EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON SOIL PROPERTIES AND PERFORMANCE OF MAIZE *(Zea mays* L.*)*

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CERTIFICATE

Ms. Vaisakhi K. C. has satisfactorily prosecuted the course of research and that thesis entitled **"Effect of integrated nutrient management on soil properties and performance of maize (*Zea mays* 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 her for a degree of any University.

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This is to certify that the thesis entitled **"EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON SOIL PROPERTIES AND PERFORMANCE OF MAIZE (*Zea mays* L.)"** submitted in partial fulfillment of the requirements for the degree of **'Master of Science in Agriculture'** of the Acharya N. G. Ranga Agricultural University, Hyderabad is a record of the bonafide original research work carried out by **Ms. Vaisakhi K. C.** 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 the assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

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I, **Vaisakhi K. C.** hereby declare that the thesis entitled **"EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON SOIL PROPERTIES AND PERFORMANCE OF MAIZE (*Zea mays* 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.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
@	:	At the rate of
a.i.	:	Active ingradient
BCR	:	Benefit cost ratio
^{0}C	:	Degree celsius
CD ($p = 0.05$)	:	Critical difference at 5 per cent probability
cm	:	Centimetre (s)
cmol (p^{+}) kg^{-1}	:	Centimole of positive charge per kilogram of soil
CV	:	Coefficient of variation
Cu	:	Copper
DAS	:	Days after sowing
dS m^{-1}	:	Deci Seimen per metre
DTPA	:	Diethylene triamino penta acetic acid
EC	:	Electrical conductivity
et al.	:	And others
etc.,	:	Etcetera
Fe	:	Iron
Fig.	:	Figure
FYM	:	Farmyard manure
g	:	Gram (s)
g ha^{-1}	:	Gram per hectare
g kg^{-1}	:	Gram per kilogram
ha^{-1}	:	Per hectare
i.e.	:	That is
INM	:	Integrated nutrient management
K	:	Potassium
K_2O	:	Potassium oxide
kg	:	Kilogram
kg ha^{-1}	:	Kilogram per hectare
m	:	Metre
m^2	:	Square metre

Max : Maximum
Mg m^{-3} : Mega gram per metre cube
mg kg^{-1} : Milligram per kilogram
Min : Minimum
mL : Millilitre
MOP : Muriate of potash
μg NH_4^+-Ng^{-1} soil h^{-1} : Microgram of ammoniacal nitrogen released per gram of soil per hour
μg g^{-1} : Microgram per gram
N : Nitrogen
No. : Number
NS : Non - significant
P : Phosphorus
P_2O_5 : Phosphorus penta oxide
pH : Potential of hydrogen ion concentration
PM : Poultry manure
ppm : Parts per million
RBD : Randomized block design
RDFN : Recommended dose of fertilizer nitrogen
RDN : Recommended dose of nitrogen
RH : Relative humidity
Rs : Rupees
SEm ± : Standard error of mean
SSP : Single super phosphate
t ha^{-1} : Tonnes per hectare
T : Treatment
viz., : Namely
Zn : Zinc

ABSTRACT

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A field experiment entitiled “**Effect of integrated nutrient management on soil properties and performance of maize** (*Zea mays* L.) was conducted during *kharif*, 2011 on a sandy loam soil of Agricultural College Farm, Bapatla with a view to study the performance of maize (variety: 30V92) in terms of yield and nutrient uptake, besides the physical, physico- chemical, available nutrient status and urease activity in soil.

The experimental soil was non saline, slightly alkaline in soil reaction with low organic carbon (1.9 g kg^{-1}) and available nitrogen (122 kg ha^{-1}), medium available phosphorus (40.4 kg ha^{-1}) and high available potassium (392 kg ha^{-1}). Except zinc, other micronutrients viz., iron, manganese and copper were well above the critical limit. The experiment was laid out in a randomized block design with ten treatments comprising of sole application of fertilizer nitrogen at 100 and 125 per cent of recommended dose and each level of fertilizer nitrogen was integrated with FYM and poultry manure at 25 and 50 per cent of recommended nitrogen. The treatments were replicated three times. Manures were applied to soil as per the treatments based on their nitrogen content 10 days before sowing of seeds. Nitrogen, phosphorus and potassium were applied through urea, single superphosphate (SSP) and muriate of potash (MOP). Fertilizer nitrogen was applied at 100 and 125 per cent of recommended dose (120 kg ha^{-1}) as per the treatments in three equal splits. Recommended dose of 60 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied uniformly to all the plots. Entire quantity of phosphorus was applied as basal whereas potassium was applied in two equal splits. The crop was harvested at 100 days after sowing. Plant and soil samples collected at tasseling and harvest were analysed.

The results showed that the performance of maize was significantly improved with increase in the level of nitrogen either alone or through integration with FYM and poultry manure. Maximum drymatter production at tasseling, yield components, yield and uptake of macro (N, P and K) and micronutrients (Fe, Zn, Mn and Cu) were obtained in T_{10} which received 125 per cent of recommended dose of nitrogen along with 50 per cent nitrogen through poultry manure. Next best treatment was T_8 which received same level of fertilizer nitrogen along with 50 per cent nitrogen through FYM. However, harvest index and shelling percentage was not significantly influenced by different treatments.

The physical and physico-chemical properties viz., bulk density, pH, EC and CEC were not significantly influenced by different levels of fertilizer nitrogen along with FYM/ poultry manure. Significant variation in organic carbon and available macro and micronutrient status in soil both at tasseling and at harvest was observed between sole application of fertilizer nitrogen and its integration with FYM/ poultry manure at higher level (50%). The highest organic carbon at both stages was observed in T_8 (125% RDFN + 50% N –FYM) while, the highest available N, P_2O_5 and K_2O, Fe, Zn, Mn and Cu were recorded in T_{10} (125%RDFN + 50% N-PM). The urease activity of soils both at tasseling and harvest was significantly influenced by the treatments and higher activity was recorded in treatments which received higher levels of nitrogen through fertilizer and FYM/ poultry manure. Significant positive correlation was observed between soil properties and performance of maize. The maximum gross returns and B:C ratio were obtained in T_{10} (125%RDFN + 50% N-PM) which was closely followed by T_8 (125% RDFN + 50% N –FYM), while the lowest was observed in T_1 (100% RDFN).

From the present study it can be concluded that under sandy loam soils of Bapatla, recommended dose of 120 kg N ha^{-1} (T_1: 100% RDFN) was not sufficient to yield the maximum potential of the variety. Increasing level of recommended dose of nitrogen along with organic manures (FYM/ poultry manure) up to 175 per cent was proved to be highly beneficial in improving performance of maize as well as soil properties.

Chapter I

INTRODUCTION

Globally, maize *(Zea mays* L.) is the third dominant cereal crop next to wheat and rice. It plays a vital role in agricultural economy both as staple food and feed for livestock as well as raw material for industry. In India, it covers an area of 8.25 M ha producing 16.72 M t while in Andhra Pradesh, it occupies an area of 5.28 lakh ha producing 27.6 lakh tonnes (Ministry of Agriculture, Government of India, 2009-2010).

Maize is called “king of cereals” because of its high production potential compared to any other cereal crop. It is a heavy feeder of nutrients hence, its continuous cultivation without proper nutrient management may deplete the soil nutrient reserves. Maize crop which gives grain yield of 10 to 12 t ha^{-1} absorbs 200, 30, 167 and 142 kg ha^{-1} of N, P_2O_5, K_2O and S, respectively (BARC, 2005). The productivity of maize mainly depends on its nutrient management especially nitrogen and its deficiency is one of the main yield limiting factors for maize production (Shah *et al.*, 2003). The existing recommended dose of nitrogen (120 kg N ha^{-1}) for hybrid maize production is low and it responds positively up to 300 kg N ha^{-1} (Khaliq *et al.*, 2009) however, application of increased rates of fertilizer nitrogen alone is not sound strategy for obtaining sustained grain yields.

Under the present trend of exploitive agriculture in India, nutrient supplying capacity of soil declines steadily and it can no longer be maintained on sustainable basis. Continuous and imbalanced use of high analysis N, P and K fertilizers fails to maintain yield levels probably due to increasing secondary and micronutrient deficiencies and also results in unfavourable alterations in the physical and chemical properties of soil.

The environmental impact of chemical fertilizer and its steadily rising price necessitates farmers to seek viable alternatives. Effective and prudent use of organic manures along with inorganic fertilizers can substantially improve crop productivity and also sustain soil health. Among the various organic sources, the by-products obtained from animal husbandry viz., farmyard manure, sheep manure, poultry manure may be used as source of plant nutrients as they are cheap, locally available and nutrient rich. Addition of well decomposed FYM not only supplies plant nutrients but also acts as binding material and improves the soil physical properties. Poultry manure has been adjudged to be the most valuable of all bulky organic manures produced and is relatively a cheap source of both macro and micronutrients and can increase soil carbon, soil porosity and microbial activity.

However, the application of organic matter alone to soil is not a complete substitute for inorganic fertilizer and vice-versa and their roles are complementary to each other. Therefore, the combined use of chemical fertilizers and organic manures seems to be the better way to replenish the soil nutrients and sustain crop productivity.

Hence, research efforts are required to find out the optimum combination of locally available materials such as farmyard manure and poultry manure with fertilizer nitrogen to satisfy the overall nutrient requirement of maize crop without impairing soil health. Keeping these points in view, the present study was carried out on nitrogen management involving FYM and poultry manure with different levels of fertilizer nitrogen in maize at Agricultural College Farm, Bapatla, during *kharif*, 2011 with the following objectives.

To study the effect of integrated use of organic and inorganic sources of nitrogen on

i. Yield and nutrient uptake of maize
ii. Available nutrient status of soil and
iii. Enzyme (urease) activity in soil

Chapter II

REVIEW OF LITERATURE

Integrated nutrient management (INM) aims at maintenance or adjustment of soil fertility for sustaining the desired crop productivity through optimization of benefits from all possible sources of plant nutrients in an integrated manner (Roy and Ange, 1991). The components of INM involved in the present study were soil, inorganic fertilizer and organic manures. The research done in India and elsewhere in recent years on individual and combined effect of components of INM on performance of maize and related crops and on soil properties is reviewed in this chapter under the following heads

2.1 Inherent soil fertility

2.2 Inorganic Fertilizers

2.3 Organic Manures viz., FYM and Poultry Manure

2.4 Integrated Nutrient Management

2.1 INHERENT SOIL FERTILITY

Soils vary largely with respect to their natural fertility and productivity resulting in no plant growth to abundant luxuriant growth of vegetation. Soil fertility is a complex quality of soils that is closest to plant nutrient management. It is one of the important component of soil productivity that deals with available nutrient status, and its ability to provide nutrients out of its own reserves and also through external applications for crop production. It is a manageable soil property and its management is of utmost importance for optimizing crop nutrition on both short-term and long-term basis to achieve sustainable crop production.

2.1.1 Effect of Inherent Soil Fertility on Performance of Crops

Yield components and yield

Onasanya *et al.* (2009) reported that without application of any fertilizer (control) to maize crop gave a grain yield of 3.08 t ha^{-1} which was significantly lower than all treatments which received different levels of N and P in sandy clay loam soils. Yield components like no. of grains per cob, weight of grain per cob and weight of grain per plot were also significantly lower than other treatments. Tetarwal *et al.* (2011) reported that lowest drymatter production at harvest, 1000 grain weight and grain yield was obtained in absolute control as compared to recommended dose of fertilizer alone and in combination with FYM @ 10 t ha^{-1}.

Brar *et al.* (2001) conducted an experiment on soils with four levels of fertility and reported that maize crop responded significantly to residual fertility .The grain and stover yields of maize was increased from 1.9 to 3.5 and 6.6 to 10.7 t ha^{-1} with the increase in fertility level of soil with respect to nitrogen from lowest (63 to 188 kg ha^{-1}) to highest (100 to 251 kg ha^{-1}). On the contrary, Masood *et al.* (2011), in phosphorus deficient soils of Pakistan observed a grain yield of 1305 kg ha^{-1} in control plot, which was on par with plot which received 50 kg P_2O_5 ha^{-1}. There was no significant difference in thousand grain weight and biological yield of control plot with that of plots fertilized with different levels (50, 100, 150 and 200 kg ha^{-1}) of phosphorus application. Shilpashree *et al.* (2012) recorded the grain and stover yields of 2.2 and 3.3 t ha^{-1}, (62.2 and 58.2 per cent lower than RDF ,respectively) in a Typic Haplustalf of sandy loam texture without supplying any nutrient to soil.

Nutrient uptake

Kamalakumari and Singaram (1996) observed a nutrient uptake of 37.6, 7.2 and 48.6 kg ha^{-1} of N, P and K in maize crop without any fertilizer application in sandy loam soils of Tamil Nadu.

In an experiment with four levels of soil fertility, Brar *et al.* (2001) reported that nutrient uptake (N, P and K) increased significantly with the rise in soil fertility status.

Setia and Sharma (2007) reported that inherent soil fertility of sandy loam soils of Ludhiana recorded phosphorus uptake of 1.40 and 1.33 kg ha^{-1} by wheat grain and straw, respectively which was very low as compared to N, P_2O_5 and K_2O @ 180:35:33 kg ha^{-1} (10.4 and 13.0 kg ha^{-1}, respectively).

2.1.2 Effect of Inherent Soil Fertility on Soil Properties

Physical properties

Selvi *et al*. (2005) reported that total porosity, hydraulic conductivity and water holding capacity of soil decreased in absolute control plots of long term fertilizer experiment under finger millet-maize- cowpea rotation in a Vertic Haplustept, whereas, bulk density increased. Similarly, Thakur *et al.* (2011) recorded decrease in bulk density (1.25 Mg m^{-3}) and increase in hydraulic conductivity (1.11 cm hr^{-1}) when FYM was applied @ 15 t ha^{-1} to soybean-wheat cropping system compared to non application of any amendment (1.30 Mg m^{-3} and 0.96 cm hr^{-1}, respectively).

Physico-chemical properties

Kamalakumari and Singaram (1996) reported that organic carbon in control plots ($N_0P_0K_0$) was lower than that of plots which received different levels of inorganic fertilizers after harvest of maize crop in a Typic Ustropept of clay loam soils of Tamil Nadu.

Varalakshmi *et al.* (2005) reported increase in organic carbon content of sandy clay loam soil from 8.1 g kg^{-1} to 8.5 g kg^{-1} after finger millet crop without addition of any fertilizers which was comparatively lower than integrated application of 50 per cent nitrogen through fertilizer and 50 per cent through FYM (9.2 g kg^{-1}).

Mishra *et al.* (2008) reported that no change was observed in organic carbon and pH of the soil after continuous cropping under maize-wheat cropping system without applying any fertilizer in an Alfisols of Ranchi. Adeniyan *et al.* (2011) reported that initial soil reaction, organic carbon (%) and CEC (cmol kg^{-1} of soil) of sandy loam soils were 6.2, 0.67 and 3.15, respectively which were reduced after maize crop where no amendments were applied to the crop (5.53, 0.49 and 1.13, respectively).

Chemical properties

Kamalakumari and Singaram (1996) reported that available N and P in control plot reduced to 157 and 5.7 kg ha^{-1} as compared to 100 per cent N, P and K (169 and 16.8 kg ha^{-1} respectively).

In a two year study under maize-mustard cropping sequence, Mahala *et al.* (2006) reported that the available nutrient status of soil after first year of crop did not reduce significantly in absolute control plot which gave maize yield comparable to that of fertilized plots in clay loam soils of Udaipur. But there was significant reduction in available N and P (16.5 and 30.4 %, respectively) after second year as compared to initial available nutrient status. Similarly, Begum *et al.* (2007) reported that under wheat-mungbean- maize cropping system in sandy clay loam soils, the available nitrogen and phosphorus content of the initial soil (82.4 and 10.4 mg g^{-1}) were decreased in control plot (80.3 and 4.9 mg g^{-1}) , where no fertilizer was applied. In a long term trial conducted in clay loam soils of Udaipur, Verma *et al.* (2005) observed that when no fertilizer was added, available phosphorus increased to 19.12 kg ha^{-1} after wheat crop as compared to initial soil status (18.2 kg ha^{-1}) available K, S and DTPA Zn decreased (596 kg ha $^{-1}$, 13.10 and 1.94 mg ha^{-1}, respectively) as compared to initial (615 kg ha $^{-1}$, 15.84 and 2.60 mg ha^{-1}, respectively).

Mwangi *et al.* (2010) reported that continuous cropping for one year without fertilizer application non significantly increased the pH and sodium, potassium, calcium and manganese contents of sandy loam soils of Kenya under maize crop.

Thakur *et al.* (2011) reported that continuous cropping under soybean-wheat cropping system without application of any amendments reduced the available sulphur and zinc content in soil (12.5 kg ha^{-1} and 0.30 mg kg^{-1}, respectively) as compared to integrated application of 100% N, P_2O_5 and K_2O and FYM @ 15 t ha^{-1} (44.1 kg ha^{-1} and 0.84 mg kg^{-1}, respectively) in black soils of Jabalpur.

Biological properties

Krishnakumar *et al.* (2005) reported that the urease activity (0.25 µg of NH_4^+ g^{-1} soil h^{-1}), dehydrogenase (1.8 g of TPF g^{-1} of soil h^{-1}) and phosphatase (3.5 g of p-nitrophenol g^{-1} h^{-1}) activities in unfertilized plots were on a par with that of recommended dose of N, P and K @ 90: 40: 40 kg ha^{-1} (0.26, 2.3 and 3.9, respectively).

In a long term fertilizer experiment in Alfisols of Ranchi, Mishra *et al.* (2008) reported that CO_2 evolution and soil microbial biomass carbon was higher in unfertilized plots compared to 100 per cent nitrogen applied plots under continuous maize-wheat crop rotations.

Rai and Yadav (2011) conducted an incubation study in sandy loam soil and reported that urease activity of soil increased from 213 to 244 µg of urea hydrolyzed g^{-1} soil h^{-1} at 120 days after incubation without adding any amendments.

2.2 INORGANIC FERTLIZERS

2.2.1 Effect of Inorganic Fertilizers on Performance of Crops

Yield components and yield

Reddy *et al.* (1987) found that application of N, P and K to maize @ 120:26.4: 33.6 kg ha^{-1}, respectively recorded significantly higher 1000 grain weight, grain yield and harvest index over 60 : 32 : 16.2 kg N, P_2O_5 and K_2O ha^{-1}, respectively and control. Mishra *et al.* (1994) stated that increasing levels of nitrogen from 100 to 200 kg ha^{-1} resulted in significant increase in yield parameters viz., number of rows per cob, 1000 grain weight and yield of maize.

Yogananda *et al.* (1999) observed higher drymatter accumulation per plant, 1000 grain weight and yield per plant (423, 152 and 36 g, respectively) with application of 100 kg P_2O_5 ha^{-1} as compared to no P_2O_5 (366, 136 and 29 g, respectively) and 50 kg P_2O_5 ha^{-1} (411, 150 and 35 g, respectively). Onasanya *et al.* (2009) reported that the treatment with 120 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1} produced significantly higher 1000-grain weight in maize than rest of the treatments.

Masood *et al.* (2011) indicated that application of 100 kg P_2O_5 ha^{-1} through fertilizers increased the number of cobs per plant, number of grains per cob, thousand grain weight and grain yield of maize as compared to 50 kg P_2O_5 ha^{-1} and control. Further increase of P_2O_5 (150 and 200 kg ha^{-1}) caused decrease in all these parameters. Mishra (1993) reported that application of 100:60:40 kg N: P_2O_5: K_2O ha^{-1}, respectively gave highest grain yield, which was significantly higher than other fertilizer levels. Application of 100:60:40, 75:40:30 and 50:30:20 N, P_2O_5 and K_2O kg ha^{-1}, respectively resulted in increase in grain yield of maize by 101, 79 and 37 per cent, respectively over control.

The highest maize yield (5.99 t ha^{-1}) was recorded when supplied with all micronutrients (B, Zn, S, Mn and Mo) in combination with N, P and K fertilizers @ 120:60 40 kg ha^{-1}, respectively which produced almost 171 per cent higher grain yield over absolute control in acidic soils of Chitwan (Adhikary *et al.*, 2010).

