stages (30 to 90 DAS). The indeterminate growth of the plants also increased in fresh weight and in turn the dry matter production leading to increase in total nutrient uptake to meet the metabolic activities of the plant.

Okra pods (edible parts) were picked at regular intervals from and the fresh yield (q ha^{-1}) was recorded. Yield attributes like number of flowers, number of pods per plant, size and weight of pods are governed by nitrogen (Ambere *et al.* 2005). Potassium also influenced the yield due to the direct or indirect involvement of potassium in major plant processes such as photosynthesis, respiration, enzyme activation and metabolism of carbohydrates (Kanaujia *et al*. 1998). Similar results were obtained by Raut (2011). The interaction effect of N x K also showed a significant increase in pod yield (126.17 q ha^{-1}) at N_3K_3. However it was on par with N_3K_2 (124.83 q ha^{-1}). The increase in yield by the combined application of nitrogen and potassium may be attributed due to efficient functioning of photosynthetic surface and increased accumulation of photosynthates (Singh and Singh, 2000).

4.1.5 Quality parameters of okra

Fresh okra pods were analyzed for their quality in terms of ascorbic acid content. Crude protein and crude fibre contents were also analyzed on dry weight basis. The results obtained were given in tables 4.17.

Ascorbic acid (Vitamin C)

Fresh okra pods were analyzed for ascorbic acid content (mg 100 g^{-1}) and results are given in table 4.17.

Ascorbic acid content significantly increased from 15.06 to 17.91 mg 100 g^{-1} from N_0 to N_3. This might be due to increase in uptake of nutrients by nitrogen which would have promoted ascorbic acid content in okra fruits (Irene Velthamoni and Balakrishnan, 1990). Similar increase in ascorbic acid content was recorded by Tomar and Singhal (2007) in tomato.

With regard to potassium levels, K_3 has recorded highest ascorbic acid content (17.77 mg 100 g^{-1}) followed by K_2 (17.06 mg 100 g^{-1}), K_1 (16.32 mg 100 g^{-1}) and K_0 (15.19 mg 100 g^{-1}). This was due to the close relationship between carbohydrates metabolism and formation of ascorbic acid (Majumdar *et al*. 2000). Similar results were obtained by Shibhila Mary and Balakrishnan (1990).

The interaction effect of nitrogen and potassium did not show significant effect on ascorbic acid content.

Crude protein content

Application of nitrogen and potassium had significant effect on crude protein content (Table 4.17). Among the nitrogen levels, N_3 recorded significantly highest crude protein (18.40 per cent) followed by N_2 (17.32 per cent), N_1 (16.25 per cent) and N_0 (14.94 per cent). This is attributed due to enhanced absorption from soil of added N and its direct participation in protein synthesis (Samlind Sujin and Sam Ruban, 2007). Similar results were reported by Muhammad Ayyub *et al*. (1993).

Among the potassium levels, K_3 has recorded highest crude protein (17.83 per cent) which was significantly superior over K_2 (17.06 per cent), K_1 (16.32 per cent) and K_0 (15.70 per cent). Similar increase was noticed by Rani and Jose (2009). The interaction effect of nitrogen and potassium did not show significant effect on crude protein content.

Crude fibre content

Crude fibre content was significantly influenced by levels of nitrogen and potassium (Table 4.17). Increase in applied nitrogen from N_0 to N_3 decreased the crude fibre per cent significantly from 13.36 to 11.06. Among the potassium levels, K_3 recorded significantly highest crude fibre per cent (13.21%) followed by $K_{2,}$ K_1 and $K_{0.}$ The decrease in crude fibre content was due to the increase in succulence by the increased application of nitrogen (Mani and Ramanathan, 1980) and increased by the levels of potassium due to the involvement of K in strenthening the thickness of the cell wall. Similar decrease in crude fibre content with increased levels of nitrogen was obtained by Irene Velthamoni and Balakrishnan (1990). The interaction effect of nitrogen and potassium did not show significant effect on crude fibre content.

4.2 Nitrogen use efficiency

Response of okra to levels of N and K found to be significant, recording high dry matter production, nutrient contents, uptake and pod yield at higher levels i.e., 180 kg ha^{-1} N and 90 kg ha^{-1} K_2O. Research findings revealed that the nitrogen use efficiency in terms of kg Pod per kg applied nitrogen was influenced by different levels of potassium. The nitrogen use efficiency varied from 40 to 60 per cent in different crops (Mosier, 2002) with a global average of 50 per cent. Increase in nitrogen use efficiency is the consequence of enhanced uptake of N. with increase in levels of potassium, there was significant increase in N and K uptake.

Table 4.18. Interaction effect of nitrogen and potassium on Nitrogen use efficiency (NUE)

NUE (Kg pod per kg N applied)					
Levels	**K_0**	**K_{30}**	**K_{60}**	**K_{90}**	**MEAN**
N_{60}	26.2	33.3	22.0	24.5	**26.5**
N_{120}	23.2	25.3	38.0	27.5	**28.5**
N_{180}	16.4	14.1	26.0	22.6	**19.8**
MEAN	**21.9**	**24.2**	**28.6**	**24.9**	

The synergistic effect of N x K on increase in NUE was used as one of the measures to identify the best combination of N and K. The values of NUE are given in table 4.18. The highest NUE (38) was recorded with N_2K_2 level and decrease in NUE was recorded with highest levels of N viz., N_3K_3 (22.6) and N_3K_2 (26.0)

4.3 Effect of different levels of nitrogen, potassium and their interactions on soil nutrient status at different crop growth stages of okra

4.3.1 Available nutrient status

The data pertaining to soil available nitrogen, phosphorus and potassium at 30, 60 and 90 DAS of okra crop were presented in table 4.19 to 4.21.

Available nitrogen

The effect of levels of nitrogen, potassium and their interactions are given in table 4.19. It was significantly influenced by different levels of nitrogen, potassium and their interactions.

The available N in soil increased with increase in levels of N from N_0 to N_3 (Fig.4.5) registering highest values with application of 180 kg N ha^{-1} (N_3). The values found to be 337.4, 277.7 and 231.2 kg ha^{-1} at 30, 60 and 90 DAS, respectively. Among the potassium levels, K_3 (90 kg ha^{-1}) recorded significantly highest available N content at 30 DAS (286.0 kg ha^{-1}), 60 DAS (224.7 kg ha^{-1}) and 90 DAS (195.2 kg ha^{-1}).

The interaction effects also found to have significant effect on available nitrogen status in soil at all the growth stages. Among the interaction effects, N_3K_3 recorded highest available N (346.7, 284.4 and 237.2 kg ha^{-1} at 30, 60 and 90 DAS, respectively) and was significantly superior over other interactions, the lowest being recorded with control (N_0K_0). However, at 30 DAS the treatments N_3K_0 (329.6 kg ha^{-1}) and N_3K_1 (332.4 kg ha^{-1}) were on par with each other and at 60 DAS N_3K_1 (279.2 kg ha^{-1}) and N_3K_2 (276.6 kg ha^{-1}) were on par with each other.

Available phosphorus

The results pertaining to available phosphorus (P_2O_5 kg ha^{-1}) at different stages of okra are given in table 4.20. Among the nitrogen levels, N_3 has recorded highest soil available P_2O_5 content. However, at 30 DAS soil available phosphorus content was not significantly influenced by nitrogen levels.

Application of different levels of potassium and their interactions with nitrogen had non significant effect on available phosphorus content at 30, 60 and 90 DAS.

Available potassium

The soil available potassium at different growth stages of okra was significantly influenced by different levels of nitrogen, potassium and their interactions (Table 4.21 and Fig. 4.6).

With increase in nitrogen levels from N_0 to N_3, available K_2O also showed an increase, recording significantly highest available K_2O of 317.0, 279.8 and 230.1 kg K_2O ha^{-1} at 30, 60 and 90 DAS, respectively at N_3 level while the lowest was recorded with N_0.

The available K_2O also increased significantly with increase in levels of potassium from K_0 to K_3. Among the different levels, application of potassium @ 90 kg ha^{-1} (K_3)

recorded highest available K_2O content of 335.9, 295.6 and 246.5 kg ha^{-1} at 30, 60 and DAS, respectively followed by K_2, K_1 and K_0 (Table 4.21).

Among the interaction effects, N_3K_3 recorded highest available K_2O content at 60 DAS (302.2 kg ha^{-1}) and at 90 DAS (252.6 kg ha^{-1}) which was significantly superior over all other interaction effects. However, at 30 DAS the treatments N_3K_3 (350.8 kg ha^{-1}) and N_2K_3 (344.3 kg ha^{-1}), N_3K_2 (332.5 kg ha^{-1}) and N_2K_2 (325.8 kg ha^{-1}) were on par with each other where as at 60 DAS the treatments N_3K_1 (273.6 kg ha^{-1}) and N_2K_1 (268.4 kg ha^{-1}), N_3K_0 (256.1 kg ha^{-1}) and N_2K_0 (251.7 kg ha^{-1}) were on par with each other. The lowest values were recorded at control (N_0K_0) and at 90 DAS N_3K_3 (252.6 kg ha^{-1}) and N_2K_3 (250.6 kg ha^{-1}), N_3K_2 (240.6 kg ha^{-1}) and N_2K_2 (236.1 kg ha^{-1}) were on par with each other.

The trends in soil available N, P_2O_5 and K_2O revealed that there was a decrease in these contents to an extent of 41.0, 40 and 23.5 per cent, respectively from initial to 90 DAS in control plots. However, with increase in levels of N and K, there was an increase in available N and K in soil. The decrease in available nutrient status is due to uptake of these nutrients by okra which reflected in increase in dry matter production, nutrient content and total N and K uptake by the crop (Bharadwaj *et al.*, 2010). This was also evident from the highly significant positive correlation observed between available nutrients, yield and uptake by okra.

4.3.2 Nitrogen fractions

The data on inorganic N fractions with respect to ammoniacal-N and nitrate-N are presented in table 4.22.

Ammoniacal Nitrogen

The inorganic N fractions were analyzed at harvesting stage of okra. Ammoniacal nitrogen was significantly influenced by different levels of nitrogen, potassium and their interactions. With increase in levels of nitrogen from N_0 to N_3, there was also a significant increase in NH_4^+-N from 32.90 to 71.95 mg kg^{-1} and maximum was attained in N_3 treatment receiving 180 kg N ha^{-1} (Table 4.22).

Similar trends were also observed with increase in levels of potassium from K_0 to K_3. Application of potassium @ 90 kg ha^{-1} (K_3) has recorded highest NH_4^+-N (55.06 mg kg^{-1}) followed by K_2, K_1 and K_0.

Among all the treatment combinations, N_3K_3 recorded highest NH_4^+-N (73.31 mg kg^{-1}) which was on par with N_3K_2 (72.80 mg kg^{-1}) and significantly superior over other treatments.

Nitrate Nitrogen

Nitrate nitrogen content in soil was also significantly influenced by different levels of nitrogen, potassium and their interactions. Among the nitrogen levels, N_3 recorded significantly highest NO_3-N content (47.23 mg kg^{-1}) followed by N_2, N_1 and N_0.

Among the potassium levels, application of potassium @ 90 kg ha^{-1} (K_3) recorded the highest NO_3-N content of 34.19 mg kg^{-1} at K_3 level (Table 4.22). However it was on par with K_2 and significantly higher over K_1 and K_0.

With regard to interaction effects, significantly highest value of NO_3-N was recorded at N_3K_3 followed by N_3K_2, N_3K_1 and N_3K_0 while the lowest values were recorded at N_0K_0. However, the treatments N_3K_3 (48.63 mg kg^{-1}) and N_3K_2 (48.29 mg kg^{-1}) were on par with each other.

Similar increase in the NH_4- N and NO_3- N with increase in levels of nitrogen was reported by Prabhakar Reddy *et al*. (2010).

4.3.3 Potassium fractions

The soil samples collected at harvesting stage of okra were analyzed for different forms of K viz., water soluble, exchangeable, and 1N HNO_3 extractable K and the values are given in tables 4.23.

Water soluble K

Application of different levels of nitrogen, potassium and their interactions had significant effect on water soluble K. Among nitrogen levels, N_3 recorded significantly highest water soluble K (13.46 mg kg^{-1}) followed by N_2 (12.02 mg kg^{-1}), N_1 (10.24 mg kg^{-1}) and was lowest at N_0 (9.38 mg kg^{-1}) level.

With increasing levels of potassium, there was significant increase in water soluble K, the highest values being recorded at K_3 (15.67 mg kg^{-1}) followed by K_2, K_1 and K_0 (Table 4.23).

With regard to interaction effects, significantly highest water soluble K content (17.16 mg kg^{-1}) was recorded at N_3K_3, while the lowest content (4.27 mg kg^{-1}) was recorded at N_0K_0. However, the values recorded at N_3K_2 (15.33 mg kg^{-1}) and N_2K_3 (16.23 mg kg^{-1}), N_2K_1 (11.03 mg kg^{-1}) and N_1K_2 (11.41 mg kg^{-1}) were on par with each other (Table 4.23).

Exchangeable K

Application of different levels of nitrogen, potassium and their interactions had significant effect on exchangeable K. Among nitrogen levels, N_3 (89.26 mg kg^{-1}) followed by N_2 (88.48 mg kg^{-1}) and N_1 (87.64 mg kg^{-1}) were significantly superior over N_0 (85.72 mg kg^{-1}).

With increasing levels of potassium from K_0 to K_3, there was significant increase in exchangeable K from 80.99 to 94.38 mg kg^{-1} and maximum attained at K_3 (Table 4.23).

Among the interaction effects, highest exchangeable K content (95.63 mg kg^{-1}) was recorded at N_2K_3 which was on par with N_3K_3 (95.60 mg kg^{-1}), while the lowest content (80.68 mg kg^{-1}) was recorded at N_0K_0. However, the values recorded at N_3K_2 (92.09 mg kg^{-1}), N_2K_2 (91.78 mg kg^{-1}) were on par with each other.

1N HNO_3 extractable K (Fixed K)

The results pertaining to 1N HNO_3 extractable K is given in table 4.23. With increase in nitrogen levels from N_0 to N_3, 1N HNO_3 extractable K also showed an increase recording significantly highest mean value of 1264.2 mg kg^{-1} at N_3 level while the lowest was recorded with N_0.

With regard to potassium levels, K_3 recorded significantly highest mean values of 1N $HN0_3$ extractable K (1293.5 mg kg^{-1}) followed by K_2 (1265.9 mg kg^{-1}), K_1 (1246.6 mg kg^{-1}) and K_0 (1214.6 mg kg^{-1}).

The interaction effects of nitrogen and potassium did not show significant effect on 1N HNO_3 extractable K in soil at harvest.

Similar increase in the levels of potassium fractions with increase in levels of applied potassium was reported by Padmaja and Sreenivasa Raju (1999).

4.4 Correlation studies:

In order to know the contribution of different forms of inorganic N and K, correlation studies were done considering the pod yield, total N and K uptake (Table 4.24 and 4.25). Though there was no specific contribution by any one of these forms, it was understood that the readily available forms of N and K significantly correlated with pod yield, N uptake and K uptake at different growth stages of crop. Duraisami *et al.* (2001) also observed that the available N and inorganic nitrogen fractions showed positive correlation with N uptake.

Table 4.24. Relationship of forms of N with yield and total uptake of nutrients by okra at harvest

Particulars	**Forms of Nitrogen**		
	Available N	**NH_4-N**	**NO_3-N**
Yield	0.860**	0.829**	0.842**
Total N uptake	0.960**	0.954**	0.959**
Total K uptake	0.927**	0.919**	0.918**

* Significant at 5 per cent level ** Significant at 1 per cent level

Table 4.25. Relationship of forms of K with yield and total uptake of nutrients by okra at harvest

Particulars	Forms of Potassium		
	Available K_2O	**Water soluble -K**	**Exchangeable-K**
Yield	0.817**	0.860**	0.768**
Total N uptake	0.619*	0.697**	0.551*
Total K uptake	0.710**	0.780**	0.646**

* Significant at 5 per cent level   ** Significant at 1 per cent level

With regard to different inorganic forms of nitrogen, NH_4^+-N is more than NO_3-N, and both these forms showed a decrease from initial to harvest to an extent of 12.1 and 13.2 per cent, respectively in control plots where nitrogen is not applied. From the correlations it was found that, NH_4^+-N and NO_3-N significantly correlated with pod yield (r = 0.829** and r = 0.842**) and total N uptake (r = 0.954** and r = 0.959**) as indicated in table 4.24. This indicates that the readily available forms of N contributed to N availability to okra at different growth stages. Also nitrogen and potassium were applied as basal followed by two splits at 30 DAS (vegetative) and before 60 DAS (flowering and pod formation stage) which helped in better growth, N uptake and pod yield.

Similar trends were observed with different forms of potassium. The water soluble K and exchangeable K significantly correlated with yield (r = 0.860** and r = 0.768**) and total K uptake (r = 0.780** and r = 0.646**) by plants (Table 4.25).

4.5 Effect of different levels of nitrogen and potassium on benefit cost ratio

Benefit cost ratio of different treatment combinations were also worked out and the information is given in table 4.26. Highest benefit cost ratio (1.85) was found at N_3K_2 followed by N_3K_3(1.84), N_2K_3 (1.58) and N_2K_2 (1.54).

Table 4.26. Interaction effect of nitrogen and potassium on Benefit Cost ratio

Levels	Benefit Cost ratio				
	K_0	K_{30}	K_{60}	K_{90}	MEAN
N_0	0.25	0.40	0.76	0.93	**0.59**
N_{60}	0.61	0.86	1.04	1.24	**0.94**
N_{120}	0.91	1.18	1.54	1.58	**1.30**
N_{180}	1.11	1.34	1.85	1.84	**1.54**
MEAN	**0.72**	**0.95**	**1.30**	**1.40**	

Results obtained from response of okra to levels of N and K, it was observed that the pod yield recorded at N_3K_2 (180:60 kg ha^{-1}) was on par with yield recorded at N_3K_3 (180:90 kg ha^{-1}). The benefit cost ratio was also highest at N_3K_2 (1.85) followed by N_3K_3 (1.84). However, from NUE point of view, N_2K_2 (120:60 kg ha^{-1}) showed highest use efficiency (38) compared to increasing levels of N and K, with a benefit cost ratio of 1.54. Hence to minimize the cost on fertilizers and to attain high nitrogen use efficiency, it can be suggested to apply 120 kg N in combination with 60 kg K_2O ha^{-1} rather than 180:60 kg ha^{-1} (N_3K_2).