Lingaraju *et al.* (2010) detailed that application of 100 per cent N, P and K recorded 13.0 and 5.4 per cent higher maize equivalent yield over 50 and 75 per cent N, P and K, respectively in maize – bengal gram cropping system. Amanullah *et al.* (2011) reported that application of 200:100:100 kg N: P_2O_5: K_2O ha^{-1} gave the highest drymatter production at 30, 60 and 90 DAS (1265, 7528 and 17337 kg ha^{-1}, respectively) of maize crop. On the basis of experimental results for two years, Waseem *et al.* (2011) concluded that hybrid maize produced better grain yield and enhanced physiological traits, when nitrogen was applied through urea @ 250 kg N ha^{-1} as compared to other sources of nitrogen like poultry manure, farm yard manure and press mud of sugarcane compost.

Nutrient uptake

Nanjundappa *et al.* (1994) observed that the uptake of potassium by fodder maize increased by applied nitrogen up to 225 kg ha^{-1}. Significantly higher uptake of N, P and K and readily available N in soil were recorded when 200 per cent RDN was applied to maize crop and it was on par with 150 per cent RDN (Harikrishna *et al.*, 2005).

Prasannakumar *et al*. (2007) reported that among inorganic fertilizer levels, application of 100 per cent RDF recorded significantly higher nitrogen, phosphorus and potassium uptakes (163.92, 51.85 and 63.74 kg ha^{-1}, respectively) when compared to 50 per cent RDF (127.33, 36.06 and 46.66 kg ha^{-1}, respectively) and it was on par with 75 per cent RDF (153.55, 48.94 and 59.59 kg ha^{-1}, respectively). Setia and Sharma (2007) reported that phosphorus uptake by grain (10.4 kg ha^{-1}) and stover (13.0 kg ha^{-1}) in maize was highest when N, P and K were applied @ 180:35:33 kg ha^{-1} as compared to lower doses of fertilizers.

Ramesh *et al*. (2008) reported that chemical fertilizer treatment recorded significantly the highest total nitrogen and potassium uptake (332.2 and 343.6 kg ha^{-1}) which was on par with poultry manure application (294.1 and 319.7 kg ha^{-1}, respectively) in maize- linseed cropping system.

2.2.2 Effect of Inorganic Fertilizers on Soil Properties

Physical properties

Prasad *et al* (1983) observed a rise in bulk density of soil from 1.34 g cm^{-3} to 1.5 g cm^{-3} with increasing doses of chemical fertilizer from 50 to 150 per cent of the recommended dose of N, P and K in soils under continuous cropping. Chawla and Chabra (1991) observed that water stable aggregates in surface of sodic soils increased with increase in the level of P application. Stability of aggregates decreased with depth in all the treatments. The decrease in water stable aggregates with depth was more rapid in the treatment where K was also applied to both the crops.

Selvi *et al.* (2005) reported that hydraulic conductivity, porosity and aggregate stability increased when level of fertilizer was increased from 50 to 150 per cent of RDF. Bulk density and water holding capacity did not change significantly due to increase in N, P and K levels, however there was a marginal improvement over control.

Physico - chemical properties

Continuous application of N, P and K fertilizers lowered the pH by 1.0 to 1.2 units while, the pH of unfertilized plot rose from 7.7 to 7.8 after twelve years of cropping (Kumar and Yadav, 1993).

Jayaprakash *et al.* (2004) reported that, application of 200 per cent RDF recorded significantly higher organic carbon content in soil as compared to control. Pathak *et al.* (2005) documented that application of 50 kg ha^{-1} of urea to each crop in maize- wheat cropping system showed an increase in soil acidity from pH 6.5 to pH 5.79. Application of N, P and K fertilizer in acid soil and nutrient depleted soil resulted change in pH from 5.1 to 5.3 and from 6.2 to 5.8 respectively (Adeniyan *et al.*, 2011).

Chemical properties

Intnawech *et al.* (1982) observed that significant accumulation of manganese and decrease in zinc content in nitrogen fertilized plots as compared to control. The total nitrogen content in the soil increased with increase in nitrogen levels. The total phosphorus status went down where nitrogen alone was applied and there was a buildup of phosphorus in the soil with its application (Brar and Bhajansingh, 1984). Yaduvanshi (2001) reported that after the harvest of ten crops of rice-wheat cropping system, available K significantly declined under N alone and NP treatments over absolute control. The available K content of soil showed increased with continuous application of fertilizer K and organic manures over its initial level. Thus a decrease in available K content of the soil was observed under N and NP treatments from initial value of 220 to 199 kg ha^{-1}.

In maize – mustard cropping sequence, application of 80 kg P_2O_5 ha^{-1} to maize crop increased the available N and P in the soil to 259 kg ha^{-1} and 22.4 kg ha^{-1}, respectively as compared to that of absolute control which recorded 228 and 12.6 kg ha^{-1} of available N and P, respectively at the end of the cropping sequence (Mahala *et al.*, 2006).

Begum *et al.* (2007) reported that the treatments which provided higher amounts of fertilizer nitrogen @ 60, 90 and 120 kg N ha^{-1} registered higher contents of ammoniacal, nitrate and alkaline $KMnO_4$ oxidisable (available) N in the soil. Similarly higher doses of fertilizer- P @ 30, 45 and 60 kg P_2O_5 ha^{-1} resulted in higher values of available P and total inorganic P. Singh *et al*. (2010) reported that the use of phosphorus fertilizer in combination with N and K raised the soil P content in all the fractions such as saloid P, Al-P, Fe-P, Ca-P and total P in soil. The increase was more at higher rates of P addition along with higher doses of N and K compared to differential combinations of N, P and K.

Biological properties

Application of recommended dose of nitrogen (120 kg ha^{-1}) through urea shown higher urease activity (237 μg of urea hydrolysed g^{-1} soil h^{-1}) as compared to sole organic treatments where recommended nitrogen was supplied through FYM, carpet waste, pressmud, digested sludge and poultry manure (232, 234, 232, 231 and 234 μg of urea hydrolysed g^{-1} soil h^{-1}, respectively) in sandy loam soil (Rai and Yadav, 2011).

Soil basal respiration rate in the chemical fertilizer treatment was significantly lower (54 mg CO_2 g^{-1} soil day^{-1}) than that in the livestock manure treatments (138 mg CO_2 g^{-1} soil day^{-1}). Compared to chemical fertilizer treatment, the livestock manure application significantly increased the value of soil microbial quotients (Li *et al.*, 2011)

Mohammadi (2011) reported that application of inorganic fertilizer (100 and 250 kg of SSP and urea ha^{-1}) to wheat crop significantly increased the microbial biomass carbon, alkaline phosphatase activity and protease activity in soil as compared to absolute control.

2.3 ORGANIC MANURES

2.3.1 FYM

Farmyard manure acts directly in increasing crop yields either by acceleration of respiratory process by cell permeability or by hormonal growth action. It supplies essential nutrients in available forms to the plants through biological decomposition. Indirectly, it improves physical properties of soil such as aggregation, aeration, permeability and water holding capacity etc.

2.3.1.1 Effect of farmyard manure on performance of crops

Yield components and yield

Srinivasan (1992) recorded increased yield components, grain and stover yields of maize due to application of FYM @ 10 t ha^{-1}. There was a 32 per cent yield increase over control.

In Haryana, on a silt loam soil under rainfed conditions, FYM application increased the number of grains per cob and grain yield of maize (Khanday *et al.*, 1993). At Palampur, Minhas and Sood (1994) reported similar results in potato and maize with the application of FYM @ 20 t ha^{-1} and in maize by Gajri *et al.* (1994).

Negassa *et al.* (2001) reported that the application of FYM alone to maize crop at the rates of 4, 8 and 12 t ha^{-1} produced average grain yields of 5.76, 5.61 and 5.93 t ha^{-1}, respectively as compared to 3.53 t ha^{-1} for the control treatment. Application of FYM @ 15 t ha^{-1} increased the grain and straw yield of maize and wheat crops in maize – wheat cropping system (Parmar and Sharma, 2001) and Vadivel *et al.* (2001) revealed that application of enriched FYM @ 750 kg ha^{-1} increased the grain and stover yields of maize. Mahala *et al.* (2006) reported that application FYM @10 t ha^{-1} had a significant positive effect on the grain and stover yields of maize with an increase of 11.86 and 9.82 per cent over the control, respectively.

Pooled data of two years revealed that among organics, application of FYM @ 7.5 t ha^{-1} recorded significantly higher maize (5899 kg ha^{-1}), bengalgram (1566 kg ha^{-1}) and maize equivalent yield (11650 kg ha^{-1}) and it was on par with vermicompost @ 2.5 t ha^{-1}. (Lingaraju *et al.*, 2010). Long term field experiment conducted by Mwangi *et al.* (2010) recorded highest maize yield of 5.4 t ha $^{-1}$ through continuous application of FYM @ 10 t ha^{-1}, while the recommended rate of inorganic fertilizer attained 4.3 t ha $^{-1}$. Islami *et al.* (2011) recorded highest yields of 4.06 and 4.56 t ha^{-1} in maize + cassava intercropping and monoculture of maize, respectively with FYM.

Nutrient uptake

Brar *et al.* (2001) found that nutrient uptake increased significantly with the application of FYM up to 20 t ha^{-1} in maize crop. This was corroborated with the findings of Parmar and Sharma (2001) who observed that, the uptake of N by maize crop increased with increasing levels of FYM application from 10 to 20 t ha^{-1}. Similarly in maize wheat cropping system Thind *et al.* (2002) observed that the residual effect of organic manures on uptake of N, P and K by succeeding wheat was more in FYM plots followed by dhaincha, moong, guar and cowpea plots.

Devarajan *et al.* (1980) reported that application of piggery manure with FYM significantly increased the Zn and Fe uptake by sorghum. This was attributed to the micronutrient content in the organic manure and also the effect of organic acids produced during decomposition of organic manures. The uptake of K, Ca, Mg and Fe by maize shoot was increased conspicuously over control due to addition of farmyard manure. Similarly K, Ca, Mg and Fe contents were significantly increased in grain and stover of maize (Madhumitadas *et al.*, 1992).

Walia and Kler (2010) reported that N, P and K uptakes (106, 44 and 94 kg ha^{-1}, respectively) in maize were significantly higher when 20 t ha^{-1} of FYM was applied as compared to only recommended dose of fertilizers @ 120: 60: 30 kg N, P_2O_5 and K_2O ha^{-1} (80, 32 and 61 kg ha^{-1}, respectively) in maize-wheat cropping sequence. Similarly uptakes of Fe, Cu, Zn and Mn were higher in FYM treatment (620, 129, 279 and 234 g ha^{-1}, respectively) as compared to RDF (450, 96, 212 and 178 g ha^{-1}, respectively).

2.3.1.2 Effect of farm yard manure on soil properties

Physical properties

Bhagat and Acharya (1989) reported an increase in organic matter content of soil which resulted in improved soil aggregation, water holding capacity and infiltration rate of soil due FYM application for three years.

Lavti (1990) observed the higher percentage of water holding capacity in Alfisols of Udaipur under rainfed condition due to incorporation of organic materials like farmyard manure, rice straw, groundnut shell and wheat straw over control. More (1994) observed reduced bulk density and increased infiltration rate in sodic Vertisols due to application of biogas slurry @ 10 t ha^{-1} or FYM @ 20 t ha^{-1}. Sheeba and Chellamuthu (2002) reported a there was significant improvement in the soil properties by continuous use of FYM @ 10 t ha^{-1} over twenty two years. They reported that significant increase in aggregate stability (68.49 %), per cent water stable aggregates (78.22) and total porosity (55.73%) with application of FYM @ 10 t ha^{-1} as compared to application 100 per cent N, P_2O_5 and K_2O through inorganic fertilizers i.e. 64.30, 75.70 and 51.03 per cent, respectively. They also noticed decrease in bulk density with the application of FYM @ 10 t ha^{-1}.

Application of FYM significantly decreased the bulk density and increased hydraulic conductivity of soil as compared to the treatment with recommended levels of N, P and K (control). It was observed that the bulk density values were in the order of 1.47, 1.39 and 1.24 Mg m^{-3} whereas, saturated hydraulic conductivity values were 3. 13, 4.49 and 5.38 $\times 10^{-4}$ cm s^{-1} in treatments which received recommended N, P_2O_5 and K_2O, FYM @ 20 and 40 Mg ha^{-1}, respectively (Khan *et al.*, 2010).

Physico- chemical properties

Bellakki and Badanur (1997) recorded significant increase in organic carbon content of surface and subsurface soils with incorporation of FYM or sunhemp to soil. The soil pH in the treatment receiving recommended dose of inorganic fertilizer was 7.24, which was decreased to 7.08 and 7.04 due to the addition of FYM and vermicompost, respectively (Srikanth *et al.*, 2000).

Kumpawat (2004) reported that pH and EC of the soils were declined after 15 years of continuous cropping. Maximum reduction was recorded in treatments receiving 100 per cent recommended dose of N through FYM compared to treatments involving N and P fertilizers alone and their combination with crop residues. Varalakshmi *et al.* (2005) reported that application of 100 per cent nitrogen through FYM increased the organic matter content of soil from 8.1 g kg^{-1} to 8.8 g kg^{-1} under groundnut- fingermillet cropping system in Alfisols.

Chemical properties

Addition of FYM reduced the loss of nitrates through leaching from the soil under maize by providing a significant amount of plant nutrients, which created a balancing effect on the supply of nitrogen, phosphorus and potassium (Singh *et al.*, 1979).

Ibraginov (1990) reported that in sandy soil N, P and K uptake increased as fertilizer rate increased resulting in progressive depletion of soil potassium reserves. Farmyard manure application enhanced the nutrient uptake at the highest N, P and K rates but reduced the depletion of soil potassium reserves. Shinde and Gowade (1992) observed an increase in the available K content of the soil from 235 to 258 kg ha^{-1} due to application of FYM @ 15 t ha^{-1}.

Mathur (1997) reported that application of FYM increased available Zn and Mn status of soil and it was attributed to mineralization of FYM and consequent release of micronutrients. Swarup and Yaduvanshi (2000) reported that soil organic carbon, available Zn and Mn were significantly lower in treatments receiving inorganic fertilizers as compared to the treatments involving organics. The N, P and K contents of soil also increased with continuous application of FYM for three years. Kumpawat (2004) reported that amount of available phosphorus increased (40 kg ha^{-1}) over initial value (37 kg ha^{-1}) when FYM and crop residues were incorporated. The organic carbon status was declined in the absolute control, while there was build up in plots incorporated with organics. Mahala *et al.* (2006) reported that application of FYM @ 10 t ha^{-1} improved the available N by 6.2 and 7.9 per cent and available P by 11.9 and 13.4 per cent compared to no application during 2001-02 and 2002-03, respectively.

The application of FYM @ 10 t ha $^{-1}$ to maize showed increase in soil available N, P_2O_5 and K_2O (208, 26 and 118 kg ha^{-1}, respectively) as compared to 100 per cent RDN through inorganics where the contents of N, P_2O_5 and K_2O were 200, 25 and 115 kg ha^{-1}, respectively (Jamwal, 2006).

Khan *et al.* (2010) documented an increase of 58.2 and 39.2 per cent nitrogen content in soil with application of FYM @ 40 Mg ha^{-1} and 20 Mg ha^{-1}, respectively as compared to recommended N, P and K . Organic carbon, phosphorus and potassium contents in soil were also increased significantly with FYM @ 40 Mg ha^{-1}.

Biological properties

The treatments with 90 kg N ha^{-1} through FYM + neem cake showed significantly higher urease activity (0.65 mg NH_4^+- N g^{-1} soil h^{-1}) than the treatment with recommended N, P and K (90: 40: 40 kg ha^{-1}) and absolute control (0.26 and 0.25 mg NH_4^+- N g^{-1} soil h^{-1}, respectively) (Krishnakumar *et al.*, 2005). Significantly higher soil dehydrogenase activity (116.8 µg TPF g^{-1} soil day^{-1}) was observed when recommended dose of nitrogen was applied through FYM as compared to application of poultry manure, vermicompost, phosphocompost and inorganic fertilizers (Ramesh *et al.*, 2008).

Mohammadi (2011) reported that application of FYM and compost @ 10 and 5 t ha^{-1}, respectively increased alkaline phosphatase, acid phosphatase, urease and dehydrogenase activities in soil as compared to application along with chemical fertilizer and also their sole application. Similarly, Rai and Yadav (2011) reported significantly highest dehydrogenase activity (53.3 µg TPF g^{-1} soil d^{-1}) in case of organic treatment which received FYM @ 120 kg N ha^{-1} over absolute control and integrated treatments in sandy loam soils.

2.3.2 Poultry Manure

The poultry manure is a valuable fertilizer material having higher quantities of nitrogen and phosphorus compared to other bulky organic manures. It is essential to have well-defined production systems, involving poultry manure to establish potential nutrient supply packages for a farm or a region.

2.3.2.1 Effect of poultry manure on performance of crops

Yield components and yield

Application of 6, 9 and 12 t ha^{-1} of dried poultry droppings with 45:30:30 kg N, P_2O_5 and K_2O ha^{-1} accelerated tasselling, silking and plant maturity and favoured production of larger ears and higher shelling percentage in maize (Ponsica *et al.*, 1983).

Poultry manure application of one t ha^{-1} has shown significantly higher weight of cob, number of grains per cob, grain weight per cob and 100 grain weight of maize crop over vermicompost and FYM (Itnal and Palled, 2001). Application of poultry manure @ 6 and 8 t ha^{-1} produced maize grain yield of 2.6 and 3.1 t ha^{-1}, respectively which was statistically different from that of the chemical fertilizer @ 60-40-40 kg N, P_2O_5 and K_2O ha^{-1} (2.29 t ha^{-1}). Among different levels of poultry manure application the thousand grain weight was in the order 6 > 8 > 4 > 2 t ha^{-1} + ½ NPK > NPK > control (Agyenim *et al.*, 2006).

Incorporation of poultry manure, castor cake and FYM into the soil recorded significant increase in maize yield (both grain and stover) compared to control (Sharma and Saxena, 1985). Similar results were also recorded by Ernani (1984) who reported that application of poultry manure increased maize grain yield than pig manure. Stefanescu and Dasca (1988) found that wheat and maize grain yields were 3.54 and 4.56 t ha^{-1} respectively, with no fertilizer and it was improved by 5.39 and 6.92 t ha^{-1} when poultry manure was applied @ 4 t ha^{-1} for both the crops. Maize responded better than wheat to poultry manure.

Application of poultry manure @ 5 t ha^{-1} mitigated P-deficiency symptoms in maize plants, increased crop yield and proved to be superior over application of pig manure, SSP alone or in combination with rock phosphate (1:1) in soils with low organic carbon content (Madhumitadas *et al.*, 1991). Similarly, increased maize yield with poultry manure application in sludge amended soils was reported by Hernandez *et al.* (1991) and Obi and Ebo (1995).

The application of poultry manure @ one t ha^{-1} recorded significantly higher seed yield (5046 kg ha^{-1}) of maize over no application (4117 kg ha^{-1}) and it was on par with application of FYM @ 10 t ha^{-1} (4749 kg ha^{-1}) (Channabasavanna *et al.,* 2002). Among the organic treatments, application of poultry manure @ 5 t ha^{-1} gave significantly higher grain yield of maize (51.52 q ha^{-1}) and it was followed by FYM @ 10 t ha^{-1} (45.73 q ha^{-1}) and incorporation of green leaf manure @ 5 t ha^{-1} (44.82 q ha^{-1}) (Nagaraj *et al.* (2004).

Nutrient uptake

Prasad *et al.* (1984) opined that poultry manure increased the Zn and Fe content of maize from deficiency to sufficiency level, which resulted improvement in maize yield in calcareous soil. Das *et al.* (1992) observed that application of poultry manure @ 5 t ha^{-1} along with SSP increased the uptake of Ca, Mg, K, Fe and also soil organic carbon. Application of poultry manure to soil increased P availability in soil and nutrient uptake by maize and wheat (Sharma and Saxena, 1990 and Gupta *et al.,* 1996). Similarly Itnal and Palled (2001) observed that application of poultry manure @ one t ha^{-1} recorded maximum uptake of N, P and K by maize crop of 249.2 kg, 43.9 kg and 170.7 kg ha^{-1}, respectively.

2.3.2.2 Effect of poultry manure on soil properties

Physical properties

Soil physical properties such as bulk density, water holding capacity and per cent water stable aggregates were noted to be favorably influenced by poultry waste addition to soil (Weil and Kroontje, 1979).

Obi and Ebo (1995) noticed that addition of poultry manure @ 10 t ha^{-1} to maize crop significantly decreased soil bulk density, increased soil organic matter content, total porosity, infiltration rate and hydraulic conductivity. Incorporation of poultry manure reduced the bulk density, improved the infiltration rate, water stable aggregates (>0.25 mm), soil porosity and water holding capacity of soil (Bellakki and Badanur, 1997).

Agbede *et al.* (2008) reported that yearly application of poultry manure @7.5 t ha^{-1} had cumulative positive effect on soil physical properties by reducing soil bulk density and temperature and increasing total porosity and moisture content from 2004 to 2006. . The mean soil bulk density values for 2004, 2005 and 2006 were 1.29, 1.26 and 1.22 g cm^{-3} and the values for total porosity were 50.9, 51.6 and 53.7 per cent, respectively.

Physico-chemical properties

Das *et al.* (1992) reported that application of poultry manure @ 5 t ha^{-1} to maize and groundnut intercropping system increased the soil organic carbon, CEC, exchangeable K, Ca and Mg contents in soil. Continuous application of poultry manure @ 7 t ha^{-1} for two years increased the organic matter content of soil from 0.98 to 4.5 per cent whereas, it was decreased to 0.59 per cent in absolute control Adeniyan (2011).

Poultry manure significantly increased the cation exchange capacity from 1.7 to 12.75 cmol (p^{+}) kg^{-1} soil and the base saturation from 47 to 80 per cent when it was applied @ 10 t ha^{-1} for 10 years continuously (Bakayoko *et al.*, 2009).

Chemical properties

Application of poultry manure decreased the adsorption capacity and increased the soluble P and phosphorus desorption (Reddy and Reddy, 1998). Soil bulk density and pH were unaffected and soil N, P and K contents were increased with increasing rate of poultry manure (Ponsica *et al.*, 1983). In an incubation study by Madhumitadas *et al.* (1991), a marked increase in the exchangeable K due to application of poultry manure up to 24th day after incubation was observed.

Savithri (1991) reported that application of poultry manure @ 6.25 t ha^{-1} to the first crop of sorghum had significant residual effect on succeeding crop yield and also increased the nutrient content of the soil. Dravid and Biswas (1996) found that phosphorus utilization was increased with application of poultry manure to wheat crop.

Pengthamkeerati *et al.* (2006) reported that poultry litter application increased NH_4^+ - N up to a depth of 20 cm and soil inorganic N at all depths. Prasad *et al.* (1984) found a considerable increase in available Zn and Fe content with the application of poultry manure in calcareous soil. Complex properties of poultry manure may prevent precipitation and fixation of Zn and Fe and keep them in slowly available form.

Reddy and Reddy (1998) studied the influence of integrated use of poultry manure and inorganic fertilizers on available micronutrient status of sandy loam soil in maize-soybean cropping system. The results indicated that availability of all the micronutrient cations increased with increase in level of organic manure application. The 100 per cent poultry manure level which was at par with 50 and 75 per cent resulted in the highest availability of Fe, Zn, Cu and Mn. Ibeawuchi *et al.* (2007) reported that in a degraded soil of Nigeria, poultry manure application increased the residual soil N, K, Ca, Mg, and organic matter.

Adeleye *et al.* (2010) observed that poultry manure treated plots had higher available P, exchangeable Mg and CEC when compared to other plots treated with swine waste or cow dung at the end of the second planting season. The concentration of nutrients in the plots treated with the different animal manures was in the order of poultry manure >swine waste > cowdung.

Biological properties

Ramesh *et al.* (2008) reported that urease activity and dehydrogenase activity in maize soils was higher when poultry manure was applied @ 100 per cent RDN (100kg ha^{-1}) to crop as compared to application of chemical fertilizer and vermicompost.

Li *et al.* (2011) reported that poultry manure treatment shown significantly higher microbial biomass carbon and nitrogen contents (89%, 74%), soil basal respiration rate (49%) and soil microbial quotient (45%) as compared to chemical fertilizer treatment.

2.4 INTEGRATED NUTRIENT MANAGEMENT

Most of the crops respond quickly to chemical fertilizers and give higher yield and maize is more responsive. But, continuous application of chemical fertilizers alone has been reported to deteriorate soil health. At the same time application of organic manures alone cannot be an alternative due to their low nutrient status and slow available nature. Sustainable yields could be achieved only by integrating all the available nutrient sources in an appropriate combination with chemical fertilizers.

2.4.1 Effect of Integrated Nutrient Management on Performance of Crops

Yield components and yield

Ponsica *et al.* (1983) found that 12 tonnes of chicken droppings along with 45:30:30 kg N, P_2O_5 and K_2O ha^{-1}, favoured production of larger ears and higher shelling percentage in maize. FYM @ 5 t ha^{-1} + 30 kg N ha^{-1} gave higher grain yield compared to farmer's practice (60 kg ha^{-1}), N and P (60 kg ha^{-1} of each), N, P and K (60 kg ha^{-1} of each N and P; K 40 kg ha^{-1}), and optimal fertilizer (200:60:120:20:5 kg N, P, K, Mg and B ha^{-1}, respectively) in Ultisols under dry conditions whereas, farmyard manure along with N, P and K gave the highest number of cobs (Achieng *et al.*, 2010).

Significantly more 1000-grain weight (282.7 g) in maize was recorded from plots fertilized @ 75 per cent N ha^{-1} as urea + 25 per cent N ha^{-1} as poultry manure, while statistically minimum 1000-grain weight (247.3 g) was recorded in control where no fertilizer (organic and inorganic) was applied (Cheema *et al.*, 2010). The highest drymatter production at harvest (150 g plant^{-1}) was obtained with application of recommended dose of fertilizer along with FYM @ 10 t ha^{-1} as compared to individual application of FYM @ 10 t ha^{-1}, 100 and 150 per cent recommended dose of fertilizers (89, 122 and 149 g plant^{-1}) to maize in a clay loam soil. (Tetarwal *et al.*, 2011).

Uwah *et al.* (2011) observed that total dry matter, weight of grains per cob, cob yield per ha and total grain yield were obtained by the application of poultry manure @ 10 t ha^{-1} along with N, P_2O_5 and K_2O @ 400 kg ha^{-1} fertilizer with ratio 20:10:10. Significantly higher 100 grain weight (37.87 g) in maize was recorded with the application of 100 per cent inorganic N along with FYM @ 7.5 t ha^{-1} when compared to the treatments which received higher levels of inorganic nitrogen (150% RDFN) in sandy loam soils of Shimoga (Shilpashree *et al.*, 2012).

Devarajan *et al.* (1988) reported that increased level of FYM application (25 t ha^{-1}) and $ZnSO_4$ (25 kg ha^{-1}) gave the highest grain and stover yield of maize. Das *et al.* (1991) reported that maximum grain yield of maize (4.95 t ha^{-1}) was noticed under 5 t ha^{-1} of poultry manure along with 28 kg P_2O_5 ha^{-1} as single super phosphate followed by poultry manure alone (3.81 t ha^{-1}). Similarly, increase in grain yield was also reported by Scherer (1995) by application of graded level of poultry manure (0, 3, 6, 9 and 12 t ha^{-1}) in combination with varying levels of nitrogen (0, 40, 80 and 120 kg ha^{-1}). Chandrashekara *et al.* (2000) observed that the application of poultry manure @ 10 t ha^{-1} along with 150:75:37.5 kg N, P and K ha^{-1} (100% recommended dose of fertilizer) recorded significantly higher grain (50.8 q ha^{-1}) and fodder yields (74.4 q ha^{-1}) than application of vermicompost, FYM @ 2.5 t ha^{-1} each and RDF alone. The per cent increase in grain yield with application of poultry manure, vermicompost and FYM was 33, 16 and 14 per cent, respectively over chemical fertilizer alone.

Highest yield of baby corn was recorded in the treatment receiving pelleted form of organic manure along with 75 per cent of the RDF compared to the 100 per cent recommended dose of fertilizer (Saha and Mondal, 2006). Among organics, application of FYM @ 7.5 t ha^{-1} + 100 per cent RDF was found to be significantly superior to rest of the organics except application of vermicompost @ 2.5 t ha^{-1} +100 per cent RDF with respect to maize and bengal gram yield. The next best treatment was application of poultry manure @ 1.0 t ha^{-1} with 100 per cent RDF (Lingaraju *et al.*, 2010). Prasad *et al.* (2010) reported that higher maize grain yield was obtained by integrated application of 50 per cent N through FYM along with 50 per cent N, P and K (4.4 t ha^{-1}) as compared to the different combinations of organic and inorganic fertilizers in sandy clay loam soils of Ranchi. Grain yield was significantly higher (4813 kg ha^{-1}) when DAP and poultry manure were applied in 50:50 ratio at recommended rate of 90 kg P_2O_5 ha^{-1} than sole application of inorganic fertilizer but was on par with application of TSP + poultry manure and DAP + compost in similar ratio with grain yield of 4715 and 4684 kg ha^{-1}, respectively (Zafar *et al.,* 2011).

Nutrient uptake

Joseph (1994) observed significant increase in the concentration and subsequent uptake of nitrogen and phosphorus by wheat due to addition of FYM along with rock phosphate. Kamalakumari and Singaram (1996) reported that application of 100 per cent N, P_2O_5 and K_2O and FYM @ 10 t ha^{-1} increased the uptake of N, P and K (170, 34 and 220 kg ha^{-1}, respectively) by maize as compared to different doses of inorganic fertilizer.

Gupta *et al.* (1999) observed increased phosphorus use efficiency due to the application of FYM @ 10 t ha^{-1} to sandy loam soil with maize as test crop. The extent of increase was 15.50, 11.57 and 3.93 per cent from soil + fertilizer, soil and fertilizer source, respectively. The combined application of sunhemp green manure with 100 per cent RDN and poultry manure @ one t ha^{-1} has increased the nutrient uptake (278.2, 47.2 and 184.0 kg of N, P and K ha^{-1}, respectively) by maize crop (Itnal and Palled, 2001).

Kumar and Thakur (2004) observed that application of 150 per cent recommended fertilizer resulted in higher uptake followed by recommended fertilizer + FYM @ 10 t ha^{-1}. Similarly, Singh *et al.* (1979) also reported that application of FYM with recommended fertilizer increased the uptake of nutrients by increasing the availability of nutrient. Saha and Mondal (2006) reported that the uptake of N, P and K by baby corn increased when 25 per cent RDF was substituted by organic manure and the maximum was recorded under the treatment receiving 75 per cent RDF + pelleted form of organic manure. Prasad *et al.* (2010) reported that application of 50 per cent NPK + 50 per cent nitrogen through FYM increased the uptake of N, P and K by maize crop (115, 24 and 126 kg ha^{-1}, respectively) as compared to different doses of inorganic fertilizers in sandy clay loam soils.

Sakal *et al.* (1982) reported that application of compost @ 10 t ha^{-1} along with $FeSO_4$ @ 100 kg ha^{-1} increased the uptake of Fe by maize seed and stover by 19 and 81 per cent, respectively over control. Similar results in maize-wheat rotation were reported by Kher and Minhas (1991) in the uptake of Zn, Mn and Fe in both the crops by the application of 100 per cent recommended dose of N, P and K and FYM. Madhavi *et al.* (1995) observed that the uptake of micronutrients (Fe, Zn, Mn and Cu) in winter maize increased with increase in levels of poultry manure (0 to 4.5 t ha^{-1}) and N, P and K fertilizers (0 – 100% recommended fertilizers of 120:60:60 kg N, P_2O_5 and K_2O ha^{-1}). Ghosh *et al.* (2001) reported that application of FYM along with recommended dose of N, P and K fertilizer considerably increased the uptake of Zn, Mn, Cu and Fe by wheat over absolute control and RDF treatment.

2.4.2 Effect of Integrated Nutrient Management on Soil Properties

Physical properties

Babhulkar *et al.* (2000) studied the effect of continuous application of fertilizers alone and in combination with graded levels of FYM for soybean based cropping system in a long term field experiment in swell-shrink soil at Nagpur. The results indicated that significant decrease in bulk density of soil and increase in soil porosity, water holding capacity and hydraulic conductivity was due to combined application of FYM and fertilizers as compared to other treatments without FYM.

Selvi *et al.* (2005) noticed that continuous application of balanced fertilization (100% N, P and K + FYM @ 10 t ha^{-1}) did not show any deteriorating effect on physical properties of the soil; rather it significantly increased the water holding capacity and reduced bulk density of the soil in long run. Significant improvement in the physical properties of the soil was observed under the integrated application of organics and inorganics.

Physico - chemical properties

Sharma and Guptha, (1998) reported that use of organic manures, viz., farmyard manure, white popinac leaves and blackgram straw along with moderate levels of fertilizers significantly increased the organic carbon content to 0.51, 0.48 and 0.49 per cent over 100 per cent N, P and K dose, respectively. Similarly, Babu and Reddy (2000) recorded significant increase in the organic carbon content of sandy clay loam soil from 0.61 to 0.92 per cent due to the addition of FYM and inorganic nitrogen @ 5 t ha^{-1} and 50 kg ha^{-1}, respectively. Studies conducted by Vasanthi and Kumaraswamy (2000) in red clay loam soil revealed that the organic carbon content of the treatment that received either poultry manure or sheep/goat manure @ 10 t ha^{-1} along with 50 per cent RDF significantly increased when compared to the treatment receiving only inorganic fertilizers.

Bhattacharya *et al.* (2004) noticed that both oxidizable and non-oxidizable soil organic carbon contents of the soil were higher in N, P and K + FYM treated plots at surface (0 - 15 cm) and sub-surface (15 - 30 cm) levels, respectively and were significantly higher than all other treatments. Kumpawat (2004) reported that maximum reduction in soil pH and EC was recorded in plots receiving 100 per cent RDN through FYM in rainy season and 100 per cent recommended NP through fertilizer in winter crop of mustard. The integrated use of organic and inorganic fertilizers improved the organic carbon as compared to control plot.

Chemical properties

Sharma and Sharma (2002) revealed that application of K significantly increased K content of soil by 3 to 4 kg ha^{-1} in the first year and by 17 to 19 kg ha^{-1} in the second year. The available K content of soil was further increased significantly with the application of FYM along with N, P and K over N, P and K alone. Baskar (2003) reported that application of 100 per cent N, P and K + FYM @ 12.5 t ha^{-1} to rice crop resulted in significant increase in the uptake of N (58.5 and 89 .4 kg ha^{-1}), P (26.5 and 8.8 kg ha^{-1}) and K (19.0 and 99.9 kg ha^{-1}) in grain and straw, respectively as compared to 100 per cent RDN through inorganics alone. The long-term application of 100 per cent NPK + FYM resulted in the highest amount of total N in soil which was closely followed by 150 per cent NPK under maize – wheat – cowpea cropping sequence (Sarawad and Dhyan Singh, 2005).

Sihag *et al.* (2005) reported that application of chemical fertilizers alone or in combination with organic manures significantly increased all the forms of nitrogen except unidentified hydrolysable N over control or their initial status. Among the various N fractions, amino acid N was the dominant N fraction. On an average, amino acid, amino sugar, ammoniacal N and unidentified hydrolysable N constituted about 33.2, 8.9, 29.0 and 29.8 per cent of total hydrolysable N, respectively. Mann *et al.* (2006) reported that available phosphorus content increased from the initial value of 13.7 to 15.1, 18.4, 27.5 and 38.7 kg ha^{-1} in 50, 100, 150 per cent N and P and 100 per cent N, P and K + farmyard manure treatments, respectively.

Saha and Mondal (2006) reported significant increase in available nitrogen (26 kg N ha^{-1}) with the addition of 75 per cent RDF + pelleted form of organic manure while the treatment receiving 75 per cent RDN recorded decrease of 66 kg N ha^{-1} from the initial available nitrogen status of soil and increase in available phosphorus (34.17%) was recorded with the treatment receiving 75 per cent RDF + organic manure rich with humus**.** Prasad *et al.* (2010) reported that integrated application of 50 per cent N through FYM along with 50 per cent N, P and K increased the availability of N, P and K (325, 85 and 157 kg ha^{-1}, respectively) and micronutrients Fe, Mn, Cu and Zn (28, 59, 1.3 and 3.2 mg kg^{-1}, respectively) as compared to sole application of inorganic fertilizers.

Biological properties

Manna and Ganguly (1995) reported that application of organics along with inorganic fertilizers under soybean-wheat cropping system increased the soil microbial population compared to only inorganic fertilizers treatment. Singaram and Kamalakumari (1995) reported favourable effect of FYM on the activity of dehydrogenase, urease and phosphatase in soil and it was more pronounced due to combined application of FYM and N, P and K fertilizers which was attributed to increased mineralization of nutrients from microbial decomposition of organic matter.

Badole and More (2001) observed that in cotton- groundnut cropping system (1997-98 to 1998-99) the microbial population such as bacteria, fungi, actinomycetes etc. were increased from one year to another year under the treatment included integrated nutrient supply than that of other treatment. According to Kanchikerimath and Singh (2001), balanced application of inorganic fertilizer and organic amendments significantly increased the dehydrogenase, urease and alkaline phosphatase activities. Chen *et al.* (1994) reported that application of N, P and K + organic manure increased the activities of urease and phosphatase in red soil. Application of 120 kg N ha^{-1} through urea along with 10 kg N ha^{-1} through carpet waste was found to be highly effective for achieving more urease activity at different days of incubation in sandy loam soils (Rai and Yadav, 2011).

Chapter III

MATERIAL AND METHODS

A field experiment entitled “Effect of integrated nutrient management on soil properties and performance of maize (*Zea mays* L.)” was conducted at Agricultural College Farm, Bapatla, during *kharif,* 2011. The details of the materials used and the methodology followed during the course of present investigation are presented in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was conducted in field number 36A of southern block, Agricultural College Farm, Bapatla of the Acharya N.G. Ranga Agricultural University. The experimental site is located at an altitude of 5.49 m above the mean sea level, 15^{o} 54’ N latitude, 80^{o}25’ E longitude and about 7 km away from the coast of Bay of Bengal in the Krishna Agro-Climatic Zone of Andhra Pradesh, India.

3.2 WEATHER DURING THE CROP GROWTH PERIOD

The data on weather parameters recorded during the crop growth period from 17.08.2011 to 26.11. 2011 are presented in the table 3.1 and depicted in figure 3.1and 3.2.

The weekly mean maximum temperature during the crop period ranged from 30.8 ^{0}C to 35.1 ^{0}C and minimum from 19.0 ^{0}C to 26.2 ^{0}C with the average of 33.2 ^{0}C and 23.7 ^{0}C, respectively. The weekly mean relative humidity ranged from 67.4 to 86.1 per cent with an average of 78.4 per cent. A total rainfall of 406.5 mm was received during the period of experimentation.