Table 4.19. Effect of levels of nitrogen, potassium and their interactions on available nitrogen status (kg ha^{-1}) in soil at 30, 60 and 90DAS

Levels	30 DAS					60 DAS					90 DAS				
	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	211.3	216.8	216.4	222.1	**216.9**	149.2	153.2	164.0	158.7	**156.3**	130.4	133.5	133.6	137.9	**133.8**
N_1	246.4	252.5	255.3	260.6	**253.7**	194.4	200.1	208.0	213.3	**204.0**	172.3	183.1	179.5	187.7	**180.6**
N_2	293.8	300.2	305.5	314.5	**303.5**	235.5	240.3	240.4	245.3	**240.4**	198.3	203.9	215.0	218.5	**208.9**
N_3	329.6	332.4	340.9	346.7	**337.4**	271.8	279.2	276.6	284.4	**277.7**	223.9	228.7	234.8	237.2	**231.2**
Mean	**270.3**	**275.7**	**279.5**	**286.0**		**213.2**	**218.2**	**222.2**	**224.7**		**181.2**	**187.3**	**190.7**	**195.2**	

	30 DAS S.Ed±	30 DAS CD (0.05)	60 DAS S.Ed±	60 DAS CD (0.05)	90 DAS S.Ed±	90 DAS CD (0.05)
N	1.15	2.34	1.13	2.30	0.95	1.93
K	1.15	2.34	1.13	2.30	0.95	1.93
N×K	2.30	4.69	2.26	4.61	1.89	3.87

Initial soil available nitrogen : 226.8 kg ha^{-1}

Table 4.21: Effect of levels of nitrogen, potassium and their interactions on available potassium status (kg ha^{-1}) in soil at 30, 60 and 90 DAS

Levels	30 DAS					60 DAS					90 DAS				
	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	260.2	281.5	298.4	317.6	**289.5**	245.2	261.3	276.2	293.6	**269.1**	190.3	203.8	219.5	238.5	**213.0**
N_1	266.6	283.3	313.6	330.7	**298.5**	250.4	264.2	283.5	298.3	**274.1**	194.4	211.3	226.9	244.4	**219.2**
N_2	270.3	291.2	325.8	344.3	**307.9**	251.7	268.4	280.8	288.2	**272.3**	196.0	217.7	236.1	250.6	**225.1**
N_3	278.6	306.2	332.5	350.8	**317.0**	256.1	273.6	287.3	302.2	**279.8**	202.7	224.5	240.6	252.6	**230.1**
Mean	**268.9**	**290.5**	**317.6**	**335.9**		**250.8**	**266.9**	**281.9**	**295.6**		**195.8**	**214.3**	**230.8**	**246.5**	

	30 DAS S.Ed±	30 DAS CD (0.05)	60 DAS S.Ed±	60 DAS CD (0.05)	90 DAS S.Ed±	90 DAS CD (0.05)
N	2.06	4.20	1.37	2.80	1.13	2.31
K	2.06	4.20	1.37	2.80	1.13	2.31
N×K	4.11	8.40	2.74	5.60	2.26	4.61

Initial soil available potassium : 278.5 kg ha^{-1}

Table 4.4. Effect of levels of nitrogen, potassium and their interactions on nitrogen content (%) in okra plants at 30 and 60 DAS

Levels	**30 DAS**					**60 DAS**				
	K_0	K_1	K_2	K_3	**Mean**	K_0	K_1	K_2	K_3	**Mean**
N_0	1.95	1.98	2.02	2.04	**2.00**	1.58	1.61	1.62	1.64	**1.61**
N_1	2.15	2.17	2.20	2.23	**2.19**	1.69	1.71	1.74	1.78	**1.73**
N_2	2.45	2.53	2.45	2.48	**2.48**	1.87	1.90	1.92	1.94	**1.91**
N_3	2.76	2.79	2.83	2.87	**2.81**	2.20	2.22	2.25	2.26	**2.23**
Mean	**2.33**	**2.37**	**2.38**	**2.40**		**1.84**	**1.86**	**1.88**	**1.90**	

	30 DAS S.Ed±	30 DAS CD (0.05)	60 DAS S.Ed±	60 DAS CD (0.05)
N	0.03	0.05	0.02	0.05
K	0.03	N.S.	0.02	N.S.
N×K	0.05	N.S.	0.05	N.S.

Table 4.7. Effect of levels of nitrogen, potassium and their interactions on potassium content (%) in okra plants at 30 and 60 DAS

Levels	**30 DAS**					**60 DAS**				
	K_0	K_1	K_2	K_3	**Mean**	K_0	K_1	K_2	K_3	**Mean**
N_0	1.64	1.75	1.77	1.80	**1.74**	1.21	1.31	1.41	1.43	**1.34**
N_1	1.71	1.81	1.88	1.97	**1.84**	1.35	1.40	1.45	1.51	**1.43**
N_2	1.67	1.86	2.15	2.18	**1.96**	1.39	1.45	1.53	1.63	**1.50**
N_3	1.76	1.97	2.31	2.33	**2.09**	1.50	1.57	1.62	1.67	**1.59**
Mean	**1.70**	**1.85**	**2.03**	**2.07**		**1.36**	**1.43**	**1.50**	**1.56**	

	S.Ed±	CD (0.05)	S.Ed±	CD (0.05)
N	0.02	0.04	0.01	0.02
K	0.02	0.04	0.01	0.02
N×K	0.04	0.08	0.02	0.04

Table 4.6. Effect of levels of nitrogen, potassium and their interactions on phosphorus content (%) in okra plants at 30, 60 and 90 DAS

Levels	30 DAS					60 DAS					90 DAS				
	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	0.47	0.48	0.47	0.48	**0.48**	0.67	0.69	0.70	0.71	**0.69**	0.27	0.28	0.28	0.27	**0.28**
N_1	0.50	0.50	0.51	0.51	**0.51**	0.72	0.74	0.73	0.73	**0.73**	0.29	0.29	0.30	0.30	**0.30**
N_2	0.54	0.56	0.55	0.56	**0.55**	0.78	0.79	0.78	0.79	**0.79**	0.34	0.35	0.34	0.35	**0.35**
N_3	0.61	0.61	0.62	0.63	**0.62**	0.82	0.82	0.83	0.84	**0.83**	0.35	0.36	0.36	0.37	**0.36**
Mean	**0.53**	**0.54**	**0.54**	**0.55**		**0.75**	**0.76**	**0.76**	**0.77**		**0.31**	**0.32**	**0.32**	**0.32**	

	30 DAS S.Ed±	30 DAS CD (0.05)	60 DAS S.Ed±	60 DAS CD (0.05)	90 DAS S.Ed±	90 DAS CD (0.05)
N	0.007	0.014	0.007	0.015	0.005	0.011
K	0.007	N.S.	0.007	N.S.	0.005	N.S.
N×K	0.014	N.S.	0.015	N.S.	0.011	N.S.

Table 4.17. Effect of levels of nitrogen, potassium and their interactions on quality parameters of okra

Levels	Ascorbic acid (mg 100 gm^{-1})					Crude protein (%)					Crude fibre (%)				
	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	13.68	14.71	15.52	16.31	**15.06**	14.09	14.67	15.19	15.83	**14.94**	12.17	12.95	13.85	14.47	**13.36**
N_1	14.53	15.98	16.65	17.66	**16.21**	15.14	15.53	16.40	17.91	**16.25**	11.75	12.45	13.15	13.41	**12.69**
N_2	16.06	16.75	17.61	18.24	**17.16**	16.27	16.86	17.86	18.28	**17.32**	11.05	11.65	12.35	13.05	**12.03**
N_3	16.48	17.82	18.46	18.87	**17.91**	17.31	18.23	18.78	19.29	**18.40**	10.15	10.80	11.40	11.92	**11.06**
Mean	**15.19**	**16.32**	**17.06**	**17.77**		**15.70**	**16.32**	**17.06**	**17.83**		**11.28**	**11.96**	**12.69**	**13.21**	

	Ascorbic acid S.Ed±	Ascorbic acid CD (0.05)	Crude protein S.Ed±	Crude protein CD (0.05)	Crude fibre S.Ed±	Crude fibre CD (0.05)
N	0.32	0.66	0.20	0.40	0.18	0.36
K	0.32	0.66	0.20	0.40	0.18	0.36
N×K	0.65	N.S.	0.40	N.S.	0.35	N.S.

Table 4.1. Effect of levels of nitrogen, potassium and their interactions on dry matter production (kg ha^{-1}) of okra plants at 30 and 60 DAS

Levels	30 DAS					60 DAS				
	K_0	K_1	K_2	K_3	**Mean**	K_0	K_1	K_2	K_3	**Mean**
N_0	404.1	487.7	521.2	681.8	**523.7**	706.9	808.3	904.7	1102.5	**880.6**
N_1	631.2	648.3	796.8	896.3	**743.1**	1000.8	1195.8	1299.6	1463.5	**1239.9**
N_2	798.0	805.6	975.5	1042.1	**905.3**	1358.3	1579.9	1706.2	1799.5	**1611.0**
N_3	904.6	1121.3	1232.9	1243.9	**1125.7**	1897.8	2022.7	2149.7	2274.4	**2086.1**
Mean	**684.5**	**765.7**	**881.6**	**966.0**		**1240.9**	**1401.7**	**1515.0**	**1660.0**	

	30 DAS S.Ed±	30 DAS CD (0.05)	60 DAS S.Ed±	60 DAS CD (0.05)
N	23.64	48.28	14.94	30.52
K	23.64	48.28	14.94	30.52
N×K	47.27	96.57	29.88	61.04

Table 4.10. Effect of levels of nitrogen, potassium and their interactions on N uptake (kg ha^{-1}) by okra plants at 30 and 60 DAS

Levels	30 DAS					60 DAS				
	K_0	K_1	K_2	K_3	**Mean**	K_0	K_1	K_2	K_3	**Mean**
N_0	7.90	9.64	10.55	13.94	**10.51**	11.20	13.00	14.65	18.08	**14.23**
N_1	13.60	14.07	17.54	19.97	**16.30**	16.91	20.45	22.61	25.99	**21.49**
N_2	19.58	20.41	23.90	25.83	**22.43**	25.39	30.01	32.77	34.89	**30.77**
N_3	24.96	31.30	34.97	35.70	**31.73**	41.76	44.92	48.36	51.39	**46.61**
Mean	**16.51**	**18.86**	**21.74**	**23.86**		**23.82**	**27.09**	**29.60**	**32.59**	

	S.Ed± (30 DAS)	CD (0.05) (30 DAS)	S.Ed± (60 DAS)	CD (0.05) (60 DAS)
N	0.73	1.48	0.44	0.90
K	0.73	1.48	0.44	0.90
N×K	1.45	N.S.	0.88	N.S.