Table 3.1 Weather data during the crop growth period from 17-08-11 to 26-11-11

Standard week	Date and month	Mean temperatures (^{0}C)		Mean RH (%)	Rainfall (mm)
		Max	**Min**		
33	13 Aug – 19 Aug	35.1	26.0	77.4	49.6
34	20 Aug – 26 Aug	31.5	24.8	83.0	66.8
35	27 Aug – 02 Sept	33.6	24.9	76.0	11.2
36	03 Sept – 09 Sept	34.8	26.2	67.4	3.0
37	10 Sept – 16 Sept	34.8	24.7	78.7	89.6
38	17 Sept – 23 Sept	35.0	25.6	73.4	2.6
39	24 Sept – 30 Sept	35.0	24.5	79.4	78.2
40	01 Oct – 07 Oct	34.9	24.1	71.0	32.2
41	08 Oct – 14 Oct	33.3	25.1	82.7	20.2
42	15 Oct – 21 Oct	33.8	23.8	74.1	-
43	22 Oct – 28 Oct	31.7	23.5	86.1	26.4
44	29 Oct – 04 Nov	31.1	23.0	83.6	26.7
45	05 Nov – 11 Nov	31.6	19.8	86.0	-
46	12 Nov – 18 Nov	31.6	20.9	80.8	-
47	19 Nov – 25 Nov	30.8	19.0	77.5	-
Total		**498.6**	**355.9**	**1177.1**	**406.5**
Average		**33.2**	**23.7**	**78.4**	

3.3 CHARACTERISTICS OF THE EXPERIMENTAL SOIL

The soil of the experimental field was non-saline (0.11 dS m^{-1}), slightly alkaline in soil reaction (pH 7.6) , sandy loam in texture with low organic carbon (1.9 g kg^{-1}) and available nitrogen (122 kg ha^{-1}), medium available phosphorus (40.4 kg ha^{-1}) and high available potassium (392 kg ha^{-1}). Except zinc, other micronutrients viz., iron, manganese and copper were well above the critical limit. The data on initial characteristics of the experimental soil are given in table 3.2.

3.4 CROPPING HISTORY OF THE EXPERIMENTAL FIELD

The cropping history of the experimental field for the three consecutive preceding years is given below.

Year	***kharif***	***rabi***
2008-09	Pigeonpea	Fallow
2009-10	Dhaincha	Fallow
2010-11	Dhaincha	Fallow
2011-12	Present experiment	

3.5 EXPERIMENTAL DETAILS

The experiment was laid out in a randomized block design with 10 treatments and each treatment being replicated three times. The details of the treatments are presented in table 3.3, while the layout plan is depicted in fig. 3.3. The other details were as follows;

A popular maize hybrid 30 V 92 released by M/s PHI Limited (Pioneer hybrid seeds), Hyderabad was used for the study. It is a medium duration hybrid (100- 120 days), yellow grained and has a yield potential of 7 to 10 t ha^{-1}. It is resistant to lodging. The spacing adopted was 75 x 20 cm.

3.5.1 Cultivation Details

The calendar of operations is presented in appendix-1 and the details of cultivation practices are presented under the following sub-heads

3.5.1.1 Field preparation

The experimental field was treated with a non-selective systemic herbicide, glyphosate @ 12 mL L^{-1} along with 10 g of urea for the control of weeds. Fifteen days after spraying of the herbicide, the field was ploughed once with tractor drawn mould board plough and then worked with blade harrow and stubbles were removed. The field was divided into thirty plots as per experimental design (Fig. 3.3) and leveling within the plots was done manually.

3.5.1.2 Application of manures and fertilizers

Manures

The organic manures *i.e.* farmyard manure (FYM) and poultry manure (PM) used in the present study were procured from College Farm of Agriculture College, Bapatla and a private poultry farm located in Bapatla, respectively. The manures were analysed for their chemical composition and the data are presented in the table 3.4. All the manures in required quantities were applied as per the treatments duly taking into account their nitrogen contents based on dry weights and incorporated in soil 10 days before sowing of seeds.

Fertilizers

Nitrogen, phosphorus and potassium were applied through urea, single superphosphate (SSP) and muriate of potash (MOP). Nitrogen was applied at 100 and 125 per cent of recommended dose (120 kg ha^{-1}) as per the treatments in three equal splits, at the time of sowing, at knee high stage and at tasseling. Recommended dose of 60 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied uniformly to all the plots. Entire quantity of phosphorus was applied as basal, whereas potassium was applied in two equal splits, one at the time of sowing and other at tasseling stage.

3.5.1.3 Sowing

Sowing was done on 17.08.2011 in furrows opened to a depth of 5 cm following a spacing of 75 cm × 20 cm. Healthy and well matured bold seeds of maize were hand dibbled into the soil @ one seed per hill by adopting a seed rate of 20 kg ha^{-1}. Wire ropes and planting boards marked at desired spacing were fixed to maintain plant to plant and row to row distance.

3.5.1.4 Gap filling and thinning

Gap filling and thinning of overcrowded seedlings was done within 10 days after sowing in order to maintain the required plant population.

3.5.1.5 Weed control

Pre-plant application of non-selective, translocative herbicide, glyphosate was done before the preparation of main field. The pre-emergence herbicide, atrazine @ 2 kg ai ha^{-1} was sprayed after sowing and manual weeding was also done to keep the experimental plot weed free.

3.5.1.6 Plant protection

Carbofuran granules were applied @ 1.5 kg ha^{-1} in sand mix (40 days after sowing) to protect the crop against early shoot borer.

3.5.1.7 Irrigation

Irrigations were given as and when required for raising good crop.

3.5.1.8 Harvesting and shelling

The crop was harvested on 26th November 2011 *i.e.* after 100 days after sowing. The cobs of border rows were removed first from each plot and then from the net plot. Later the stalks were cut above ground level for recording grain and stover yield, respectively. The cobs from each plot were dried properly in sun to facilitate easy shelling and shelling was done with the help of hand operated sheller.

3.6 ESTIMATION OF DRYMATTER PRODUCTION, YIELD COMPONENTS AND YIELD

3.6.1 Drymatter Production

At tasseling, five randomly selected plants from each plot were cut close to the base. The plants were dried under shade and subsequently in a hot air oven at 60° C to a constant weight and weight was expressed as kg ha^{-1}.

3.6.2 Yield Components

3.6.2.1 Thousand grain weight

The weight of thousand grains (g) was recorded from the grain samples drawn randomly from the net plot produce of each treatment.

3.6.2.2 Number of grains per cob

Grain number per cob was calculated from the grain weight per cob and the corresponding thousand grain weight as follows.

$$\text{Grain number per cob} = \frac{\text{Grain weight per cob (g)}}{\text{Weight of 1000-grains (g)}} \times 1000$$

3.6.2.3 Grain weight per cob

The grains from the sun dried cob of five cobs were separated and the weight of the grains was recorded. The average grain weight per plant was expressed as ‘g’ per cob.

3.6.2.4 Shelling percentage

After obtaining cob dry weight as well as shelled grain weight in each plot shelling percentage was calculated as follows.

$$\text{Shelling percentage} = \frac{\text{Grain yield per plot}}{\text{Cob yield per plot}} \times 100$$

3.6.3 Grain Yield

At physiological maturity cobs from each net plot were harvested. Cobs were separated, sun dried, shelled, cleaned and weighed. Grain weight per plot was recorded at 10 per cent moisture. Grain yield per ha was worked out and expressed in kg ha^{-1}.

3.6.4 Stover Yield

The stalk obtained from each net plot was thoroughly sun dried to attain a constant weight and expressed as stover yield in kg ha^{-1}.

3.6.5 Harvest Index

Harvest index is defined as the ratio of economic yield to total biological yield (Donald and Humblin, 1976) and expressed in percentage. The harvest index for maize was worked out as indicated below.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Total biological yield (kg ha}^{-1}\text{)}} \times 100$$

3.7 SOIL SAMPLE COLLECTION AND PREPARATION

Representative surface soil samples (0-30 cm) were collected before taking up the experiment, at tasseling and at harvest of maize crop. The collected samples were dried under shade, gently ground with wooden hammer, sieved through 2mm sieve and stored in labelled new polythene lined cloth bags. Processed soil samples were used for analysing various physical, physico-chemical, chemical properties and urease activity.

3.7.1 Methods of Analysis

Standard methods of analysis followed in determining various physical, physico-chemical, chemical properties and urease activity of soil samples is as follows.

3.7.1.1 Soil reaction (pH)

Soil reaction was determined in 1: 2.5 soil water suspension using combined glass electrode DIGISUN electronics pH meter model: DI-707 (Jackson, 1973).

3.7.1.2 Electrical conductivity

The soluble salt content of soil samples was determined in 1: 2.5 soil water suspension using electrical conductivity bridge CM -180 (Jackson, 1973).

3.7.1.3 Particle size analysis

Particle size analysis was carried out by international pipette method for determining textural class of the soil (Piper, 1966).

3.7.1.4 Bulk density

Bulk density of initial and post-harvest soils was determined by core sampler method (Dastane, 1967).

3.7.1.5 Organic carbon

Wet digestion method was followed to determine the organic carbon content of the soil (Walkley and Black, 1934).

3.7.1.6 Cation exchange capacity

Cation exchange capacity of the soils was determined by sodium saturation method (Bower, *et al.* 1952). Five gram of soil was centrifuged for five minutes with 33 mL of 1 N sodium acetate of pH 8.2. The supernatant solution was decanted and extraction was repeated two or more times. Then, the soil was washed with isopropyl alcohol in the same manner to remove excess of sodium which was later replaced by ammonium (NH_4^+) by treating the soil with neutral normal ammonium acetate. The displaced sodium was determined by flame photometer and expressed as cmoles (p^+) kg^{-1} soil.

3.7.1.7 Available macro nutrients

Available nitrogen: Available nitrogen content of the soils was determined by the alkaline potassium permanganate method (Subbiah and Asija, 1956).

Available phosphorus: The available phosphorus in soils was extracted by employing Olsen's extractant (Olsen *et al.,* 1954) and phosphorus in the extract was determined by ascorbic acid method using spectrophotometer at 660 nm.

Available potassium: The available potassium in soil was extracted with neutral normal ammonium acetate and potassium in the extract was determined by flame photometer (Muhr *et al.,* 1965).

3.7.1.8 Available micronutrients

Available zinc, iron, manganese and copper in the soils were extracted using DTPA extractant and were determined using atomic absorption spectrophotometer (Lindsay and Norvell, 1978).

3.7.1.9 Urease activity

Urease activity was estimated by quantifying the rate of release of NH_4^+ - N from the hydrolysis of urea as described by Tabatabai and Bremner (1972). Five gram of soil sample was taken in 50 mL capacity glass tubes to which 9 mL of distilled water was added. The tubes were gently swirled to mix the contents followed by the addition of 1 mL of 0.2 M urea solution. The glass tube was swirled gently again for a few seconds and closed with stoppers. After incubation for a definite time at 37^0C in a thermostatic waterbath, the reaction was terminated by adding 15 mL potassium chloride - silver sulphate solution (100 mg Ag_2SO_4 was dissolved in 700 mL distilled water to which 300 mL water containing 149 g of KCl was added). The contents were agitated in a mechanical shaker for one hour to release all the NH_4^+-N formed and the suspension was allowed to settle. Control samples were run simultaneously in the same way except adding 1 mL of 0.2 M urea solution. The NH_4^+-N released was determined by distilling the suspension with magnesium oxide for 5 minutes. The urease activity was expressed in the terms of μg of NH_4^+- N released g^{-1} soil h^{-1}.

3.8 PLANT SAMPLE COLLECTION AND PREPARATION

The plant samples collected at tasseling and at harvest were cleaned, air dried and subsequently dried in a hot air oven at 60^0C to a constant weight and were ground with the help of willey mill. The samples were analysed for N, P, K, Zn, Fe, Mn and Cu contents by following standard methods as outlined below. The analysis for nutrient content was done separately for grain and stover at harvest.

3.8.1 Nitrogen

The nitrogen content in plant samples was estimated by micro kjeldahl distillation method, as given by Piper (1966).

3.8.2 Wet Digestion

One gram of powdered leaf sample taken in 150 mL conical flask was digested with di-acid mixture (HNO_3: $HClO_4$ in 9: 4 ratio). The sample digest was filtered through Whatman No.42 filter paper by washing with small quantities of double glass distilled water until it becomes chloride free and diluted to 100 mL. The clear extract obtained was used for the determination of P, K, Fe, Zn, Mn and Cu.

3.8.2.1 Phosphorus

The phosphorus content in the diacid digest was determined by vanadophosphomolybdate yellow colour method. The intensity of yellow colour was determined using spectrophotometer at 420 nm, as given by Piper (1966).

3.8.2.2 Potassium

The potassium concentration in the diacid mixture was determined using flame photometer, as described by Muhr *et al.* (1965).

3.8.2.3 Micronutrients

The procedure outlined by Lindsay and Norvell (1978) was followed for determining micronutrient cations viz., Fe, Zn, Mn and Cu by using atomic absorption spectrophotometer.

3.8.3 Nutrient Uptake by Crop

The uptake of primary and micronutrient cations by crop at tasseling and at harvest of the crop was computed by using the formulae

$$\text{Uptake of N,P and K (kg ha}^{-1}\text{)} = \frac{\text{Drymatter production (kg ha}^{-1}\text{)} \times \text{nutrient concentration (\%)}}{100}$$

$$\text{Uptake of micronutrients (g ha}^{-1}\text{)} = \frac{\text{Drymatter production (kg ha}^{-1}\text{)} \times \text{nutrient concentration } (\mu\text{g g}^{-1})}{1000}$$

3.9 STATASTICAL ANALYSIS

The data obtained on pre and post-harvest observations were analyzed statistically using Fisher’s method of analysis of variance as suggested by Panse and Sukhatme (1978) for the randomized block design, statistical significance was tested by F value at $p=0.05$ level of significance.

Relationship of soil organic carbon, available primary nutrients, micronutrients and urease activity with drymatter production, grain yield and stover yield were established with simple correlation.

3.10 NUTRIENT BALANCE

Nutrient balances were calculated for nitrogen, phosphorus and potassium based on nutrient inputs and outputs. Nutrient inputs include applied nutrients. Output includes crop uptake. Balance was worked out with the following formulae.

Nutrient balance = Nutrient input - Nutrient output

Expected residual soil nutrient = (Initial soil nutrients + Applied nutrients) - Crop uptake

Apparent gain/loss = Residual soil nutrient - Expected residual nutrient

Increase over initial status = Residual soil nutrient- Initial soil nutrient

3.11 ECONOMICS

The cost of cultivation for each treatment was worked out. Similarly gross returns were calculated based on the prevailing market price of the produce. The net returns were obtained after deducting the cost of cultivation from gross returns. Benefit cost ratio was worked out by using the formula

$$\text{BCR} = \frac{\text{Net returns}}{\text{Cost of cultivation}}$$

Table 3.2 Initial characteristics of the experimental soil

	Characteristics	Value
I.	**Physical properties**	
A.	**Mechanical analysis**	
a)	Sand (%)	77.68
b)	Silt (%)	14.32
c)	Clay (%)	8.0
d)	Textural class	Sandy loam
e)	Bulk density (Mg m^{-3})	1.5
II.	**Physico-chemical properties**	
a)	Soil reaction (pH 1 : 2.5)	7.6
b)	Electrical conductivity (EC 1:2.5) (dS m^{-1})	0.11
c)	Cation exchange capacity (cmol (p+) kg^{-1})	13.9
d)	Organic carbon (g kg^{-1})	1.9
III.	**Chemical properties**	
A.	**Macronutrients (kg ha^{-1})**	
a)	Available nitrogen	122
b)	Available P_2O_5	40.4
c)	Available K_2O	392
B.	**Micronutrient cations (mg kg^{-1})**	
a)	Iron	8.12
b)	Zinc	0.53
c)	Manganese	6.49
d)	Copper	1.68
IV	**Biological activity**	
a)	Urease activity (µg NH_4^+ - N g^{-1} soil h^{-1})	8.4

Table 3.3 The details of the treatments adopted in the study

Treatment No.	Treatment details	Abbreviation
1	100 per cent of recommended dose of nitrogen through fertilizer (urea)	100% RDFN
2	100 per cent of recommended dose of nitrogen through fertilizer (urea) along with 25 per cent of nitrogen through FYM	100% RDFN + 25% N -FYM
3	100 per cent of recommended dose of nitrogen through fertilizer (urea) along with 50 per cent of nitrogen through FYM	100% RDFN + 50% N - FYM
4	100 per cent of recommended dose of nitrogen through fertilizer (urea) along with 25 per cent of nitrogen through poultry manure	100% RDFN + 25% N - PM
5	100 per cent of recommended dose of nitrogen through fertilizer (urea) along with 50 per cent of nitrogen through poultry manure	100%RDFN + 50% N - PM
6	125 per cent of recommended dose of nitrogen through fertilizer (urea)	125% RDFN
7	125 per cent of recommended dose of nitrogen through fertilizer (urea) along with 25 per cent of nitrogen through FYM	125% RDFN + 25% N- FYM
8	125 per cent of recommended dose of nitrogen through fertilizer (urea) along with 50 per cent of nitrogen through FYM	125% RDFN + 50% N -FYM
9	125 per cent of recommended dose of nitrogen through fertilizer (urea) along with 25 per cent of nitrogen through poultry manure	125% RDFN + 25 % N - PM
10	125 per cent of recommended dose of nitrogen through fertilizer (urea) along with 50 per cent of nitrogen through poultry manure	125%RDFN + 50% N-PM

Table 3.4 Nutrient composition of FYM and poultry manure (on dry weight basis).

Nutrient	**FYM**	**Poultry Manure**	**Procedure**
Organic carbon (%)	18.4	16.5	Chopra and Kanwar (1976)
N (%)	0.5	1.2	Macro Kjeldahl method as outlined by Chopra and Kanwar (1976)
P_2O_5 (%)	0.36	1.8	Wet digestion method as described by Chopra and Kanwar (1976)
K_2O (%)	0.74	1.6	
Fe (ppm)	1300	1421	Wet digestion method as described by Chopra and Kanwar (1976)
Zn (ppm)	60	69	
Mn (ppm)	208	319	
Cu (ppm)	8.5	12	

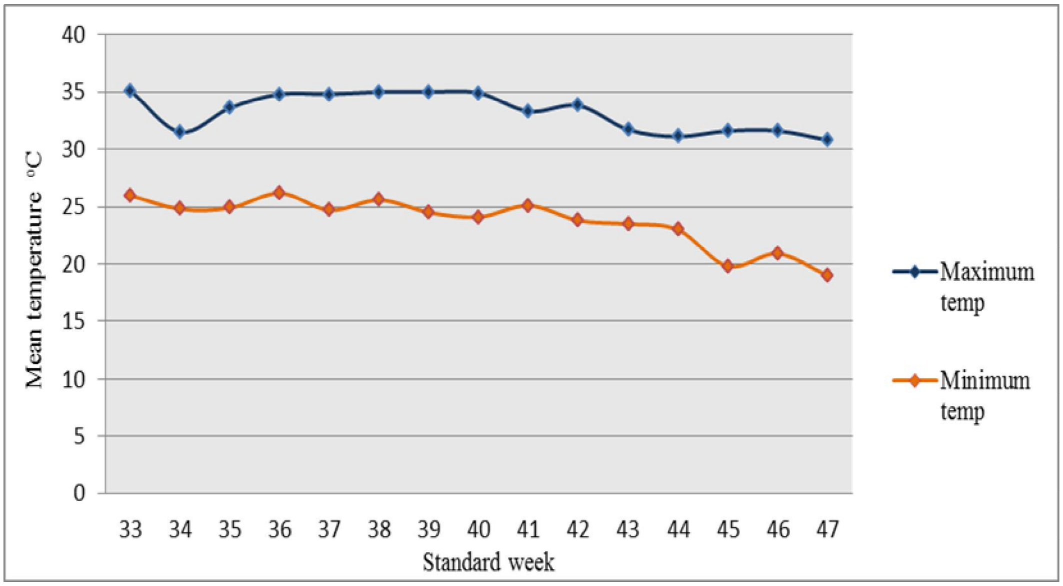


Figure 3.1 Weekly mean maximum and minimum temperatures during the crop growth period of maize