Table 4.13. Effect of levels of nitrogen, potassium and their interactions on K uptake (kg ha^{-1}) by okra plants at 30 and 60 DAS

Levels	30 DAS					60 DAS				
	K_0	K_1	K_2	K_3	**Mean**	K_0	K_1	K_2	K_3	**Mean**
N_0	4.13	5.46	6.21	8.79	**6.15**	8.55	10.58	12.75	15.77	**11.91**
N_1	7.32	7.59	10.03	12.28	**9.30**	13.50	16.74	18.85	22.10	**17.80**
N_2	9.89	10.41	12.88	14.46	**11.91**	18.88	22.91	26.11	29.32	**24.30**
N_3	11.85	15.14	17.24	17.54	**15.44**	28.47	31.76	34.83	37.99	**33.26**
Mean	**8.30**	**9.65**	**11.59**	**13.27**		**17.35**	**20.50**	**23.13**	**26.29**	

	30 DAS S.Ed±	30 DAS CD (0.05)	60 DAS S.Ed±	60 DAS CD (0.05)
N	0.30	0.62	0.27	0.55
K	0.30	0.62	0.29	0.55
N×K	0.61	1.24	0.54	1.11

Table 4.12. Effect of levels of nitrogen, potassium and their interactions on P uptake (kg ha^{-1}) by okra plants at 30, 60 and 90 DAS

Levels	30 DAS					60 DAS					90 DAS				
	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	1.90	2.34	2.45	3.29	**2.50**	4.76	5.57	6.36	7.86	**6.14**	3.88	4.45	4.80	5.34	**4.62**
N_1	3.18	3.26	4.09	4.54	**3.76**	7.17	8.89	9.53	10.68	**9.07**	5.42	6.18	6.70	7.43	**6.43**
N_2	4.28	4.48	5.37	5.81	**4.99**	10.64	12.48	13.30	14.27	**12.67**	8.01	9.28	9.33	10.31	**9.23**
N_3	5.52	6.81	7.65	7.88	**6.96**	15.56	16.65	17.92	19.11	**17.31**	10.58	11.72	12.17	12.83	**11.83**
Mean	**3.72**	**4.22**	**4.89**	**5.38**		**9.53**	**10.90**	**11.78**	**12.98**		**6.97**	**7.91**	**8.25**	**8.98**	

	30 DAS S.Ed±	30 DAS CD (0.05)	60 DAS S.Ed±	60 DAS CD (0.05)	90 DAS S.Ed±	90 DAS CD (0.05)
N	0.15	0.30	0.13	0.26	0.13	0.27
K	0.15	0.30	0.13	0.26	0.13	0.27
N×K	0.30	0.61	0.26	N.S.	0.26	N.S.

Table 4.20. Effect of levels of nitrogen, potassium and their interactions on available phosphorus status (kg ha^{-1}) in soil at 30, 60 and 90DAS

Levels	30 DAS					60 DAS					90 DAS				
	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	54.16	62.72	61.28	53.2	**57.84**	38.54	39.27	40.96	39.12	**39.47**	21.47	22.58	24.84	23.87	**23.19**
N_1	55.23	67.93	64.35	65.76	**63.32**	44.21	43.79	44.69	46.85	**44.89**	30.23	26.55	27.37	30.13	**28.82**
N_2	66.27	63.64	61.41	70.18	**65.38**	45.88	46.39	48.28	50.65	**47.80**	35.68	32.32	33.11	36.21	**34.33**
N_3	71.33	60.04	52.82	74.36	**64.64**	56.37	52.53	51.26	54.23	**53.60**	40.16	38.78	37.84	41.00	**39.70**
Mean	**61.75**	**63.59**	**59.97**	**65.88**		**46.25**	**45.49**	**46.30**	**47.71**		**31.89**	**30.06**	**30.79**	**32.81**	

	30 DAS S.Ed±	30 DAS CD (0.05)	60 DAS S.Ed±	60 DAS CD (0.05)	90 DAS S.Ed±	90 DAS CD (0.05)
N	3.33	N.S.	0.84	1.72	1.06	2.17
K	3.33	N.S.	0.84	N.S.	1.06	N.S.
N×K	6.66	N.S.	1.68	N.S.	2.13	N.S.

Initial soil available phosphorus : 38.63kg ha^{-1}

Table 4.2. Effect of levels of nitrogen, potassium and their interactions on dry matter production (kg ha^{-1}) of okra plants and pods at 90 DAS

Levels	Okra plants					Okra pods				
	K_0	K_1	K_2	K_3	**Mean**	K_0	K_1	K_2	K_3	**Mean**
N_0	1438.1	1572.3	1711.5	1977.7	**1674.9**	884.2	972.4	1174.1	1263.6	**1073.6**
N_1	1846.8	2106.4	2235.4	2502.9	**2172.8**	1108.5	1347.3	1406.9	1508.8	**1342.8**
N_2	2356.8	2629.6	2771.7	2917.2	**2668.8**	1313.3	1446.2	1534.5	1614.3	**1477.1**
N_3	3052.4	3256.6	3351.4	3467.4	**3281.9**	1462.5	1584.1	1670.2	1685.5	**1600.5**
Mean	**2173.5**	**2391.2**	**2517.5**	**2716.3**		**1192.1**	**1337.5**	**1446.4**	**1518.0**	

	S.Ed± (Okra plants)	CD (0.05) (Okra plants)	S.Ed± (Okra pods)	CD (0.05) (Okra pods)
N	21.30	43.49	13.04	26.63
K	21.30	43.49	13.04	26.63
N×K	42.60	86.99	26.07	53.26

Table 4.5. Effect of levels of nitrogen, potassium and their interactions on nitrogen content (%) in okra plants and pods at 90 DAS

Levels	Okra plants					Okra pods				
	K_0	K_1	K_2	K_3	**Mean**	K_0	K_1	K_2	K_3	**Mean**
N_0	0.98	1.02	1.14	1.07	**1.05**	1.26	1.32	1.38	1.42	**1.35**
N_1	1.15	1.20	1.25	1.29	**1.22**	1.45	1.48	1.52	1.54	**1.50**
N_2	1.28	1.34	1.37	1.39	**1.35**	1.64	1.68	1.71	1.71	**1.69**
N_3	1.43	1.45	1.48	1.50	**1.47**	1.72	1.75	1.79	1.88	**1.79**
Mean	**1.21**	**1.25**	**1.31**	**1.31**		**1.52**	**1.56**	**1.60**	**1.64**	

	Okra plants S.Ed±	Okra plants CD (0.05)	Okra pods S.Ed±	Okra pods CD (0.05)
N	0.02	0.04	0.007	0.015
K	0.02	0.04	0.007	0.015
N×K	0.04	N.S.	0.014	0.029

Table 4.8. Effect of levels of nitrogen, potassium and their interactions on potassium content (%) in okra plants and pods at 90 DAS

Levels	Okra plants					Okra pods				
	K_0	K_1	K_2	K_3	**Mean**	K_0	K_1	K_2	K_3	**Mean**
N_0	1.02	1.12	1.19	1.29	**1.16**	1.13	1.24	1.32	1.42	**1.28**
N_1	1.16	1.17	1.26	1.37	**1.24**	1.29	1.30	1.38	1.49	**1.37**
N_2	1.24	1.29	1.32	1.39	**1.31**	1.37	1.41	1.44	1.52	**1.44**
N_3	1.31	1.35	1.40	1.41	**1.37**	1.42	1.49	1.54	1.56	**1.50**
Mean	**1.18**	**1.23**	**1.29**	**1.37**		**1.30**	**1.36**	**1.42**	**1.50**	

	Okra plants S.Ed±	Okra plants CD (0.05)	Okra pods S.Ed±	Okra pods CD (0.05)
N	0.01	0.03	0.008	0.018
K	0.01	0.03	0.008	0.018
N×K	0.02	0.05	0.017	0.035

Table 4.11. Effect of levels of nitrogen, potassium and their interactions on nitrogen uptake (kg ha^{-1}) by okra plants and pods at 90 DAS

Levels	Okra plants					Okra pods				
	K_0	K_1	K_2	K_3	**Mean**	K_0	K_1	K_2	K_3	**Mean**
N_0	14.08	16.04	19.51	21.17	**17.70**	11.14	12.84	16.20	17.94	**14.53**
N_1	21.24	25.26	27.93	32.28	**26.68**	16.07	19.94	21.38	23.24	**20.16**
N_2	30.17	35.24	37.98	40.55	**35.99**	21.54	24.30	26.24	27.65	**24.93**
N_3	43.64	47.22	49.74	52.14	**48.19**	25.16	27.72	29.89	31.69	**28.61**
Mean	**27.28**	**30.94**	**33.79**	**36.54**		**18.48**	**21.20**	**23.43**	**25.13**	

	Okra plants S.Ed±	Okra plants CD (0.05)	Okra pods S.Ed±	Okra pods CD (0.05)
N	0.61	1.25	0.21	0.43
K	0.61	1.25	0.21	0.43
N×K	1.22	N.S.	0.42	0.86

Table 4.14. Effect of levels of nitrogen, potassium and their interactions on potassium uptake (kg ha^{-1}) by okra plants and pods at 90 DAS

Levels	Okra plants					Okra pods				
	K_0	K_1	K_2	K_3	**Mean**	K_0	K_1	K_2	K_3	**Mean**
N_0	14.66	17.61	20.37	25.50	**19.54**	9.99	12.05	15.49	17.94	**13.87**
N_1	21.42	24.65	28.17	34.29	**27.13**	14.30	17.51	19.41	22.48	**18.43**
N_2	29.23	33.91	36.58	40.54	**35.07**	17.99	20.39	22.10	24.54	**21.26**
N_3	39.99	43.96	46.93	48.90	**44.95**	20.76	23.61	25.72	26.29	**24.10**
Mean	**26.33**	**30.03**	**33.01**	**37.31**		**15.76**	**18.39**	**20.68**	**22.81**	

	S.Ed±	CD (0.05)	S.Ed±	CD (0.05)
N	0.43	0.89	0.20	0.42
K	0.43	0.89	0.20	0.42
N×K	0.87	1.77	0.41	0.84

Table 4.9. Effect of levels of nitrogen, potassium and their interactions on total N and K contents (%) in okra (plant + pods) at 90 DAS

Levels	Total nitrogen content (%)					Total potassium content (%)				
	K_0	K_1	K_2	K_3	**Mean**	K_0	K_1	K_2	K_3	**Mean**
N_0	2.24	2.34	2.52	2.49	**2.40**	2.15	2.36	2.51	2.71	**2.43**
N_1	2.60	2.68	2.77	2.83	**2.72**	2.45	2.47	2.64	2.86	**2.61**
N_2	2.92	3.02	3.08	3.10	**3.03**	2.61	2.70	2.76	2.91	**2.75**
N_3	3.15	3.20	3.27	3.38	**3.25**	2.73	2.84	2.94	2.97	**2.87**
Mean	**2.73**	**2.81**	**2.91**	**2.95**		**2.49**	**2.59**	**2.71**	**2.86**	

	S.Ed±	CD (0.05)	S.Ed±	CD (0.05)
N	0.02	0.04	0.014	0.028
K	0.02	0.04	0.014	0.028
N×K	0.04	N.S.	0.028	0.057

Table 4.15. Effect of levels of nitrogen, potassium and their interactions on total N and K uptake (kg ha^{-1}) by okra (plant + pods) at 90 DAS

Levels	Total N uptake (kg ha^{-1})					Total K uptake (kg ha^{-1})				
	K_0	K_1	K_2	K_3	**Mean**	K_0	K_1	K_2	K_3	**Mean**
N_0	25.23	28.87	35.71	39.11	**32.23**	24.66	29.66	35.87	43.45	**33.41**
N_1	37.31	45.20	49.32	55.52	**46.84**	35.73	42.16	47.58	56.77	**45.56**
N_2	51.71	59.54	64.21	68.20	**60.92**	47.22	54.30	58.68	65.08	**56.32**
N_3	68.79	74.94	79.63	83.83	**76.80**	60.76	67.57	72.65	75.19	**69.04**
Mean	**45.76**	**52.14**	**57.22**	**61.67**		**42.09**	**48.42**	**53.70**	**60.12**	

	S.Ed±	CD (0.05)	S.Ed±	CD (0.05)
N	0.66	1.34	0.51	1.03
K	0.66	1.34	0.51	1.03
N×K	1.31	N.S	1.01	2.07

Table 4.23. Effect of levels of nitrogen, potassium and their interactions on potassium fractions (Water soluble-K, Exchangeable-K and 1N HNO_3 in mg kg^{-1}) in soil at harvest.

Levels	Water soluble-K					Exchangeable-K					1 N HNO_3 extractable-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	4.27	8.56	10.24	14.43	**9.38**	80.68	82.42	87.73	92.05	**85.72**	1200.1	1238.2	1259.2	1284.2	**1245.4**
N_1	5.11	9.55	11.41	14.87	**10.24**	81.69	84.76	89.86	94.24	**87.64**	1210.7	1250.5	1265.6	1286.4	**1253.3**
N_2	7.18	11.03	13.62	16.23	**12.02**	80.33	86.17	91.78	95.63	**88.48**	1220.5	1245.5	1268.4	1296.3	**1257.7**
N_3	9.21	12.15	15.33	17.16	**13.46**	81.27	88.09	92.09	95.60	**89.26**	1226.9	1252.3	1270.2	1307.3	**1264.2**
Mean	**6.44**	**10.32**	**12.65**	**15.67**		**80.99**	**85.36**	**90.37**	**94.38**		**1214.6**	**1246.6**	**1265.9**	**1293.5**	

	S.Ed±	CD (0.05)	S.Ed±	CD (0.05)	S.Ed±	CD (0.05)
N	0.23	0.47	0.51	1.04	6.22	12.71
K	0.23	0.47	0.51	1.04	6.22	12.71
N×K	0.46	0.94	1.02	2.09	12.45	N.S.

Initial WSK : 7.85 mg kg^{-1} Initial Exchangeable K : 116.48 mg kg^{-1} Initial 1N HNO_3 K : 1223.04 mg kg^{-1}

Table 4.22. Effect of levels of nitrogen, potassium and their interactions on nitrogen fractions in soil (mg kg^{-1}) at harvest.

Levels	NH_4^+-N					NO_3-N				
	K_0	K_1	K_2	K_3	**Mean**	K_0	K_1	K_2	K_3	**Mean**
N_0	30.26	32.30	33.42	35.64	**32.90**	15.51	17.43	18.18	19.39	**17.63**
N_1	48.76	50.21	52.71	52.48	**51.04**	26.24	28.46	29.22	27.88	**27.95**
N_2	57.23	56.53	58.21	58.83	**57.70**	38.41	40.17	39.54	40.84	**39.74**
N_3	70.15	71.56	72.80	73.31	**71.95**	45.35	46.63	48.29	48.63	**47.23**
Mean	**51.60**	**52.65**	**54.28**	**55.06**		**31.38**	**33.17**	**33.81**	**34.19**	

	NH_4^+-N S.Ed±	NH_4^+-N CD (0.05)	NO_3-N S.Ed±	NO_3-N CD (0.05)
N	0.30	0.61	0.19	0.39
K	0.30	0.61	0.19	0.39
N×K	0.59	1.21	0.38	0.78

Initial NH_4^+-N: 37.42 mg kg^{-1}

Initial NO_3-N: 20.31 mg kg^{-1}

Plate 4.1. Over all view of the experimental field

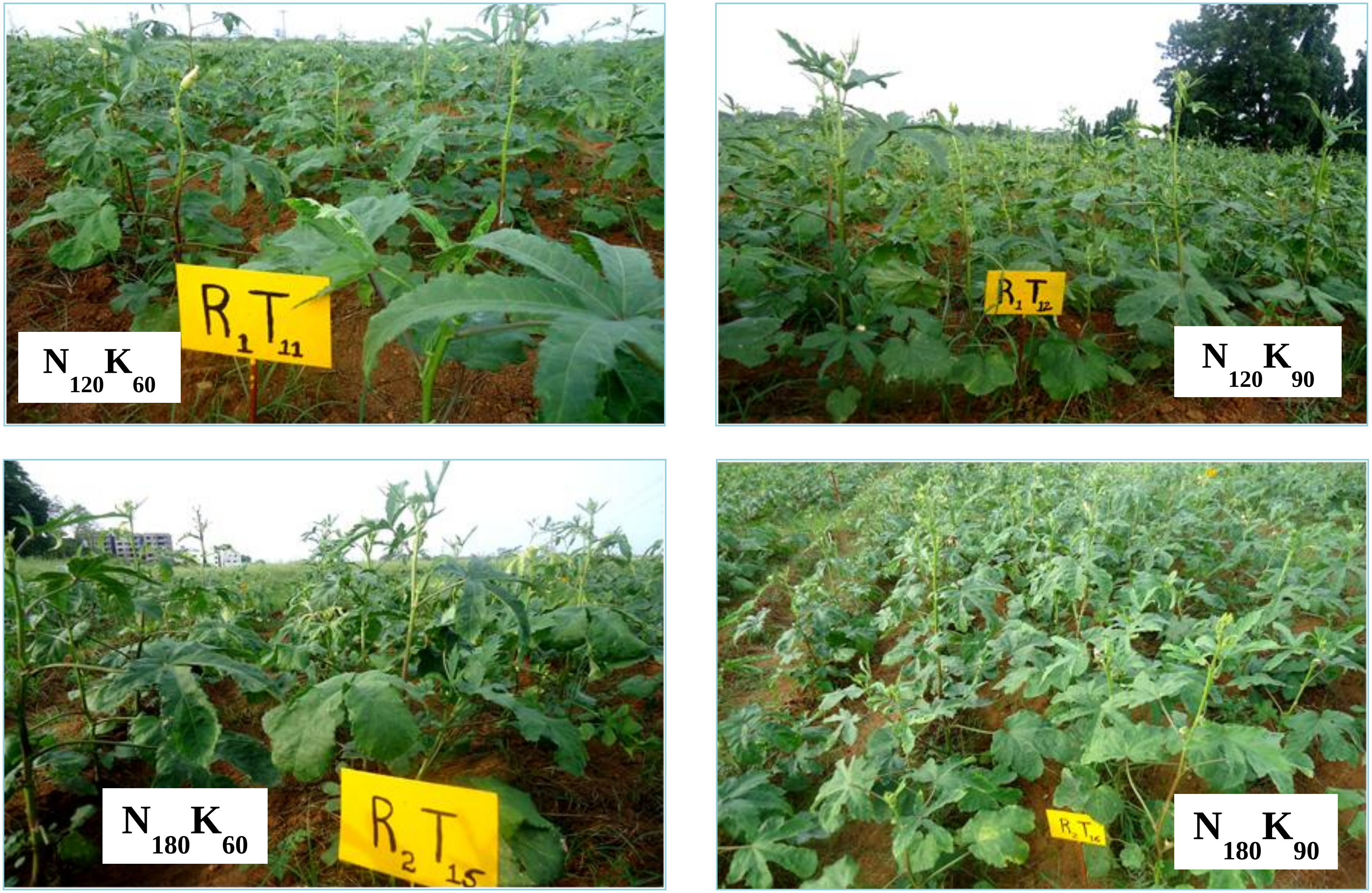


Plate 4.2. Interaction effects of N x K on growth and pod yield of okra

Table 4.16. Effect of levels of nitrogen, potassium and their interactions on pod yield ($q\ ha^{-1}$) of okra

Levels	Pod yield ($q\ ha^{-1}$)				
	K_0	K_1	K_2	K_3	**Mean**
N_0	50.56	57.47	73.37	81.45	**65.71**
N_1	66.26	77.48	86.52	96.16	**81.60**
N_2	80.18	92.68	109.27	112.63	**98.69**
N_3	90.01	101.13	124.83	126.17	**110.53**
Mean	**71.75**	**82.19**	**98.50**	**104.10**	
	S.Ed±		CD (0.05)		
N	1.48		3.02		
K	1.48		3.02		
N×K	2.95		6.03		

Fig 4.4. Effect of levels of nitrogen, potassium and their interactions on pod yield ($q\ ha^{-1}$) of okra