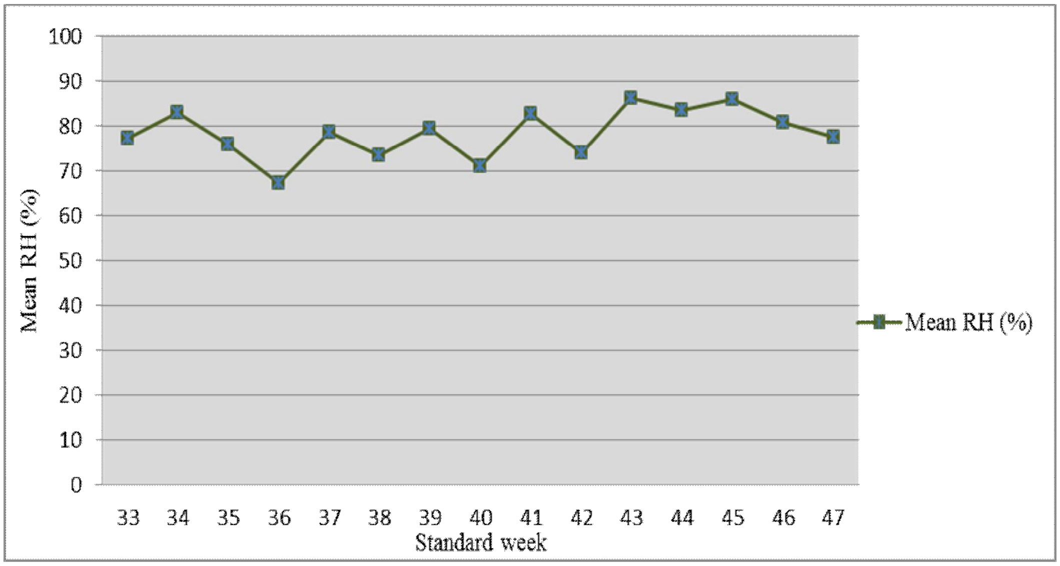


Figure 3.2 Weekly mean relative humidity during the crop growth period of maize

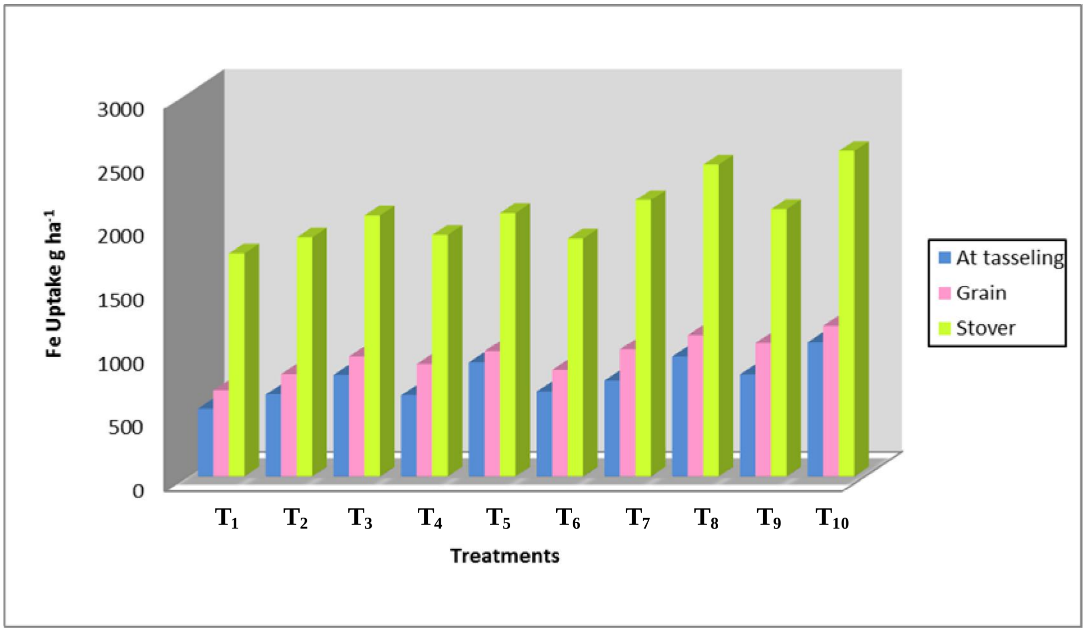


Figure 4.7. Iron uptake by maize as influenced by various treatments

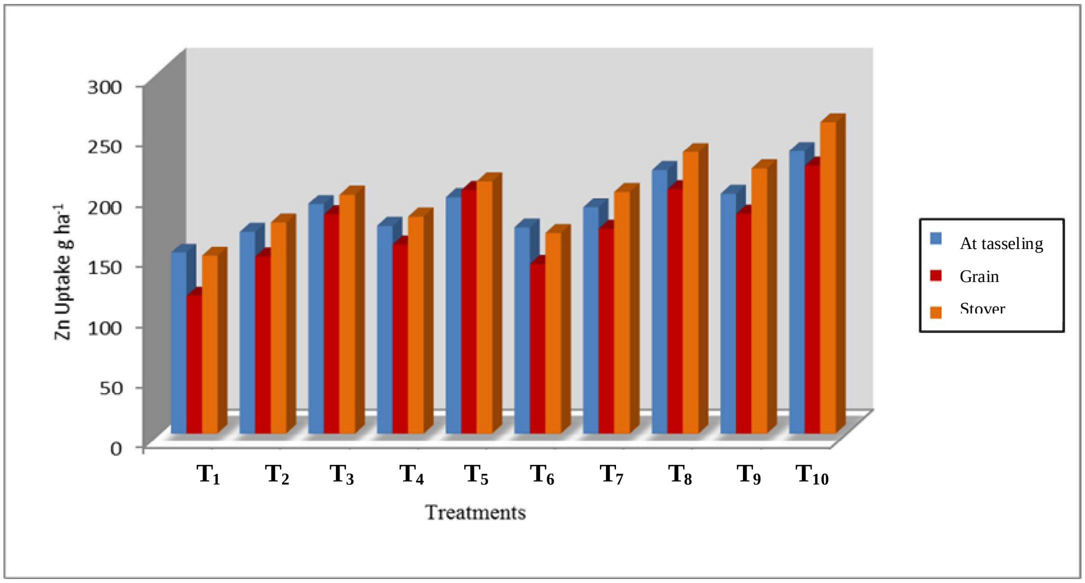


Figure 4.8. Zinc uptake by maize as influenced by various treatments

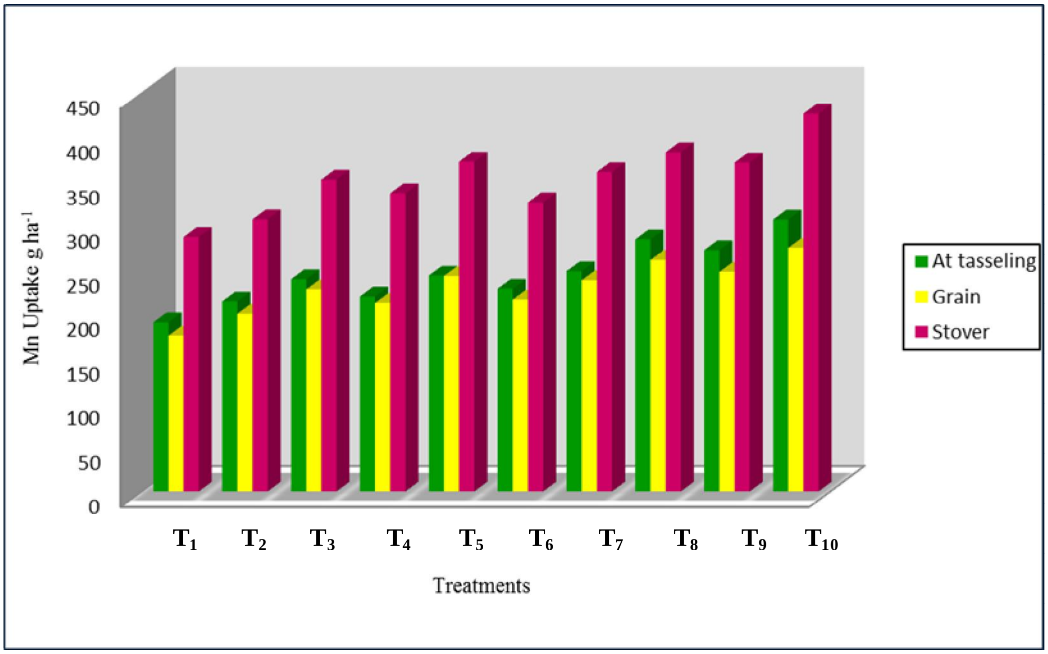


Figure 4.9. Manganese uptake by maize as influenced by various treatments

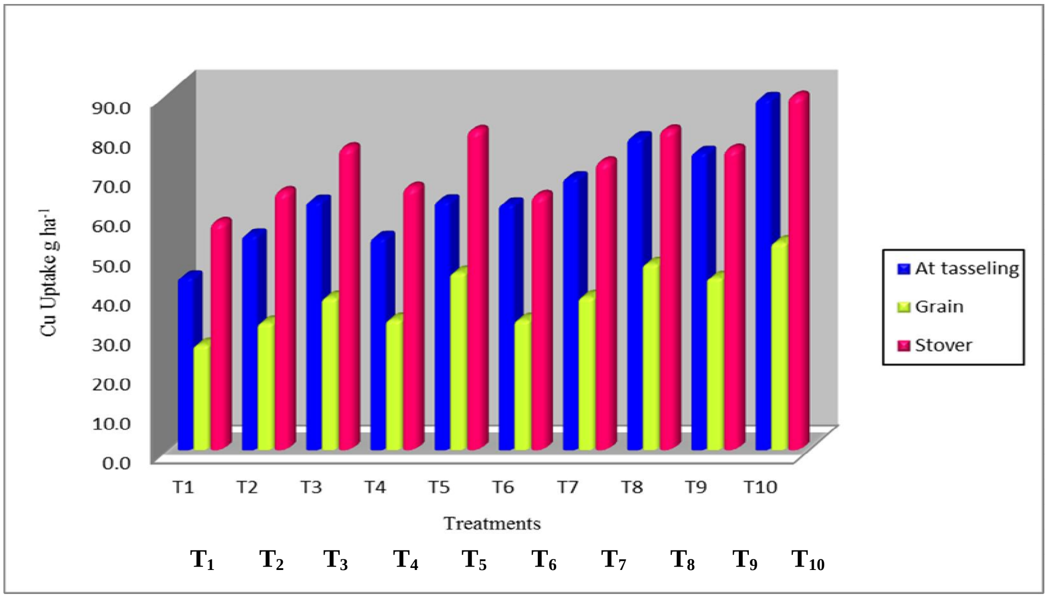
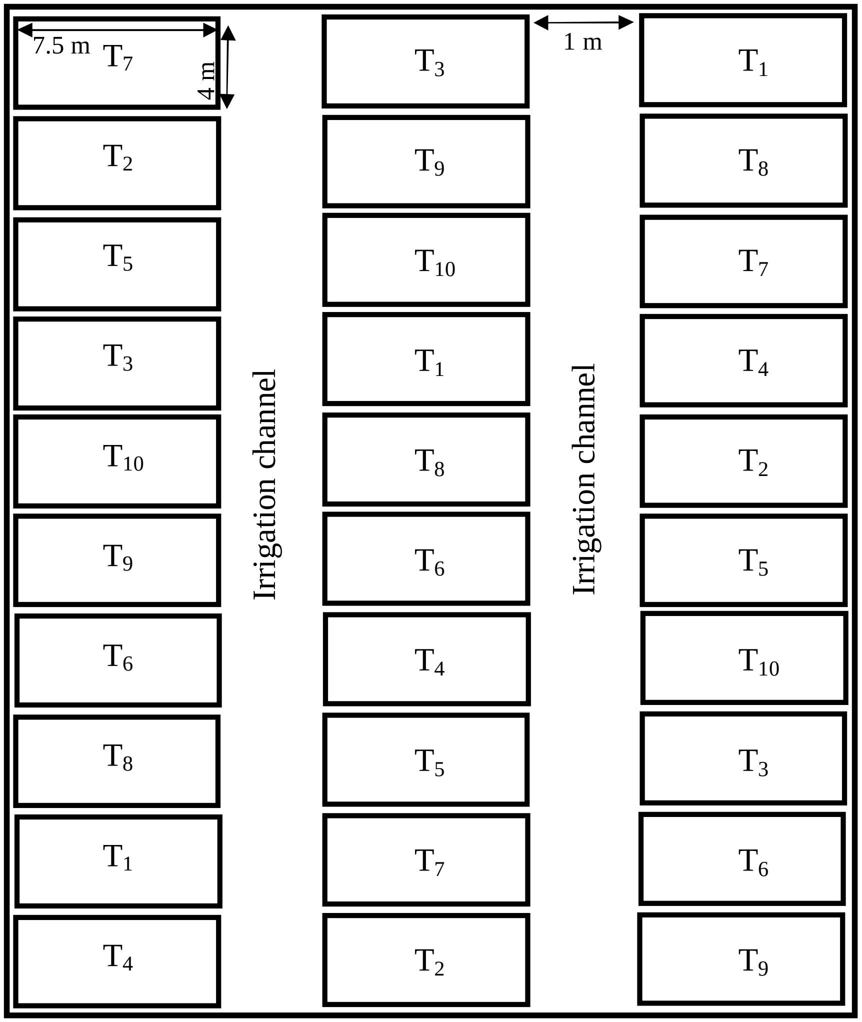
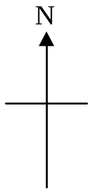


Figure 4.10. Copper uptake by maize as influenced by various treatments



T_7	T_3	T_1
T_2	T_9	T_8
T_5	T_{10}	T_7
T_3	T_1	T_4
T_{10}	T_8	T_2
T_9	T_6	T_5
T_6	T_4	T_{10}
T_8	T_5	T_3
T_1	T_7	T_6
T_4	T_2	T_9

Figure 3.3 Layout plan of the experimental plot



Season: *kharif* 2011

Variety: Hybrid pioneer (30V92)

Spacing: 75cm x 20 cm

Gross plot size: 7.5m x 4 m

Net plot size: 4.5m x 3.2 m

Design : Randomised Block Design

Treatments

T_1: 100% RDFN

T_2: 100% RDFN + 25% N - FYM

T_3: 100% RDFN + 50% N - FYM

T_4: 100% RDFN + 25% N - PM

T_5: 100%RDFN + 50% N - PM

T_6: 125% RDFN

T_7: 125% RDFN + 25% N- FYM

T_8: 125% RDFN + 50% N -FYM

T_9: 125% RDFN + 25 % N – PM

T_{10}:125%RDFN + 50% N-PM

General view of the experimental plot

Plate 1 : General view of the experimental plot at tasseling stage

Plate 2 : General view of the experimental plot at harvest stage

Chapter IV

RESULTS AND DISCUSSION

The present investigation entitled "Effect of integrated nutrient management on soil properties and performance of maize (*Zea mays* L.)" was undertaken on a sandy loam soil during *kharif*, 2011 at Agricultural College Farm, Bapatla. The results obtained from the experiment were analysed statistically and are presented and discussed in this chapter with cause, effects and corroborative research findings under the following heads.

4.1. WEATHER CONDITIONS DURING CROP GROWTH

The weather factors viz., temperature, relative humidity and rainfall were normal during the crop growth period without any major fluctuations (Table 3.1). The average maximum and minimum temperatures during crop growth period were 32.8^0C and 20.4^0C, respectively. The weekly mean relative humidity was 77 per cent. A total rainfall of 406.5 mm was received during the period of experimentation. In general, the weather was congenial for the successful growth of the crop.

4.2 EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON PERFORMANCE OF MAIZE

4.2.1. Yield Components

The data pertaining to yield components viz. thousand grain weight, no. of grains per cob, weight of grains and shelling percentage are presented in the table 4.1.

4.2.1.1 Thousand grain weight

The grain yield is a function of combined effect of the individual yield components nourished under applied inputs and 1000-grain weight is important one of them. The data indicated that 1000-grain weight was significantly affected by different levels of organic and inorganic fertilizers. The maximum 1000-grain weight (313.7 g) was recorded in T_{10} (125%RDFN + 50% N - PM) followed by T_8 (125% RDFN + 50% N - FYM), T_9 (125% RDFN + 25 % N - PM) and T_7 (125% RDFN + 25% N - FYM) and were on par with one another. The minimum 1000-grain weight (256.1 g) was recorded in T_1 where 100 per cent RDFN was applied which was on par with T_3 (100% RDFN + 25% N - FYM), T_6 (125% RDFN) and T_2 (100% RDFN + 25% N - FYM). The treatments which received higher level of nitrogen either through FYM/ poultry manure or inorganic nitrogen recorded higher 1000 grain weight compared to lower level of nitrogen and 100 per cent recommended dose of fertilizer nitrogen which might be due to balanced supply of nutrients from both inorganic source and poultry manure throughout the plant growth. Similar higher values of 1000 grain weight with higher doses of nitrogen were also reported by Onasanya *et al.* (2009).

Comparatively, treatments receiving poultry manure recorded noticeable increase in 1000-grain weight than FYM treatments at different levels of nitrogen due to the production of larger and heavier grains in those treatments. This might be due to the accelerated mobility of photosynthates from the source to sink as influenced by the growth hormones synthesized due to application of poultry manure (Anuradha, 2003). These results are in accordance with the findings of Ma *et al.* (1999) and Garg and Bahla (2008).

4.2.1.2 No. of grains per cob

The highest number of grains per cob was observed in T_{10} (125% RDFN + 50% N-PM). The next best treatment was T_8 (125% RDFN + 50% N - FYM) which was followed by T_9 (125% RDFN + 25 % N - PM). The lowest number of grains per cob was observed in T_1 (100% RDFN) and it was on a par with T_6 (125% RDFN). Among the integrated treatments, T_8 and T_{10} which received 175 per cent of nitrogen through urea and either FYM or poultry manure were found to be superior over the treatments which received 150 and 125 per cent nitrogen indicating the positive response of crop to higher level of nitrogen and beneficial effects of organic manures in transportation of growth stimulating materials through phloem tissues thereby resulting in enhanced cell division and grain number. Similar results were also obtained by Raisi and Nejad (2012).

4.2.1.3. Weight of grains per cob

The results presented in table 4.1 indicated that weight of grains per cob varied from 68.0 to 105.3 with a mean value of 83 g. The highest was recorded in T_{10} (125% RDFN + 50% N-PM) and the lowest was observed in T_1 (100% RDFN). Weight of grains per cob also followed same trend among the treatments as that of other yield components.

Application of nitrogen either through inorganic or organic sources positively influenced the 1000 grain weight and no. of grains per cob, which in turn increased the weight of grains per cob. The significantly higher weight of grains per cob in treatments including organic manures might be due to steady supply of nutrients throughout the growing period of the crop. The positive response of crop to poultry manure may be due to higher quantity of phosphorus and secondary nutrients supplied through it. The plants with ample phosphorus might have showed the highest meristematic activity which resulted in increase in number of flowers and fruit setting percentage per plant. Similar opinion was expressed by Mosali *et al*. (2006).

4.2.1.4 Shelling percentage

The perusal of data presented in table 4.1 indicated that shelling percentage of maize was not influenced significantly by different treatments. However, higher shelling percentage was observed in treatments which received higher level of nitrogen than the treatments with lower level of nitrogen. Numerically the highest and lowest shelling percentage was observed in T_{10} (125%RDFN + 50% N-PM) and T_6 (125% RDFN) with 68.8 and 62.3 per cent, respectively.

4.2.2 Yield

The drymatter produced at tasseling, grain and stover yields at harvest and harvest index are presented in table 4.2 and depicted in figures 4.1, 4.2 and 4.3.

4.2.2.1 Drymatter at tasseling

The drymatter production at tasseling ranged from 4187 to 6337 kg ha^{-1} with a mean value of 5190 kg ha^{-1}. The highest dry matter production was observed in T_{10} where 125 per cent fertilizer nitrogen was applied along with 50 per cent nitrogen through poultry manure which was 51.3 per cent higher than 100 per cent RDN. This was statistically on par with T_8 (125% RDFN + 50% N - FYM) and T_9 (125% RDFN + 25 % N - PM) with 5910 and 5656 kg ha^{-1} drymatter production, respectively. The lowest drymatter (4187 kg ha^{-1}) was observed in T_1 which received the sole application of fertilizer nitrogen at 100 per cent RDN which was on par with T_2 (100% RDFN + 25% N - FYM) and T_4 (100% RDFN + 25% N - PM). The treatments which received 150 per cent RDN through urea and poultry manure/ FYM (T_3, T_5, T_7 and T_9) were not significantly different from each other but were superior over the application of 100 per cent RDFN (T_1). There was a significant increase in drymatter production from 4187 to 4954 kg ha^{-1} with increased level of fertilizer nitrogen from 100 to 125 per cent of recommended dose which was 18.3 per cent higher.

Superiority of integrated treatments in drymatter production over sole inorganic nitrogen application (100 and 125 per cent recommended dose) might be due to improved physical conditions of soil and microbial activity, resulting in enhanced nutrient availability and also increased uptake of nutrients consequently leading to higher drymatter production. The existence of significant positive correlation between drymatter yield and organic carbon (r= 0.7601*), available N (r= 0.9673**), available K_2O (r= 0.7048*), available Mn (r= 0.6393*) and available Fe (r= 0.6818*) further strengthens these observations (Table 4.13). These results narrate the findings of Waseem *et al.* (2011) who suggested that enhancement in dry matter accumulation was due to availability of nitrogen to plant at proper time and in proper proportion. Similar results were also reported by Baruah *et al.* (1999) and Indumati (2000). The rate of increase in drymatter accumulation was more when poultry manure was applied instead of FYM. The reason for this might be the narrow C: N ratio in poultry manure which hastens the mineralization process and higher availability of the nutrients during crop growth.

4.2.2.2 Grain yield

The data pertaining to grain yield is presented in the table 4.2. All the treatments which received organic manures along with inorganic nitrogen exerted a significant influence on grain yield except T_2. Grain yield ranged from 4747 to 7225 kg ha^{-1} with a mean value of 6062 kg ha^{-1}. The highest grain yield (7225 kg ha^{-1}) was recorded with application of T_{10} which received 175 per cent of recommended dose of nitrogen (125 per cent through urea and 50 per cent through poultry manure) and significantly the lowest grain yield (4747 kg ha^{-1}) was obtained in T_1 (100% RDFN). The increase in grain yield in T_{10} was 52 per cent over T_1. Application of 125% RDFN + 50% N through FYM (T_8) was identified as the next best treatment followed by 125% RDFN + 25% N through poultry manure (T_9). However, these three treatments were found on par with one another. The treatments which received 150 per cent of recommended nitrogen (T_3, T_5, T_7 and T_9) were on par with each other, however the treatments T_7 and T_9, which received higher level of inorganic nitrogen (125%) produced higher grain yields than that of T_3 and T_5 (100%). The treatments T_2 and T_4 which received 125 per cent recommended dose of nitrogen (100 per cent nitrogen as urea and 25 per cent nitrogen either through poultry manure or FYM) were on par with T_6 which received entire nitrogen through urea. With increased level of inorganic nitrogen from 100 to 125 per cent, a significant increase in grain yield of 22 per cent was observed. Integrated application of inorganic nitrogen with poultry manure was found to be superior to FYM at all levels of nitrogen.

The increase in grain yield under organic manure treated plots might be due to better and continuous availability of nutrients for plants up to cob development which ultimately increased the grain yield (Farhad *et al*., 2009). As compared to the use of N, P and K fertilizer alone, its combined use with organic manures ensured more availability of essential nutrients such as Mg, Fe, Zn, Mn and Cu. This was further substantiated by positive relationship of grain yield with organic carbon and available N, P, K, Fe, Zn, Mn and Cu content of soil (Table 4.13). The findings are in conformity with those of Shilpashree *et al.*

(2012), who reported that the higher grain yield was due to optimum supply of nutrients at right time of crop requirement and increased translocation of photosynthates from leaves to the sink for better development of grains. Maize responds well to fertilizer application as a result of its well-developed root system which absorbs required nutrients for effective dry matter production. Similarly, Ayeni and Adetunji (2010) stated that addition of poultry manure or FYM along with NPK fertilizers assures a more balanced nutrition and residual effect of the nutrients. Boateng *et al*. (2006) recommended the combined application of poultry manure and NPK because of the complementary and synergistic effects of the fertilizers on maize growth and yield.

Higher yields in treatments with poultry manure as organic source can be ascribed to the higher concentrations of macro and micro nutrients in poultry manure.

4.2.2.3 Stover yield

The results indicated that stover yield ranged from 7497 to 9825 kg ha^{-1} with a mean value of 8626 kg ha^{-1}. The highest stover yield (9825 kg ha^{-1}) was observed when 125 per cent of recommended dose of fertilizer nitrogen (RDFN) was applied along with 50 per cent of nitrogen through poultry manure (T_{10}) which was on par with T_8 which received 50 per cent nitrogen through FYM (9348 kg ha^{-1}) and T_9 (125% RDFN + 25 % N - PM; 9144 kg ha^{-1}). The treatments T_3, T_5, T_7 and T_9 were on par with each other. The lowest stover yield (7497 kg ha^{-1}) was observed in T_1 (100% RDFN) which was found on par with T_2 (100% RDFN + 25% N – FYM) and T_4 (100% RDFN + 25% N - PM) but was significantly different from T_6 which received 125 per cent RDFN as urea.

Among the treatments which received poultry manure, the highest stover yield was obtained by adding it @ 50 per cent of recommended nitrogen along with either 100 or 125 per cent of RDFN. Similar trend was observed in the case of FYM also. The poultry manure treatments performed better than their corresponding treatments of FYM.

The production of organic acids and growth promoting substances during decomposition of organic manures might have facilitated easy availability of macro as well as micronutrients. Adequate supply of nutrients to the crop helps in the synthesis of carbohydrates, which are required for the formation of protoplasm, thus resulting in higher cell division and cell elongation. Thus an increase in stover yield might have been on account of overall improvement in the vegetative growth of the plant due to the application of organic manures in combination with inorganic N fertilizer.

Similar results were obtained by Makinde and Ayoola (2010) who reported that conjunctive application of organic and inorganic fertilizers is effective for the growth of maize and improving the yields. This might be due to addition of organic material which can markedly increase soil productivity by providing essential plant nutrients and by improving physical properties (Shah *et al.*, 2010).

4.2.2.4 Harvest index

Conversion of dry matter into economic yield is a physiological ability of a genotype and is expressed as harvest index (HI). Harvest index of maize did not differ significantly among the treatments. Numerically the highest harvest index (42.6%) was observed in T_5 (100% RDFN + 50% N – PM) and the lowest (39.1%) was observed in T_1 (100% RDFN). This was corroborated with the findings of Nagaraj *et al.* (2004) who also reported non-significant effect of poultry manure and FYM on harvest index of maize.

4.2.3 Nutrient Uptake

The plant samples collected at tasselling and grain and stover at harvest were analysed for nitrogen, phosphorus and potassium content and computed for uptake.

4.2.3.1 Macronutrients

The data on contents and uptake of nitrogen, phosphorus and potassium in drymatter at tasseling and in grain and stover at harvest are furnished in the tables 4.3 and 4.4, respectively and depicted graphically in figures 4.4, 4.5 and 4.6.

N, P and K contents

Significant difference was not observed in nitrogen, phosphorus and potassium contents of maize among the various treatments. The nitrogen content was higher at tasseling stage compared to grain and stover at harvest in all the treatments. The highest nitrogen content was recorded in T_{10} (175% recommended nitrogen by integrating 125% nitrogen through fertilizer and 50% nitrogen through poultry manure) at tasselling (3.10%), in grain (1.93%) and stover (1.07%) followed by T_8 (125% RDF + 50% N through FYM). The same trend was observed with respect to phosphorus content at tasseling and harvest. The highest phosphorus content at tasseling and in grain and stover at harvest was 0.40, 0.35 and 0.21 per cent, respectively. More content of nitrogen and phosphorus were accumulated in maize grain than stover in each treatment.

Similarly the highest potassium content at tasseling and at harvest in grain and stover were recorded in T_{10} (2.18, 0.62 and 1.63 %, respectively) whereas lowest content was observed in T_1 (1.80, 0.42 and 1.33%, respectively). The content of potassium in maize decreased from tasseling to harvest and a higher content of potassium was observed in stover than grain in all treatments. The decrease in N, P and K concentrations with plant maturity might be due to the dilution effect of the high rate of dry matter accumulation. Similar decrease in nutrient concentration with maturity was reported by Samarah *et al*., (2010).

Among different levels of nitrogen application, higher contents of nitrogen, phosphorus and potassium were recorded in treatments which received 50 per cent of extra nitrogen through FYM/ poultry manure than the treatments which received only 25 per cent extra nitrogen at both the stages of crop growth.

The integrated application of FYM/ poultry manure and inorganic nitrogen resulted in higher nutrient contents at both the stages of crop growth compared to sole application of inorganic nitrogen. This might be due to the fact that inorganic fertilizer component provided nutrients during the early vegetative growth stage, while the organic component provided nutrients at the later stage of the crop development as it takes some time for the mineralization. These results were in corroboration with those of Aziz *et al*. (2010).

Uptake of N, P and K

Significant influence of treatments on nitrogen, phosphorus and potassium uptake by maize was recorded at both stages of crop growth. The highest nitrogen uptake at tasselling (197 kg ha^{-1}), in grain (138 kg ha^{-1}) and stover (105 kg ha^{-1}) at harvest was recorded in treatment which received 175 per cent recommended nitrogen by integrating 125 per cent nitrogen through fertilizer and 50 per cent through poultry manure (T_{10}) followed by T_8 (125% RDF + 50% N - FYM), T_9 (125% RDFN + 25% N- PM) and T_7 (125% RDFN + 25% N - FYM). The lowest was observed in T_1 (100% RDFN), which was on par with T_2 (100% RDFN + 25% N - FYM).

Similarly the treatments T_{10} and T_8 which received the highest level (175%) of recommended nitrogen recorded higher phosphorus and potassium uptakes at tasseling and in grain and stover at harvest compared to the treatments which received 150 (T_3, T_5, T_7 and T_9) and 125 (T_2, T_4 and T_6) per cent of recommended nitrogen. The results also revealed that at same level of nitrogen, there was no significant difference in N, P and K uptakes at both stages of crop growth among the treatments. It was further observed that substitution of 25 per cent nitrogen through organic manures at 125 per cent recommended dose of nitrogen (T_2 and T_4) was on par with the sole application of fertilizer nitrogen (T_6). Increase in fertilizer nitrogen from 100 to 125 per cent of recommended dose recorded significant increase in nitrogen uptake by grain and stover, while there was no significant increase with respect to phosphorus and potassium uptake.

Higher biomass production might be the most pertinent reason for the higher uptake of nutrients in the treatments which received higher levels of recommended nitrogen. This was evident from highly significant relation between soil available nitrogen with dymatter production, grain and stover yields at harvest (Table 4.13). However, the treatments which received higher level of FYM/ poultry manure showed higher uptake of nitrogen which might be due to the greater capacity of applied organic manures to retain nutrients in forms that can easily be taken up by plants over a longer period of time. The nutrients in the inorganic fertilizer are already in the mineral form and it provides a ready source of nutrients to the crop and are available for a short period of time. Similarly, Adeniyan *et al.,* (2011) reported that leaching of nutrients may be higher in the soil treated with NPK fertilizer rather than the soil treated with organic manures. Poultry manure performed better over FYM owing to its low C: N ratio and faster mineralization.

The ability of a plant to take up phosphorus is largely due to its root distribution relative to phosphorus in soil. Because phosphorus is very immobile in the soil, it does not move very far in the soil to get in contact with roots. Application of organic manures have improved the soil environment, which encouraged proliferous root system resulting in better absorption of water and nutrients from lower layers and thus resulting in higher yield and nutrient uptake (Thenmozhi and Paulraj, 2009). Similar results were also reported by Pathak *et al.* (2005).

Similarly, higher uptake of K under integrated inorganic and organic nitrogen management might be due to release of K from organic manures during decomposition and increase of native K availability. Similar results were also reported by Bhandari *et al.* (1992) and Baruah *et al.* (1999). Results obtained from this study implied that nitrogen application had much greater effect on uptake of other nutrients and there by yield. This can be explained by the fact that the supply of nitrogen enhanced the development of small root hairs which in turn facilitated the absorbing ability per unit dry weight (Hammad *et al.*, 2011). In general, high uptake of nutrients in organic treatments could also be due to the addition of extra quantities of phosphorus and potassium along with nitrogen.

4.2.3.2 Micronutrients

The data on content and uptake of iron, zinc, manganese and copper in drymatter and in grain and stover at harvest are presented in the tables 4.5, 4.6, 4.7 and 4.8 and depicted graphically in figures 4.7, 4.8, 4.9 and 4.10.

Fe, Zn, Mn and Cu contents in maize

Iron, zinc, manganese and copper contents in maize at tasseling and in grain and stover at harvest were not significantly influenced by the treatments. However, the treatments which received 50 per cent nitrogen through FYM or poultry manure (T_3, T_5, T_8 and T_{10}) either at 150 or 175 per cent of recommended dose of nitrogen recorded higher iron, zinc, manganese and copper contents of drymatter at tasseling and in grain and stover at harvest followed by T_7 and T_9 with 25 per cent nitrogen supplied through FYM or poultry manure. Compared to the sole application of fertilizer nitrogen (T_6), integrated application of fertilizer nitrogen along with FYM or poultry manure at 125 per cent recommended nitrogen recorded higher values with respect to all catioinic micronutrients, while the lowest contents were recorded in T_1 where 100 per cent RDFN was applied.

Uptake of Fe, Zn, Mn and Cu

The iron, zinc, manganese and copper uptakes at tasseling and in grain and stover at harvest were significantly affected by different treatments. The highest iron uptake at tasseling was recorded in T_{10} (125%RDFN + 50% N- PM) which was on par with T_8 (125% RDF + 50% N - FYM), T_5 (100%RDFN + 50% N – PM) and T_9 (125% RDFN + 25% N- PM) while in case of zinc, the treatments were in the order of $T_{10} > T_8 > T_9 > T_5$. The total uptake of iron and zinc at harvest recorded higher values compared to tasseling in all the treatments. At different levels of recommended nitrogen in combination with FYM or poultry manure (either at 25 or 50% N supplementation) poultry manure was superior with respect to iron and zinc uptake by crop.

The manganese and copper uptakes by crop at tasseling and in grain and stover at harvest were significantly affected by different treatments. The highest manganese and copper uptake at tasseling was recorded in T_{10} (307 and 88.4 g ha^{-1}) which was on par with T_8 (284 and 78.4 g ha^{-1}) and T_9 (272 and 74.8 g ha^{-1}) and the lowest was observed in T_1 (190 and 43.2 g ha^{-1}). The total uptake of manganese at harvest followed the same trend while in the case of copper the treatments were in the order of $T_{10} > T_8 > T_5$. Lowest uptake of manganese and copper both at tasseling and harvest were recorded in T_1 (190 and 43.2 at tasseling; 463 and 83.2 g ha^{-1} at harvest).

Uptake of micronutrients was improved when organic manure was added along with chemical fertilizers. The increase in the uptake of cationic micronutrients with the application of FYM or poultry manure along with inorganic nitrogen might be due to the release of micronutrients on mineralization or production of organic acids during their decomposition which aids in solubilization of insoluble micronutrient compounds in soil or due to supply of natural chelating agents which renders it more available (Stevenson and Ardakani, 1972). The uptake of micronutrients were higher in poultry manure treatments compared to the corresponding FYM treatments which might be due to the presence of micronutrients like iron, zinc, manganese and copper in ample quantities in it and slow release of these micronutrients into the soil solution which facilitated more uptake (Simpson, 1990). The increased absorption of micronutrient cations also might be due to complexing properties of poultry manure which prevent precipitation, fixation of these nutrients and keep them in soluble form (Prasad *et al.*, 1984 & Sinha and Prasad, 1997).

4.3 EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON SOIL PROPERTIES

4.3.1 Physical Properties

Bulk density

The data in the table 4.9 indicated that bulk density of soil at harvest of the crop was not significantly influenced by the various treatments. However there was a marginal reduction in integrated treatments which received fertilizer nitrogen and FYM/ poultry manure than sole fertilizer nitrogen. The lowest bulk density was observed in treatments which received 50 per cent of nitrogen through FYM along with 100 or 125 per cent of nitrogen through urea (T_3 and T_8) and the highest was observed in treatment which received 100 per cent RDFN (T_1). Lowering of bulk density by application of organic manures under long term experiments was reported by Thakur *et al.* (2011) and Selvi *et al.* (2005) who reported that reduction in bulk density is due to higher organic carbon, more pore space and good soil aggregation. Non-significant effect of manures on bulk density was because of shorter time period of study. It has also been well documented by several workers that a greater quantity of organic material is needed to improve soil structural properties.

4.3.2 Physico-Chemical Properties

Soil pH and electrical conductivity

The data in table 4.9 indicated that there was no significant effect on soil reaction and electrical conductivity by the imposed treatments. Numerically the highest pH (7.54) was observed in T_6 (125% RDFN) and the lowest (7.37) was observed in T_7 (125% RDFN + 25% N - FYM). However the pH decreased in all treatments as compared to the initial pH of experimental soil and the decrease was more in treatments which received FYM/ poultry manure at different levels along with inorganic fertilizers at 125, 150 or 175 per cent of RDN.

Several researchers (Marschner, 1995 and Walker *et al.*, 2004) observed changes in soil pH on addition of organic manure owing to organic matter oxidation and release of CO_2 in the soil. The release of organic acids during decomposition of manures results in slight decline of pH (Babu *et al.*, 2007). However, the effect was non-significant, might be because of short duration of present study.

Non-significant effect of applied sole inorganic fertilizers or in combination with FYM/ poultry manure on electrical conductivity at different levels might be due to balanced fertilization, which might not have allowed an increase in salt concentration. This was corroborated with the findings of Badanur *et al.* (1990) and Kumar *et al.* (1995) who reported no change in electrical conductivity even after five years of continuous cropping. The total soluble salt content remained unaltered due to the fact that the doses of fertilizers added in different treatments were quite small and salts added through fertilizers might have been leached down due to good number of irrigations and rains received by crop (Venkatesh, 1995).

Cation Exchange Capacity

The data pertaining to cation exchange capacity (CEC) of soils at harvest is presented in table 4.9. The CEC of soils was not significantly influenced by different treatments and it ranged from 14.1 to 17.9 cmol (p+) kg^{-1} with a mean value of 16.0 cmol (p+) kg^{-1}. The highest CEC was observed in T_8 (125% RDF + 50% N - FYM) which was followed by T_3 (100% RDFN + 50% N – FYM), T_{10} (125%RDFN + 50% N- PM) and T_5 (100%RDFN + 50% N – PM). The lowest was observed in T_1 (100% RDFN). It was inferred that CEC of the soil was increased at harvest as compared to that of initial soil and that increase was higher in treatments which received higher levels of organic manure especially through FYM. Similar influence of integrated nutrient supply system on CEC was earlier reported by McConnell *et al.* (1993); Pareek and Yadav (2011). Applied organic manures decompose in soils to form humus and humic substances, which play a dominant role along with clay micelle in the complex soil reactions that enhance the CEC of soils (Adeniyan *et al.*, 2011).

4.3.3 Available Nutrient Status

4.3.3.1 Organic carbon and macronutrient status

The data pertaining to organic carbon content, available nitrogen, phosphorus and potassium are presented in table 4.10.

Organic Carbon

The data presented in table 4.10 revealed significant improvement in organic carbon content of soils with the application of 125 per cent RDFN along with 50 per cent N through FYM (T_8) both at tasseling (3.8 g kg^{-1}) and harvest (3.2 g kg^{-1}) of the crop over the initial (1.9 g kg^{-1}) and the treatments T_1 and T_6 which received sole fertilizer nitrogen. The treatment T_8 was statistically on a par with all the treatments which received 50 per cent of nitrogen through FYM/ poultry manure along with inorganic fertilizers at 150 and 175 per cent of RDN at tasseling. There was no significant difference in organic carbon content with increase in inorganic nitrogen level from 100 to 125 per cent RDN, but these treatments recorded significantly lower organic carbon content than the treatments which received 25 per cent nitrogen through FYM/ poultry manure at 125 per cent RDN (T_2 and T_4). Though there was an increase in organic carbon content in soil at both stages of crop growth as compared to initial soil, all the treatments at harvest recorded lesser amounts as compared to tasseling. This might be due to loss of applied organic matter by oxidation.