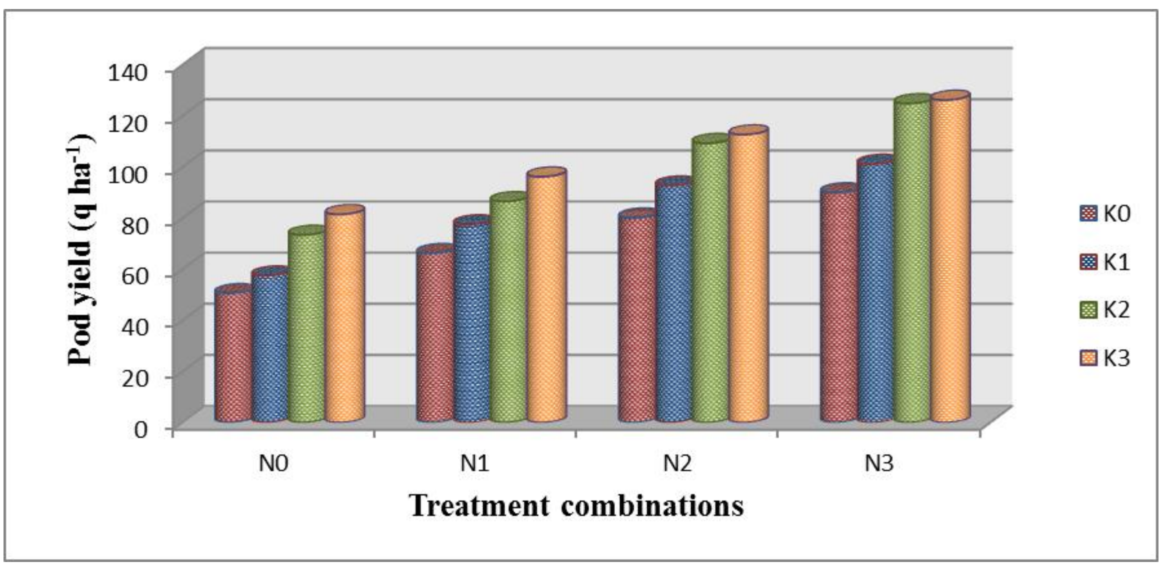


Table 4.3. Effect of levels of nitrogen, potassium and their interactions on total dry matter production (kg ha^{-1}) of okra (plant + pods) at harvest (90 DAS)

Levels	Total dry matter production (kg ha^{-1})				
	K_0	K_1	K_2	K_3	**Mean**
N_0	2322.3	2544.7	2885.6	3241.2	**2748.5**
N_1	2955.2	3453.6	3642.2	4011.7	**3515.7**
N_2	3670.1	4075.8	4306.1	4531.6	**4145.9**
N_3	4514.8	4840.7	5021.5	5152.9	**4882.5**
Mean	**3365.6**	**3728.7**	**3963.9**	**4234.3**	

	S.Ed±	CD (0.05)
N	24.82	50.71
K	24.82	50.71
N×K	49.64	101.41

Fig 4.1. Effect of levels of nitrogen, potassium and their interactions on total dry matter production (kg ha^{-1}) of okra (plant + pods) at harvest (90 DAS)

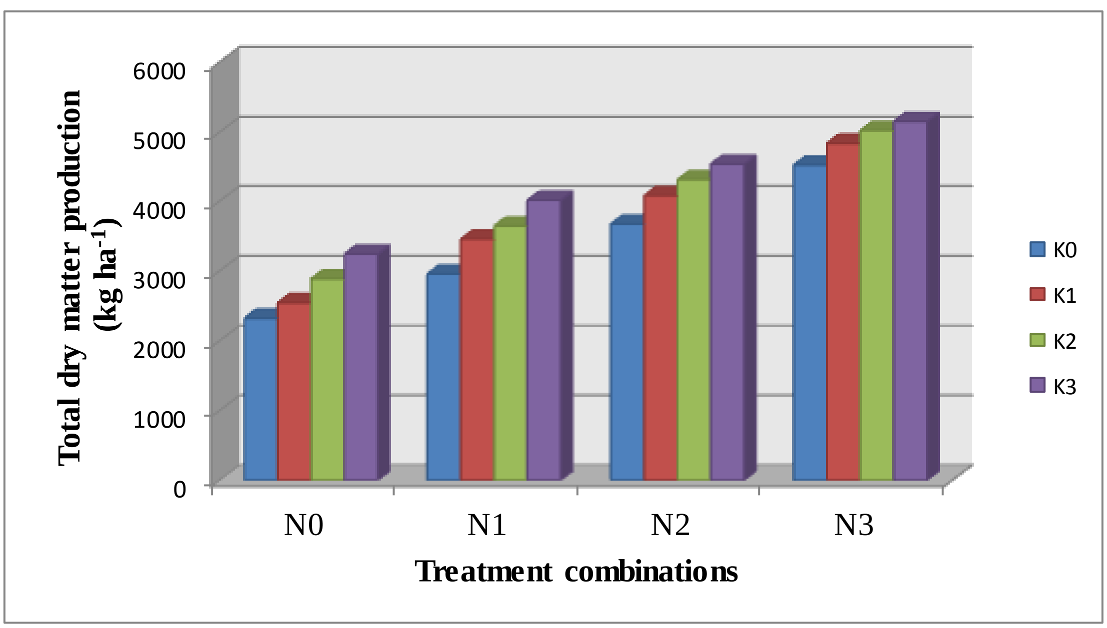


Fig 4.2. Effect of levels of nitrogen, potassium and their interactions on total N uptake ($kg\ ha^{-1}$) by okra (plant + pods) at 90 DAS

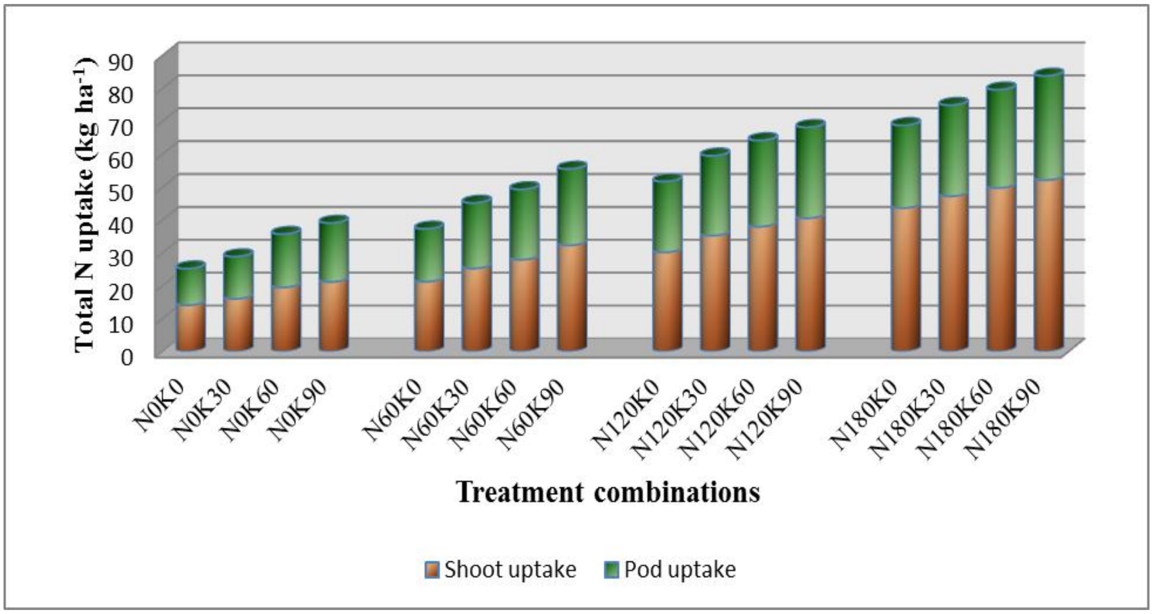


Fig 4.3. Effect of levels of nitrogen, potassium and their interactions on total K uptake ($kg\ ha^{-1}$) by okra (plant + pods) at 90 DAS