The significant increase in organic content in all the treatments with integrated use of nutrient sources as compared to use of inorganic fertilizer alone might be due to the enhanced root growth, which leads to the accumulation of organic residues and also direct incorporation of organic matter through FYM and poultry manure in the soil. These findings are in agreement with that of Sharma and Gupta (1998).

Higher level of organic manure application might have created environment conducive for the formation of humic acid which stimulated the activity of soil microorganisms resulting in an increase in the organic carbon content of soil (Bajpai *et al.*, 2006). The differences in the organic carbon content of soil with application of FYM/poultry manure might be due to the differences in organic carbon content which results in differential rate of oxidation of organic matter by microbes. Improvement in organic carbon status with increasing level of fertilizer nitrogen from 100 to 125 per cent over initial soil organic carbon content could be attributed to increased contribution from increased biomass production as it was observed that with increased level of fertilizer application the crop yields had increased (Table 4.2).

Nitrogen

Data pertaining to the available nitrogen content of the soils at tasseling and harvest presented in the table 4.10 and depicted in figure (4.11) revealed that there was an increase in available nitrogen content both at tasseling and harvest of crop over the initial soil status (122 kg ha^{-1}). The maximum available nitrogen both at tasseling and harvest (196 and 162 kg ha^{-1}) was recorded with T_{10} (125%RDFN + 50% N-PM), whereas the lowest (154 and 125 kg ha^{-1} was recorded with T_1 (100% RDFN). Comparatively the treatments which received higher level of recommended nitrogen maintained higher nitrogen content at both the stages of the crop.

The higher availability of nitrogen in soil by application of organic manures can be attributed to mineralization of organic forms of nitrogen from the manures. Though equal quantities of nitrogen was applied through FYM and poultry manure at different levels of nitrogen, slightly higher available nitrogen was observed in poultry manure treated plots due to its narrow C: N ratio. The low available nitrogen status at both stages in sole inorganic nitrogen treated plots might be ascribed to higher leaching loss of nitrogen compared to integrated treatments.

The higher content of available nitrogen at tasseling in all the treatments compared to harvest was due to application of fertilizers only upto tasseling stage and also due to higher utilization by crop during grain formation.

Phosphorus

Available phosphorus was significantly influenced by different treatments at tasseling and harvest of crop. The highest available phosphorus at tasseling and harvest stages was observed in T_5 (100% RDFN + 50% N – PM) which was 36.9 and 31.9 per cent, respectively higher than initial available phosphorus status of soil. This was followed by T_{10} (125%RDFN + 50% N- PM), T_3 (100% RDFN + 50% N – FYM) and T_8 (125% RDFN + 50% N - FYM). The lowest was observed in T_6 (125% RDFN) at both stages and there was 6.4 per cent decrease over initial phosphorus status at harvest. At the same level of nitrogen with increase in substitution of nitrogen from 25 to 50 per cent either through FYM or poultry manure increased the phosphorus availability status of soil both at tasseling and harvest. However the treatments which received poultry manure maintained higher phosphorus status.

The increase in available phosphorus content of soil due to application of FYM/ poultry manure may be attributed to the direct addition of phosphorus as well as solubilization of native phosphorus through release of organic acids. Similar improvement in available phosphorus status due to integrated use of manures and fertilizers has been reported by Sharma and Saxena (1985) and Zhang *et al*. (1998) who reported that precise application of manure and fertilizer to maize can be as effective as commercial N fertilizer for yield response. Moreover, phosphorus is relatively immobile nutrient which moves in soil by diffusion and is regulated by soil moisture (Marschner, 1995). Addition of organic manure increases soil moisture content (Boateng *et al*., 2006) thereby improving the P availability in soil.

The higher phosphorus availability in poultry manure (1.8%) treated plots might be due to its higher phosphorus content over FYM (0.36%), moreover, low C:N ratio experienced by poultry manure might have enhanced faster decomposition of poultry manure (Titiloye, 1992) and thereby enhanced more and quick release of phosphorus.

Potassium

The perusal of data presented in table 4.10 indicated that available potassium was significantly influenced by different treatments at tasseling and harvest. Maximum available K contents at tasseling (461 kg ha^{-1}) and harvest (439 kg ha^{-1}) were observed in T$_{10}$ (125% RDFN + 50% N- PM), which was 17.6 per cent and 13.3 per cent higher than initial available K (392 kg ha^{-1}), respectively. This was on par with all treatments which received poultry manure along with inorganic nitrogen and those which received 50 per cent RDN through FYM along with inorganic nitrogen *i.e.* T$_3$, T$_4$, T$_5$, T$_8$ and T$_9$. The lowest was observed in T$_6$ (125% RDFN) both at tasseling (414 kg ha^{-1}) and harvest (397 kg ha^{-1}).

The higher buildup of available potassium in the soil treated with FYM/ poultry manure compared to sole inorganic nitrogen treated soil might be due to addition of potassium to available pool of the soil. In addition, the organic acids released during decomposition of manures mobilize the native or non-exchangeable forms of potassium and charge the soil solution with potassium ions, so that it will be readily available (Anuradha, 2003). Further increase in available potassium due to addition of poultry manure can be attributed to its high concentration of potassium. The results were corroborated with the findings of Babu *et al*. (2007).

4.3.3.2 Available Micronutrients

The status of available micronutrients viz., Fe, Zn, Mn and Cu was significantly influenced by different treatments at tasseling and harvest (Table 4.11). The maximum availability of cationic micronutrients was observed in T_{10} (125%RDFN + 50% N- PM) which was followed by T_5 (100% RDFN + 50% N – PM). An increase of 27.3, 26.0, 8.0 and 15.5 per cent than initial Fe, Zn, Mn and Cu contents, respectively was observed under T_{10} (125%RDFN + 50% N-PM) at harvest. The lowest contents of micronutrient cations were observed in T_1 (100% RDFN) at tasseling and harvest. The contents of all the micronutrients decreased with maturity of the crop in all the treatments. Critical observation of the data presented in table 4.11 inferred a no significant difference in Fe, Zn, Mn and Cu contents with increase in fertilizer nitrogen level from 100 to 125 per cent at both the stages of crop growth. However, the treatments which received higher levels of FYM/ poultry manure (@ 50% RDN) (T_3, T_5, T_8 and T_{10}) maintained higher contents of nutrients than the treatments which received lower levels of FYM/ poultry manure (@ 25% RDN) (T_2, T_4, T_7 and T_9). Relatively higher contents of available Fe, Zn, Mn and Cu in poultry manure treatments over FYM were observed at tasseling and harvest of crop.

The maximum availability of Fe, Zn, Mn and Cu in soils treated with FYM/ poultry manure might be due to their release through mineralization of manures and also due to production of chelating agents which have the ability to reduce their adsorption, fixation and precipitation resulting in their enhanced availability in soil (Kher, 1993).

Decrease in pH of soils by application of organic manure also might have increased the availability of micronutrients in soil. Sanders *et al.* (1986) found that each unit decrease in pH results in approximately two times increase in the concentrations of metals in soil solution. Similar results were also reported by Prasad *et al.* (2010).

4.3.4 Urease Activity

Data presented in the table 4.12 indicated that urease activity of the soils at tasseling and harvest of crop was significantly influenced by different treatments. Urease activity at tasseling ranged from 9.8 to 17.0 µg NH_4^+ - N g^{-1} soil h^{-1} with a mean value of 13.9 µg NH_4^+ - N g^{-1} soil h^{-1} while at harvest, it was from 6.8 to 9.8 µg NH_4^+ - N g^{-1} soil h^{-1} with a mean value of 8.3 µg NH_4^+ - N g^{-1} soil h^{-1}. The highest urease activity at tasseling and harvest was found in T_{10} (125%RDFN + 50% N- PM) which was followed by T_8 (125% RDF + 50% N - FYM). The lowest was observed in T_1 (100% RDFN) which was on par with T_2 (100% RDFN + 25% N - FYM) at tasseling and with T_2 (100% RDFN + 25% N - FYM) and T_4 (100% RDFN + 25% N - PM) at harvest.

There was a significant increase in urease activity with increase in fertilizer nitrogen from 100 to 125 per cent recommended dose both at tasseling (9.8 to 14.5 µg NH_4^+ - N g^{-1} soil h^{-1}) and harvest (6.8 to 8.6 µg NH_4^+ - N g^{-1} soil h^{-1}). This might be due to addition of amide form of nitrogen through urea. In fact, the enzyme activity in the soil is very much governed by the nature of substrate present in the soil. The rate of urea hydrolysis by soil urease increases with increase in substrate (urea) concentration until the quantity of urea added is saturated and its activity becomes constant (Bremner and Mulvaney, 1978). The differences in urease activity between poultry manure and FYM at the same level of recommended dose of nitrogen was non-significant. However, the variability in enzyme activities of FYM and poultry manure was very much governed by their N content and C: N ratio. Similar results were also reported by Rai and Yadav (2011).

Maximum urease activity with increased rate of nitrogen application along with FYM/ poultry manure to soil might be due to added organic manures which acted as sole source of carbon and energy for microbes by which their population increased with an increase in enzymatic activities as also reported previously by Selvi *et al.* (2004) and Qureshi *et al.* (2005). This was evident from significant positive correlation between urease activity and organic carbon at tasseling (r= 0.5807) and harvest (r= 0.6701*) of crop. Similar relationships with organic carbon and enzyme activities were reported by Bohme and Bohme (2006). Further, the applied organic manures undergo mineralization and provide sufficient nutrition for the proliferation of microbes and their activities in terms of soil enzymes. This statement was further supported by a positive relationship of urease activity with available N, P, K, Fe, Zn, Mn and Cu at both stages as presented in table 4.14. Balanced nutrition of crop under integrated use of fertilizer nitrogen with FYM / poultry manure responsible for better proliferation of root was responsible for maximum activity of enzymes.

4.4 CORRELATION BETWEEN PERFORMANCE OF MAIZE AND SOIL PROPERTIES

Drymatter production at tasseling and grain and stover yields of maize at harvest were positively correlated with soil properties (Table 4.13). The organic carbon content of soil and drymatter yield at tasseling were positively and significantly correlated (r= 0.7601*), while grain and stover yields showed positive but non-significant correlation. The magnitude of relationships between available nitrogen and drymatter production at tasseling (r= 0.09673**), grain (0.8202**) and stover yields (0.7457*) at harvest was positively significant. Available P status of soil at harvest showed significant correlation with grain yield, while potassium was positively correlated. Similarly, grain and stover yield were positively correlated with available Fe, Zn, Mn and Cu in soil at harvest but significant correlation was observed between grain yield and iron, zinc and manganese. The significant and positive correlation of available soil nutrient status with drymatter at tasseling grain and stover yields at harvest indicated that the integrated use of inorganic and organic sources of nutrients not only produces higher yield but also maintains higher contents of soil nutrients in available form. Urease activity in soil showed significant positive correlation with yield (r= 0.9457**) and stover yield (r= 0.9599**) and drymatter production at tasseling (r =0.8987**). This showed that all the factors which affected higher yields and growth in maize positively influenced the urease activity in soil also

4.5 EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON NUTRIENT BALANCE

4.5.1 Nitrogen

The nitrogen balance in soil is given in table 4.15. Negative balance of nitrogen was observed in all treatments. The negative balance in the present study indicated that the N uptake by the crop exceeded the quantity of nitrogen applied which can be attributed to exhaustive nature of maize crop. The higher negative balance is recorded even in treatments which received higher (175%) level of nitrogen through urea and FYM/ poultry manure might be due the adequate addition of nutrients that stimulated biomass production and extracted considerable quantities of nitrogen from the soil. Similar results of nitrogen utilization were reported by Olasantan *et al.* (1995) and Amanullah *et al.* (2007) in maize and maize + cassava intercropping system, respectively. The variation in soil available nitrogen over initial status (residual nitrogen – initial soil nitrogen) showed that there was a net gain in soil available nitrogen after the harvest of crop. These results were in accordance with that of Balik *et al.* (2003) who suggested that a certain movement of nitrogen occurred in all fertilized treatments although the intensity of fertilization was much lower than nitrogen uptake by biomass. The root system of maize would penetrate to a depth of more than 60 cm in the soil and nitrogen from the lower layers would also be taken up by the plants; in addition, there might be a movement of nitrate nitrogen towards the soil surface as a result of capillary rise of soil solution.

Among the treatments, the actual residual N content in the soil showed an increase of 3 to 40 kg ha^{-1} with the highest increase observed under the treatments where 50 per cent nitrogen was applied through FYM/ poultry manure along with inorganic fertilizers. Even after the completion of growing period of maize, mineralization of nitrogen could be continued and added to the soil pool (Bouldin *et al.*, 1988). This might have helped in maintaining the soil available nitrogen. Similar results were also observed by Amanullah *et al.* (2007).

4.5.2 Phosphorus

The phosphorus balance in soil is given in table 4.16. Mean positive phosphorus balance was observed in all treatments. This is due to lower requirement of phosphorus by crop. Such positive phosphorus balance was also reported by Wang *et al.* (2007). All treatments have positive phosphorus balance which lead to increase in extractable phosphorus in soil. However, only a fraction of the phosphorus added to the soil appeared as available phosphorus. This was shown as apparent loss in the table 4.16. Wang *et al*. (2007) suggested that the relatively low available P might be due to low P saturation index. Nevertheless, the treatments with received additional phosphorus through FYM and poultry manure showed a stronger response in extractable phosphorus than with fertilizer alone and maintained high residual phosphorus.

4.5.3 Potassium

The potassium balance in soil is given in table 4.17. Mean negative balance of potassium was observed in all treatments. The negative balance is due to the high potassium requirement by crop. All the treatments had negative potassium balance, but this negative balance did not lead to a strong drop in available soil K. The weak relationship between K balance and residual available K indicated that the soil had a high K buffering capacity. Conversely, available K in soil in all treatments was slightly higher at the end than the beginning of the experiment. Hoa *et al.* (2006) suggested that the available pool in the soil might have been strongly buffered by recalcitrant K pool in the soil. The available K values were higher in treatments with higher doses of organic manures than inorganic fertilizers suggesting that organic manures facilitated the transfer of K from recalcitrant pools to the available K pool (Wang *et al.*, 2007).

The nutrient losses in soil were calculated based on available nutrient status in the soil. However, the content of total nutrients in the soil should be determined to get a more accurate estimate of nutrient losses. The values can be 5 to 10 times greater than the available fraction generally determined (Howeler, 2001).

A positive partial balance denotes that the plant was not able to consume all that was applied during the period. On the other hand, a negative partial balance suggests that the crop uptake exceeded the fertilizer application. The deficit is thus derived from the soil nutrient stock. Therefore much attention is required in formulation of recommended doses especially for nitrogen and potassium requirement by crops to maintain sufficient nitrogen and potassium status in soils and to prevent mining.

4.6 EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON ECONOMICS

Economics of this study presented in table 4.18 revealed that the maximum gross returns was obtained by T_{10} (125%RDFN + 50% N-PM) which gave Rs. 97851 followed by T_8 (125% RDFN + 50% N -FYM - Rs. 92371). Maximum net returns of Rs. 67442 was obtained from T_{10} (125%RDFN + 50% N-PM) and it was followed by T_9 (125% RDFN + 25% N –PM- Rs. 58764). This can be attributed to higher cost of cultivation of FYM treatments due to higher cost of FYM than poultry manure. This was prominent in B:C ratio. B:C ratio of FYM treatments ranged from 1.3 to 1.7 while, poultry manure treatments ranged from 1.6 to 2.2. The highest B: C ratio (2.2) was observed in T_{10} (125%RDFN + 50% N-PM) while lowest (1.2) was observed in T_1 (100% RDFN). Similar reports of higher B: C ratio and net returns in maize by application of poultry manure compared to FYM were recorded by Prasannakumar *et al*. (2007).

Table 4.1. Effect of integrated nutrient management on yield components of maize

Treatments	1000 grain weight (g)	No. of grain per cob	Grain weight per cob (g)	Shelling percentage
T_1 : 100% RDFN	256.1	264.5	68.0	65.1
T_2 : 100% RDFN + 25% N - FYM	263.5	265.6	70.2	64.3
T_3 : 100% RDFN + 50% N - FYM	280.2	281.1	79.0	66.6
T_4 : 100% RDFN + 25% N - PM	270.3	275.6	74.3	64.6
T_5 : 100% RDFN + 50% N - PM	285.5	285.5	81.7	68.7
T_6 : 125% RDFN	276.2	283.7	78.3	62.3
T_7 : 125% RDFN + 25% N- FYM	290.6	299.2	87.0	67.9
T_8 : 125% RDFN + 50% N -FYM	307.9	310.1	95.3	64.6
T_9 : 125% RDFN + 25 % N – PM	291.3	321.8	93.7	66.0
T_{10} :125% RDFN + 50% N-PM	313.7	335.8	105.3	68.8
SEm±	7.8	13.6	4.7	2.3
CD (P = 0.05)	23.0	40.4	14.0	NS
CV%	4.7	8.1	9.8	6.0

Table 4.2. Effect of integrated nutrient management on drymatter production, yields and harvest index of maize

Treatments	**Dry matter production**	**Grain yield**	**Stover yield**	**Harvest index (%)**
	(kg ha^{-1})			
T_1 : 100% RDFN	4187	4747	7497	39.1
T_2 : 100% RDFN + 25% N - FYM	4618	5291	7973	40.0
T_3 : 100% RDFN + 50% N - FYM	5095	5979	8397	41.6
T_4 : 100% RDFN + 25% N - PM	4732	5615	8077	41.2
T_5 : 100% RDFN + 50% N - PM	5156	6353	8663	42.6
T_6 : 125% RDFN	4954	5783	8365	40.9
T_7 : 125% RDFN + 25% N - FYM	5255	6284	8968	41.3
T_8 : 125% RDFN + 50% N - FYM	5910	6818	9348	42.3
T_9 : 125% RDFN + 25 % N - PM	5656	6530	9144	41.8
T_{10} :125% RDFN + 50% N - PM	6337	7225	9825	42.3
SEm±	256	261	280	1.2
CD (P = 0.05)	761	776	833	NS
CV%	8.6	7.5	5.6	4.9

Table 4.3. Effect of integrated nutrient management on nitrogen, phosphorus and potassium contents in maize

Treatments	Nitrogen			Phosphorus			Potassium		
	(%)								
	Tasseling	Harvest		Tasseling	Harvest		Tasseling	Harvest	
		Grain	Stover		Grain	Stover		Grain	Stover
T_1 : 100% RDFN	2.70	1.66	0.83	0.40	0.35	0.21	1.80	0.42	1.33
T_2 : 100% RDFN + 25% N - FYM	2.80	1.73	0.88	0.45	0.37	0.26	1.94	0.50	1.42
T_3 : 100% RDFN + 50% N - FYM	2.91	1.79	0.93	0.53	0.40	0.29	2.07	0.55	1.49
T_4 : 100% RDFN + 25% N - PM	2.83	1.77	0.90	0.50	0.39	0.27	2.03	0.53	1.47
T_5 : 100% RDFN + 50% N - PM	2.93	1.80	0.98	0.57	0.43	0.32	2.10	0.57	1.55
T_6 : 125% RDFN	2.90	1.78	0.95	0.52	0.36	0.22	1.89	0.47	1.40
T_7 : 125% RDFN + 25% N - FYM	2.95	1.87	1.00	0.55	0.38	0.25	2.02	0.53	1.55
T_8 : 125% RDFN + 50% N - FYM	3.07	1.92	1.05	0.57	0.43	0.29	2.08	0.60	1.63
T_9 : 125% RDFN + 25 % N - PM	2.97	1.88	1.03	0.56	0.41	0.27	2.03	0.58	1.60
T_{10} :125% RDFN + 50% N - PM	3.10	1.93	1.07	0.62	0.44	0.32	2.18	0.62	1.63
SEm±	0.12	0.07	0.04	0.07	0.02	0.02	0.07	0.07	0.06
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	7.2	7.14	7.7	12	8.99	15.32	6.25	13	7

Table 4.4. Effect of integrated nutrient management on nitrogen, phosphorus and potassium uptakes by maize