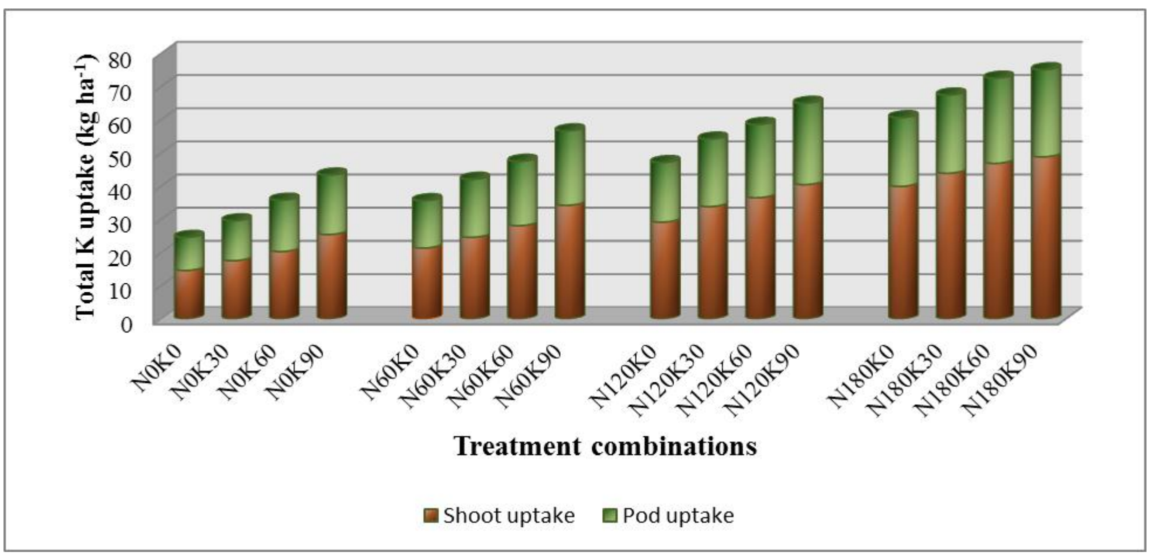
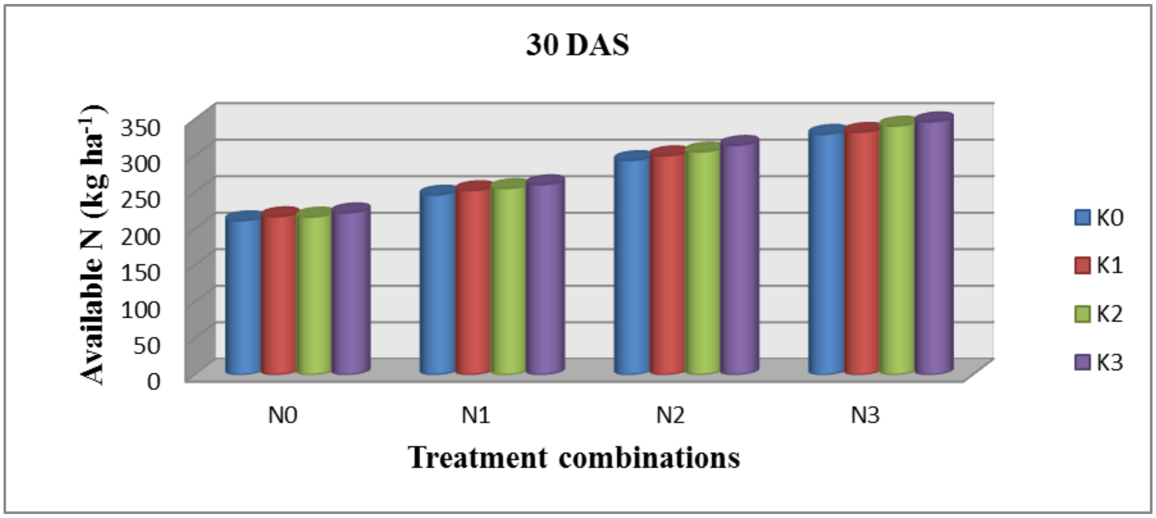
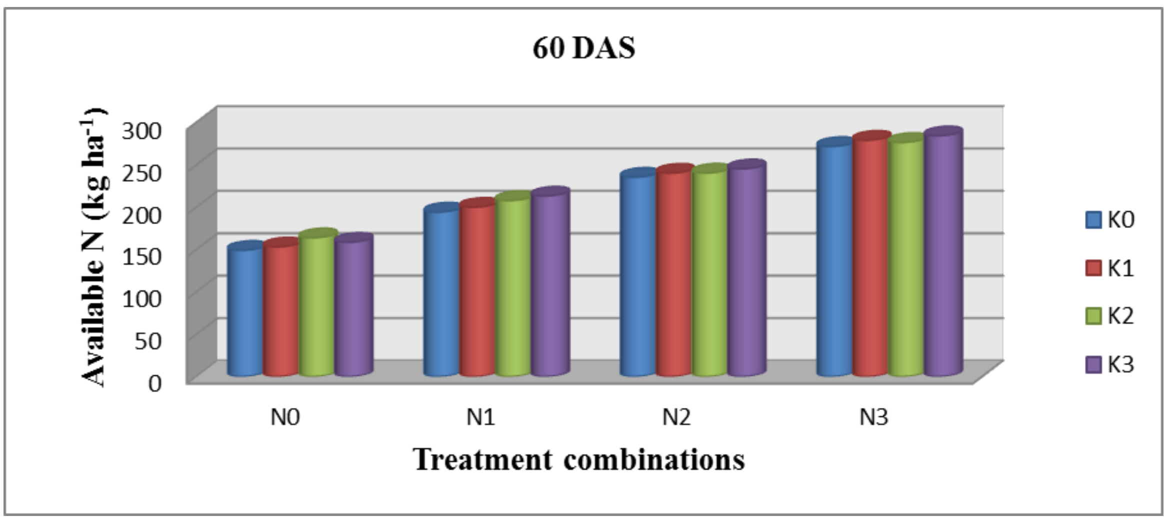


Fig 4.5. Effect of levels of nitrogen, potassium and their interactions on available nitrogen status (kg ha^{-1}) in soil at 30, 60 and 90 DAS





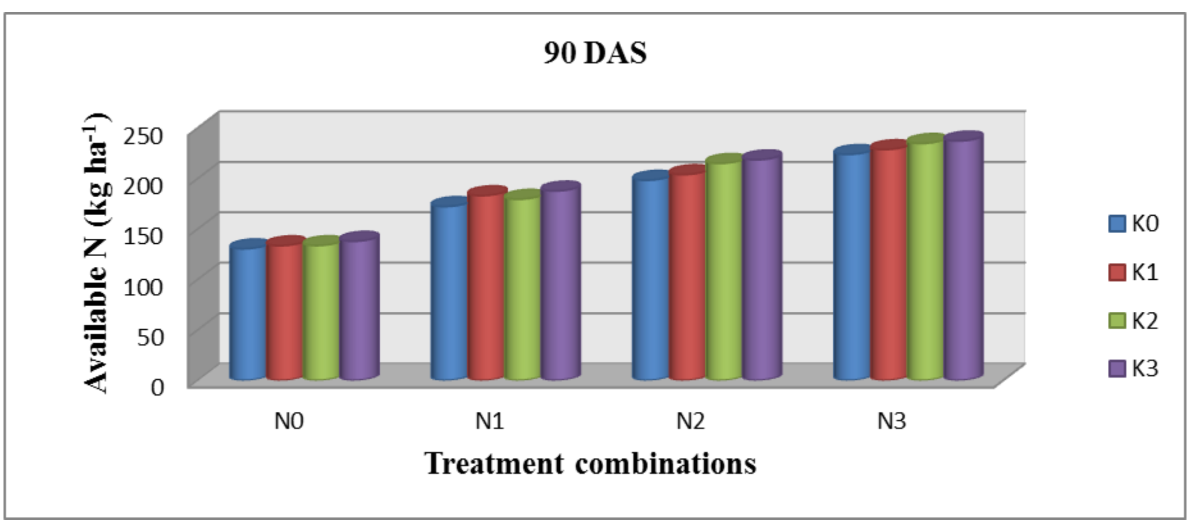
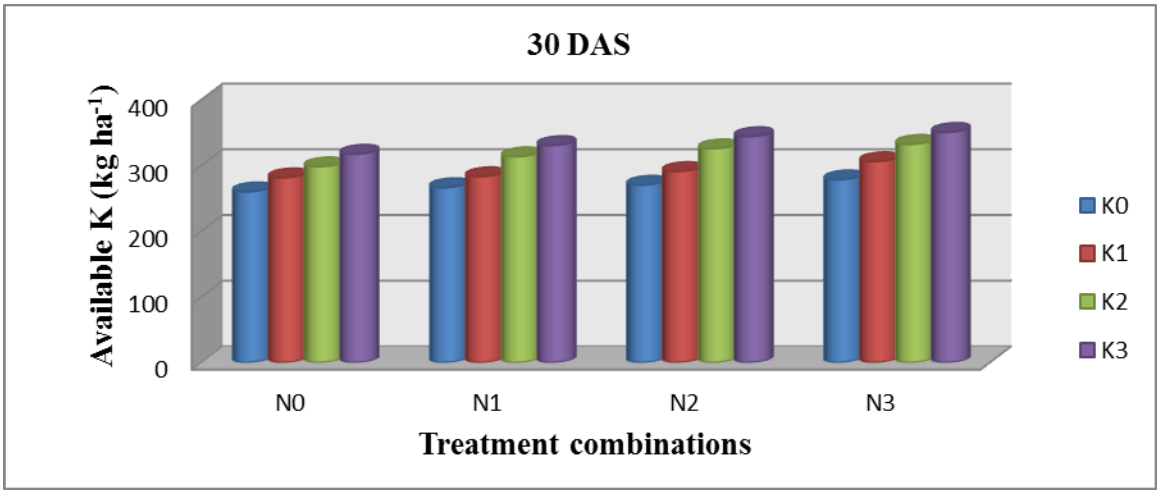
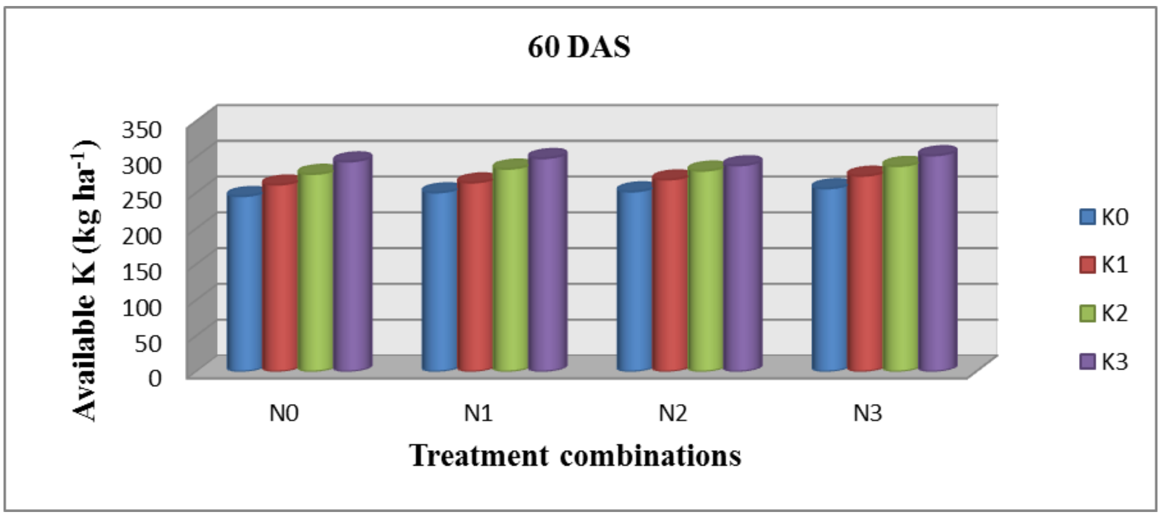
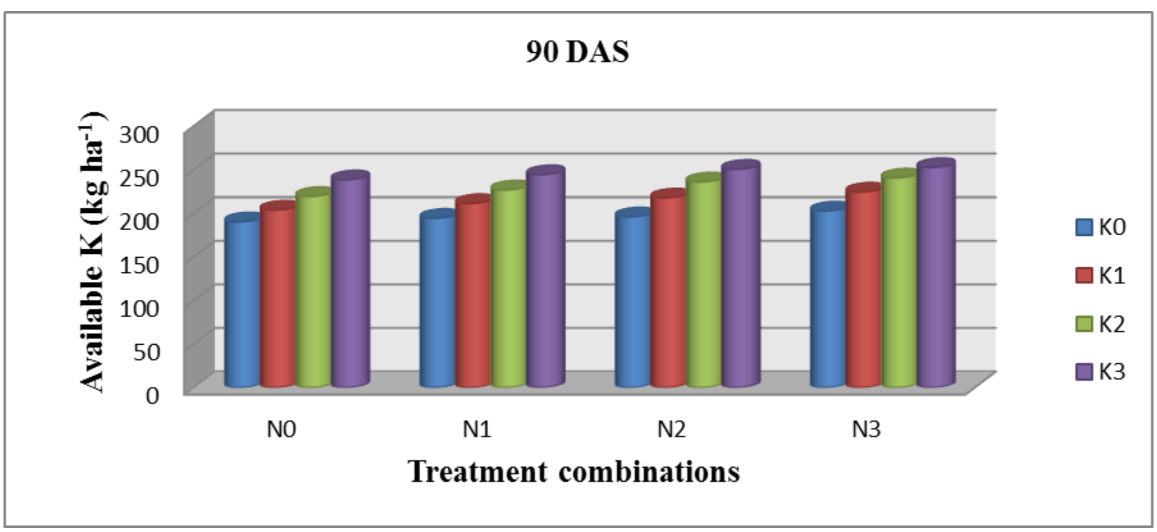


Fig 4.6. Effect of levels of nitrogen, potassium and their interactions on available potassium status (kg ha^{-1}) in soil at 30, 60 and 90 DAS







Chapter V
SUMMARY AND CONCLUSIONS

The field experiment was carried out during *kharif*, 2011 on a sandy loam soil (*Alfisol)* at Student Farm, College of Agriculture, Rajendranagar, Hyderabad to study the "**Interaction effects of nitrogen and potassium on soil fertility, yield, quality and nutrient uptake by okra''.** The experimental soil was slightly alkaline (pH 7.8) in reaction, non saline (0.23 dS m^{-1}), low in organic carbon (0.48 per cent) and available N (226.8 kg ha^{-1}), medium in available P_2O_5 (38.63 kg ha^{-1}) and K_2O (278.5 kg ha^{-1}). The experiment was laid out in randomized block design with factorial concept, having four levels each of nitrogen (0, 60, 120 and 180 kg N ha^{-1}), potassium (0, 30, 60 and 90 kg K_2O ha^{-1}) and replicated thrice. The investigation was under taken with sixteen treatment combinations.

The observations on dry matter production, pod yield, nutrient content, uptake, quality parameters, soil available nutrient status and inorganic N and K fractions were studied. Economics of okra cultivation and NUE with respect to treatments were also calculated.

5.1 Summary

The salient results of the experiment and the conclusions drawn are summarized here under.

Response of okra to different levels of nitrogen, potassium and their interactions revealed that with increase in successive levels of N upto 180 kg ha^{-1} and potassium upto 90 kg ha^{-1} there was significant increase in dry matter production of okra at all the stages of crop growth viz., 30, 60 and 90 DAS. However, the total dry matter production was higher (5152.9 kg ha^{-1}) with combined application of 180 kg N ha^{-1} along with 90 kg K_2O ha^{-1} than with nitrogen and potassium alone.

Similar results were obtained with regard to per cent nutrient content viz., N, P and K and total nutrient uptake by okra. The highest total uptake of N and K by okra at harvest found to be 83.83 and 75.19 kg ha^{-1} at N_3K_3.

The highest yield (126.17 q ha^{-1}) was recorded with combined application of 180 kg N ha^{-1} and 90 kg K_2O ha^{-1} (N_3K_3). However, the pod yield at N_3K_3 was on par with the yield obtained at N_3K_2 (124.83 q ha^{-1}) and were significantly different from all other treatment combinations.

The values pertaining to quality parameters of okra revealed that the increasing levels of nitrogen and potassium not only increased the pod yield but also increased the quality parameters like ascorbic acid and crude protein contents and the values found to vary from 13.68 to 18.87 mg 100 g^{-1} and 14.09 to 19.29 per cent, respectively with combined application of nitrogen and potassium. where as the crude fibre content decreased with increasing levels of nitrogen and increased with increasing levels of potassium.

The soil available nutrients viz., N and K_2O increased significantly with application N of 180 kg ha^{-1} + 90 kg K_2O ha^{-1} (N_3K_3) at 30, 60 and 90 DAS. The values of N and K_2O found to be 346.7 and 350.8 kg ha^{-1} at 30 DAS, 284.4 and 302.2 kg ha^{-1} at 60 DAS and 237.2 and 252.6 kg ha^{-1} at 90 DAS, respectively. However, significant differences were not observed among potassium levels with regard to available P_2O_5 content in soil at all the growth stages of okra.

With regard to changes in available nutrients in soil from initial to harvest (90 DAS), there was build up in N and K upto 30 DAS and later it showed a decrease upto 90 DAS. These results indicate that the crop removed N and K to greater extent to meet its requirement at pod formation and development stage.

The soil samples collected at harvesting stage were also analyzed for inorganic N and K fractions. The interaction effect of N×K revealed that there was significant increase in contents of all forms of N and K at higher levels of N and K fertilization to okra. Compared to initial soil status, all the treatments have resulted in build up of all the forms of N and K except exchangeable K.

The correlation studies revealed the contribution of both the inorganic N fractions and easily available forms of potassium to nutrient uptake, pod yield and other yield attributing characters of crop.

The interaction effects of N and K showed variations in NUE, the highest use efficiency being recorded at N_2K_2 (38) followed by N_2K_3 (27.5), N_3K_2 (26) and N_3K_3

(22.6). Higher levels of N (180 kg ha^{-1}) and K_2O (90 kg ha^{-1}) decreased the nitrogen use efficiency. According to benefit-cost ratio, though the highest value was recorded at N_3K_2 (1.85), it is better to choose N_2K_2 (1.54) combination with high NUE.

5.2 Conclusions

* Okra crop responded to increasing levels of N and K in terms of drymatter production, N and K uptake. However, the yield recorded at N_3K_2 (180: 60 kg ha^{-1}) was on par with the pod yield recorded at N_3K_3 (180: 90 kg ha^{-1}).

* The quality of okra fruits viz., crude protein, ascorbic acid and crude fibre were influenced by different levels of nitrogen and potassium. while the interaction effects of N x K did not show any significant effect on quality parameters.

* Split application of N and K fertilizers helped in meeting the N and K requirements of okra crop at different growth stages which reflected through increase in plant drymatter production, N and K uptake and pod yield.

* The easily available forms of K i.e., water soluble and exchangeable K contributed to K nutrition of crop. Among the N fractions, both NO_3-N and NH_4-N contributed to N nutrition of crop.

* The NUE showed a decrease at higher levels of N and K (180:90 kg ha^{-1}). The NUE was 38 at N_2K_2 followed by N_2K_3 (27.5), N_3K_2 (26) and N_3K_3 (22.6) combinations.

* Keeping in view the B:C ratio and improvement in NUE, application of N @ 120 kg ha^{-1} along with 60 kg ha^{-1} K_2O can be suggested as the optimum combination which minimizes the cost on N and K fertilizers.

5.3 Future line of work

* Detailed studies pertaining to interaction effects of N and K on NUE, Apparent nitrogen recovery, potassium use efficiency by okra and other vegetable crops needs to be carried out further to suggest best combinations of N and K fertilizers in different soil types of Ranga Reddy and Mahaboobnagar districts where vegetables are grown around Hyderabad.

* Nitrogen and potassium dynamics in vegetable growing soils need to be studied for understanding the fixation and release patterns.

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* Originals not seen

Note : The pattern of ‘Literature cited’ presented above is in accordance with the Guidelines for thesis presentation for Acharya N G Ranga Agricultural University, Hyderabad.

ANNEXURE – I

Effect of nitrogen and potassium fertilizers on benefit cost ratio of okra

Treatments	Yield (q ha^{-1})	Gross returns (Rs / ha)	Total cost of cultivation	Net returns (Rs / ha)	Benefit cost ratio
T_1 N_0K_0	50.56	50556.7	38630	11926.67	0.25
T_2 N_0K_1	57.47	57466.7	41024	16442.67	0.40
T_3 N_0K_2	73.37	73373.3	41618	31755.33	0.76
T_4 N_0K_3	81.45	81453.3	42212	39241.33	0.93
T_5 N_1K_0	66.26	66256.7	41163	25093.65	0.61
T_6 N_1K_1	77.48	77483.3	41757	35726.31	0.86
T_7 N_1K_2	86.52	86520.0	42351	44168.98	1.04
T_8 N_1K_3	96.16	96156.7	42945	53211.65	1.24
T_9 N_2K_0	80.18	80183.3	41896	38287.30	0.91
T_{10} N_2K_1	92.67	92666.7	42490	50176.64	1.18
T_{11} N_2K_2	109.27	109266.7	43084	66182.64	1.54
T_{12} N_2K_3	112.63	112633.3	43678	68955.30	1.58
T_{13} N_3K_0	90.01	90006.7	42629.1	47377.54	1.11
T_{14} N_3K_1	101.13	101126.7	43223.1	57903.54	1.34
T_{15} N_3K_2	124.83	124830.0	43817.1	81012.87	1.85
T_{16} N_3K_3	126.17	126173.3	44411.1	81762.20	1.84

Cost of okra pods per kg	=	Rs.10.00	Cost of SSP per 50 kg	=	Rs. 240
Cost of urea per 50 kg	=	Rs. 280.10	Cost of MOP per 50 kg	=	Rs. 594