Treatments	Nitrogen				Phosphorus				Potassium			
	(kg ha^{-1})											
	Tasseling	Harvest			Tasseling	Harvest			Tasseling	Harvest		
		Grain	Stover	Total		Grain	Stover	Total		Grain	Stover	Total
T$_1$: 100% RDFN	114	79	63	143	16.8	16.6	15.8	32.4	75	20	100	120
T$_2$: 100% RDFN + 25% N - FYM	129	91	70	162	20.8	19.8	20.8	40.6	90	26	113	139
T$_3$: 100% RDFN + 50% N - FYM	149	107	78	185	27.4	23.7	24.2	47.9	112	33	125	158
T$_4$: 100% RDFN + 25% N - PM	135	100	73	173	23.7	22.2	21.5	43.7	100	30	119	150
T$_5$: 100% RDFN + 50% N - PM	152	114	86	200	29.6	27.5	27.9	55.4	115	36	135	171
T$_6$: 125% RDFN	144	103	79	182	25.5	20.7	18.5	39.3	93	28	116	144
T$_7$: 125% RDFN + 25% N - FYM	155	119	90	208	28.7	23.9	22.3	46.2	102	33	139	172
T$_8$: 125% RDFN + 50% N - FYM	180	131	98	230	33.8	29.0	27.0	56.0	119	41	153	194
T$_9$: 125% RDFN + 25 % N - PM	167	122	94	216	31.8	26.9	25.3	52.2	113	38	146	185
T$_{10}$:125% RDFN + 50% N - PM	197	138	105	243	39.5	32.3	31.7	64.0	138	45	160	205
SEm±	11	7	5	9	4.2	2.2	2.2	3.5	8	4	8	10
CD (P = 0.05)	32	21	15	26	12.4	6.5	6.4	10.5	25	13	23	28
CV%	12.4	11.2	10.3	7.9	26.0	15.6	15.9	12.8	13.7	23.1	10.5	10.1

Table 4.5. Effect of integrated nutrient management on iron and zinc contents in maize

Treatments	Iron			Zinc		
	($\mu g\ g^{-1}$)					
	Tasseling	Tasseling		Tasseling	Tasseling	
					Grain	Stover
T_1 : 100% RDFN	125	35.8	35.8	35.8	142	231
T_2 : 100% RDFN + 25% N - FYM	139	36.1	36.1	36.1	151	234
T_3 : 100% RDFN + 50% N - FYM	159	37.5	37.5	37.5	157	243
T_4 : 100% RDFN + 25% N - PM	135	36.5	36.5	36.5	156	234
T_5 : 100% RDFN + 50% N - PM	173	38.0	38.0	38.0	154	242
T_6 : 125% RDFN	134	34.4	34.4	34.4	144	222
T_7 : 125% RDFN + 25% N - FYM	143	35.2	35.2	35.2	158	242
T_8 : 125% RDFN + 50% N - FYM	160	36.8	36.8	36.8	162	262
T_9 : 125% RDFN + 25 % N - PM	140	35.2	35.2	35.2	160	230
T_{10} :125% RDFN + 50% N - PM	166	36.8	36.8	36.8	165	260
SEm±	14	1.5	1.5	1.5	5	10
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
CV%	16.3	7.2	7.2	7.2	5.3	7.2

Table 4.7. Effect of integrated nutrient management on iron and zinc uptakes by maize

Treatments	Iron				Zinc			
	(g ha^{-1})							
	Tasseling	Tasseling		Total	Tasseling	Tasseling		Total
						Grain	Stover	
T_1 : 100% RDFN	528	674	1748	2422	150	114	147	261
T_2 : 100% RDFN + 25% N - FYM	640	801	1873	2674	167	146	175	321
T_3 : 100% RDFN + 50% N - FYM	794	938	2044	2982	190	182	198	379
T_4 : 100% RDFN + 25% N - PM	634	879	1892	2771	172	157	180	336
T_5 : 100% RDFN + 50% N - PM	892	979	2063	3042	196	202	209	411
T_6 : 125% RDFN	664	833	1864	2697	171	140	166	306
T_7 : 125% RDFN + 25% N - FYM	750	995	2165	3160	187	170	200	370
T_8 : 125% RDFN + 50% N - FYM	937	1107	2443	3550	218	202	233	435
T_9 : 125% RDFN + 25 % N - PM	797	1046	2092	3138	199	182	219	401
T_{10} :125% RDFN + 50% N - PM	1052	1181	2552	3733	234	222	257	479
SEm±	66	44	93	105	14	12	14	18
CD (P = 0.05)	195	132	276	316	42	36	42	54
CV%	14.8	8.2	7.7	6.1	13.1	12.4	12.2	8.6

Table 4.6. Effect of integrated nutrient management on manganese and copper contents in maize

Treatments	Manganese			Copper		
	($\mu g\ g^{-1}$)					
	Tasseling	Harvest		Tasseling	Harvest	
		Grain	Stover		Grain	Stover
T_1 : 100% RDFN	45.6	36.9	38.3	10.4	5.5	7.6
T_2 : 100% RDFN + 25% N - FYM	46.4	37.7	39.0	12.1	6.0	8.1
T_3: 100% RDFN + 50% N - FYM	46.8	37.9	41.8	12.5	6.4	9.0
T_4: 100% RDFN + 25% N - PM	46.5	37.9	41.2	11.6	5.8	8.3
T_5: 100% RDFN + 50% N - PM	47.2	38.2	42.7	12.1	7.0	9.3
T_6: 125% RDFN	46.1	37.4	38.9	11.2	5.6	7.7
T_7: 125% RDFN + 25% N - FYM	47.4	37.9	40.2	12.9	6.1	8.1
T_8: 125% RDFN + 50% N - FYM	48.2	38.3	40.7	13.3	6.8	8.6
T_9: 125% RDFN + 25 % N - PM	48.2	37.9	40.5	13.2	6.6	8.3
T_{10} :125% RDFN + 50% N - PM	48.4	38.0	43.1	13.9	7.2	9.0
SEm±	0.9	0.8	1.9	0.8	0.4	0.4
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
CV%	3.4	3.6	8.2	10.9	10.6	7.4

Table 4.8. Effect of integrated nutrient management on manganese and copper uptakes by maize

Treatments	Manganese				Copper			
	(g ha^{-1})							
	Tasseling	Harvest		Total	Tasseling	Harvest		Total
		Grain	Stover			Grain	Stover	
T$_1$: 100% RDFN	190	175	287	463	43.2	26.1	57.1	83.2
T$_2$: 100% RDFN + 25% N - FYM	214	200	307	507	53.9	31.7	64.8	96.5
T$_3$: 100% RDFN + 50% N – FYM	239	228	352	579	62.5	38.1	75.9	114.0
T$_4$: 100% RDFN + 25% N - PM	220	212	336	549	53.2	32.5	65.9	98.4
T$_5$: 100% RDFN + 50% N - PM	243	243	372	615	62.5	44.4	80.3	124.7
T$_6$: 125% RDFN	229	216	326	542	61.7	32.4	63.9	96.3
T$_7$: 125% RDFN + 25% N - FYM	248	238	360	598	68.3	38.2	72.3	110.5
T$_8$: 125% RDFN + 50% N - FYM	284	261	383	644	78.4	46.6	80.5	127.1
T$_9$: 125% RDFN + 25 % N - PM	272	247	371	618	74.8	43.1	75.6	118.7
T$_{10}$:125% RDFN + 50% N - PM	307	275	426	701	88.4	52.1	88.9	141.1
SEm±	12	12	21	30	5.3	3.0	3.7	4.4
CD (P = 0.05)	35	35	62	88	15.8	8.8	11.1	13.0
CV%	8.5	9.0	10.2	8.8	14.2	13.3	8.9	6.8

Table 4.9 Effect of integrated nutrient management on physical and physico-chemical properties of soil at harvest of maize

Treatments	Bulk density (Mg m^{-3})	pH	EC (dS m^{-1})	CEC (cmol (p+) kg^{-1})
T_1 : 100% RDFN	1.47	7.51	0.11	14.1
T_2 : 100% RDFN + 25% N - FYM	1.43	7.49	0.13	15.9
T_3: 100% RDFN + 50% N - FYM	1.41	7.44	0.13	17.6
T_4: 100% RDFN + 25% N - PM	1.45	7.45	0.12	15.1
T_5: 100% RDFN + 50% N - PM	1.43	7.42	0.13	16.4
T_6: 125% RDFN	1.46	7.54	0.11	14.6
T_7: 125% RDFN + 25% N- FYM	1.44	7.37	0.12	16.1
T_8: 125% RDFN + 50% N -FYM	1.41	7.38	0.13	17.9
T_9: 125% RDFN + 25 % N - PM	1.45	7.40	0.12	15.4
T_{10}: 125% RDFN + 50% N - PM	1.44	7.44	0.12	17.2
SEm±	0.03	0.2	0.01	0.9
CD (P =0.05)	NS	NS	NS	NS
CV%	3.80	5.1	10.87	10.5

Table 4.10. Effect of integrated nutrient management on organic carbon and available macro nutrients in soil

Treatments	Organic carbon g kg^{-1}		Nitrogen (N)		Phosphorus (P_2O_5)		Potassium (K_2O)	
			(kg/ha)					
	Tasseling	Harvest	Tasseling	Harvest	Tasseling	Harvest	Tasseling	Harvest
T_1 : 100% RDFN	2.0	2.4	152	125	43.7	41.0	414	397
T_2 : 100% RDFN + 25% N - FYM	2.9	3.2	164	141	47.7	41.9	427	411
T_3 : 100% RDFN + 50% N - FYM	3.8	3.4	173	153	51.8	47.8	442	436
T_4 : 100% RDFN + 25% N - PM	2.8	3.0	164	144	49.6	47.1	440	430
T_5 : 100% RDFN + 50% N - PM	3.6	3.2	175	155	55.3	53.3	455	438
T_6 : 125% RDFN	2.4	2.6	166	129	42.6	40.8	412	391
T_7 : 125% RDFN + 25% N - FYM	3.0	3.2	183	141	46.4	42.1	428	412
T_8 : 125% RDFN + 50% N - FYM	3.9	3.5	195	159	49.9	47.8	441	424
T_9 : 125% RDFN + 25 % N - PM	3.2	3.0	182	147	48.1	47.2	439	422
T_{10} :125% RDFN + 50% N - PM	3.7	3.2	196	162	55.2	52.7	461	439
SEm±	0.2	0.2	3.7	3.5	1.5	1.7	9	11
CD (P= 0.05)	0.6	0.6	11.0	10.0	4.4	4.9	27	32
CV%	10.28	11.16	3.7	4.0	5.2	6.2	3.6	4.5

Table 4.11. Effect of integrated nutrient management on available micronutrients in soil

Treatments	Available zinc		Available copper		Available manganese		Available iron	
	(mg kg^{-1})							
	Tasseling	Harvest	Tasseling	Harvest	Tasseling	Harvest	Tasseling	Harvest
T_1 : 100% RDFN	0.50	0.43	1.62	1.56	6.01	5.95	8.02	7.64
T_2 : 100% RDFN + 25% N - FYM	0.68	0.48	1.71	1.70	8.61	6.39	9.23	8.24
T_3 : 100% RDFN + 50% N - FYM	0.80	0.61	1.85	1.84	9.52	6.90	10.94	9.03
T_4 : 100% RDFN + 25% N - PM	0.72	0.50	1.81	1.80	8.92	6.39	9.11	8.06
T_5 : 100% RDFN + 50% N - PM	0.81	0.61	1.93	1.87	9.83	6.98	11.29	10.18
T_6 : 125% RDFN	0.53	0.42	1.63	1.55	6.04	5.90	8.16	7.30
T_7 : 125% RDFN + 25% N - FYM	0.65	0.45	1.72	1.68	8.47	6.30	9.04	8.67
T_8 : 125% RDFN + 50% N - FYM	0.75	0.56	1.81	1.76	9.74	6.83	10.41	9.52
T_9 : 125% RDFN + 25 % N - PM	0.72	0.50	1.74	1.71	8.71	6.34	9.57	8.74
T_{10} :125% RDFN + 50% N - PM	0.83	0.63	1.99	1.94	9.93	7.01	11.50	10.34
SEm±	0.04	0.03	0.07	0.07	0.5	0.22	0.38	0.42
CD (P = 0.05)	0.11	0.09	0.21	0.21	1.4	0.64	1.1	1.2
CV%	8.8	10.1	6.8	7.3	9.7	5.78	6.8	8.2

Table 4.12. Effect of integrated nutrient management on urease activity of soil under maize crop

Treatments	Urease activity ($\mu g\ NH_4^+ - N\ g^{-1}$ soil h^{-1})	
	At tasseling	At harvest
T_1 : 100% RDFN	9.8	6.77
T_2 : 100% RDFN + 25% N - FYM	10.5	7.70
T_3 : 100% RDFN + 50% N - FYM	12.1	8.33
T_4 : 100% RDFN + 25% N - PM	13.5	7.47
T_5 : 100% RDFN + 50% N - PM	14.7	8.10
T_6 : 125% RDFN	14.5	7.90
T_7 : 125% RDFN + 25% N - FYM	14.7	8.87
T_8 : 125% RDFN + 50% N - FYM	16.1	9.10
T_9 : 125% RDFN + 25 % N - PM	15.6	8.87
T_{10} :125% RDFN + 50% N - PM	17.0	9.57
SEm±	0.7	0.4
CD (P = 0.05)	2.1	1.0
CV%	8.8	7.4

Table 4.13 Correlation between soil properties and yield of maize

Soil properties	At tasseling	At harvest	
	Drymatter	**Grain yield**	**Stover yield**
Organic Carbon	0.7601*	0.5896	0.5229
Available N	0.9673**	0.8202**	0.7457*
Available P_2O_5	0.5657	0.6959*	0.5888
Available K_2O	0.7048*	0.6085	0.5015
Available Zn	0.6115	0.6358*	0.5226
Available Mn	0.6393*	0.6738*	0.5781
Available Cu	0.5366	0.5876	0.4679
Available Fe	0.6818*	0.8237**	0.7453*
Urease activity	0.8987**	0.9457**	0.9599**

Table 4.14 Correlation between urease activity and soil properties

Soil properties	At tasseling	At harvest
Organic Carbon	0.5807	0.6701*
Available N	0.8805**	0.7075*
Available P_2O_5	0.4361	0.4544
Available K_2O	0.5995	0.4398
Available Zn	0.4773	0.4786
Available Mn	0.4885	0.5609
Available Cu	0.4790	0.3959
Available Fe	0.5005	0.6688*

* significant at 5% probability level
** significant at 5% and 1% level

Table 4.15. Effect of integrated nutrient management on nitrogen balance in soil (kg ha^{-1} of N)

Treatments	Initial soil N status (a)	N added (input) (b)	Total N supplied c= (a+b)	N uptake by crop (output) (d)	N balance (b-d)	Expected residual N in soil e = (c- d)	Actual residual N in soil (f)	Apparent gain/ loss (f-e)	Increase over initial soil status (f-a)
T_1 : 100% RDFN	122	120	242	143	-23	99	125	26	3
T_2 : 100% RDFN + 25% N -FYM	122	150	272	162	-12	110	141	31	19
T_3 : 100% RDFN + 50% N - FYM	122	180	302	185	-5	117	153	35	31
T_4 : 100% RDFN + 25% N - PM	122	150	272	173	-23	99	144	45	22
T_5 : 100% RDFN + 50% N - PM	122	180	302	200	-20	102	155	53	33
T_6 : 125% RDFN	122	150	272	182	-32	90	129	39	7
T_7 : 125% RDFN + 25% N- FYM	122	180	302	208	-28	94	141	48	19
T_8 : 125% RDFN + 50% N -FYM	122	210	332	230	-20	102	159	56	37
T_9 : 125% RDFN + 25 % N – PM	122	180	302	216	-36	86	147	61	25
T_{10}: 125% RDFN + 50% N-PM	122	210	332	243	-33	89	162	73	40

Table 4.16. Effect of integrated nutrient management on phosphorus balance in soil (kg ha^{-1} of P_2O_5)

Treatments	Initial soil P status (a)	P added (input) (b)	Total P supplied c= (a+b)	P uptake by crop (output) (d)	P balance (d-b)	Expected residual P in soil e = (c- d)	Actual residual P in soil (f)	Apparent gain/ loss (f-e)	Increase over initial soil status (f-a)
T_1 : 100% RDFN	40.4	60	100	32	28	68	41.0	-27	0.6
T_2 : 100% RDFN + 25% N - FYM	40.4	82	122	41	41	81	41.9	-40	1.5
T_3 : 100% RDFN + 50% N - FYM	40.4	103	144	48	55	96	47.8	-48	7.4
T_4 : 100% RDFN + 25% N – PM	40.4	105	145	44	61	102	47.1	-55	6.7
T_5 : 100% RDFN + 50% N – PM	40.4	150	190	55	95	135	53.3	-82	12.9
T_6 : 125% RDFN	40.4	60	100	39	21	61	40.8	-20	0.4
T_7 : 125% RDFN + 25% N- FYM	40.4	82	122	46	35	76	42.1	-34	1.7
T_8 : 125% RDFN + 50% N -FYM	40.4	103	144	56	47	88	47.8	-40	7.4
T_9 : 125% RDFN + 25 % N – PM	40.4	105	145	52	53	93	47.2	-46	6.8
T_{10} :125% RDFN + 50% N-PM	40.4	150	190	64	86	126	52.7	-74	12.3

Table 4.17. Effect of integrated nutrient management on potassium balance in soil (kg ha^{-1} of K_2O)

Treatments	Initial soil K status (a)	K added (input) (b)	Total K supplied c= (a+b)	K uptake by crop (output) (d)	K balance (d-b)	Expected residual K in soil e = (c- d)	Actual residual K in soil (f)	Apparent gain/ loss (f-e)	Increase over initial soil status (f-a)
T_1 : 100% RDFN	392	40	432	120	-80	312	397	85	5
T_2 : 100% RDFN + 25% N-FYM	392	84	476	139	-54	338	411	73	19
T_3: 100% RDFN + 50% N -FYM	392	128	520	158	-30	362	436	74	44
T_4: 100% RDFN + 25% N - PM	392	80	472	150	-70	322	430	108	38
T_5: 100%RDFN + 50% N - PM	392	120	512	171	-51	341	439	98	47
T_6: 125% RDFN	392	40	432	144	-104	288	391	103	-1
T_7: 125% RDFN + 25% N- FYM	392	84	476	172	-88	304	412	108	20
T_8: 125% RDFN + 50% N -FYM	392	128	520	194	-65	327	424	97	32
T_9: 125% RDFN + 25 % N – PM	392	80	472	185	-105	287	422	135	30
T_{10}:125%RDFN + 50% N-PM	392	120	512	205	-85	307	438	131	46

Table 4.18. Economics of maize as influenced by integrated nutrient management

Treatments	Cost of cultivation	Gross returns	Net returns	BCR
	(Rs)			
T_1 : 100% RDFN	28794	64714	35920	1.2
T_2 : 100% RDFN + 25% N - FYM	31194	71976	40783	1.3
T_3 : 100% RDFN + 50% N - FYM	33594	81086	47493	1.4
T_4 : 100% RDFN + 25% N - PM	29419	76220	46801	1.6
T_5 : 100% RDFN + 50% N - PM	30044	86056	56013	1.9
T_6 : 125% RDFN	29159	78526	49367	1.6
T_7 : 125% RDFN + 25% N - FYM	31559	85275	53716	1.7
T_8 : 125% RDFN + 50% N - FYM	33959	92371	58411	1.7
T_9 : 125% RDFN + 25 % N - PM	29784	88548	58764	2.0
T_{10} :125% RDFN + 50% N - PM	30409	97851	67442	2.2

Cost of fertilizers
Urea: Rs. 5.62 kg^{-1}
SSP: Rs. 4.5 kg^{-1}
MOP: Rs. 6.6 kg^{-1}

Cost of manures
FYM: Rs. 400 t^{-1}
Poultry manure: Rs. 250 t^{-1}

Price of maize grain: Rs. 13 kg^{-1}
Price of maize stover: Rs. 400 t^{-1}

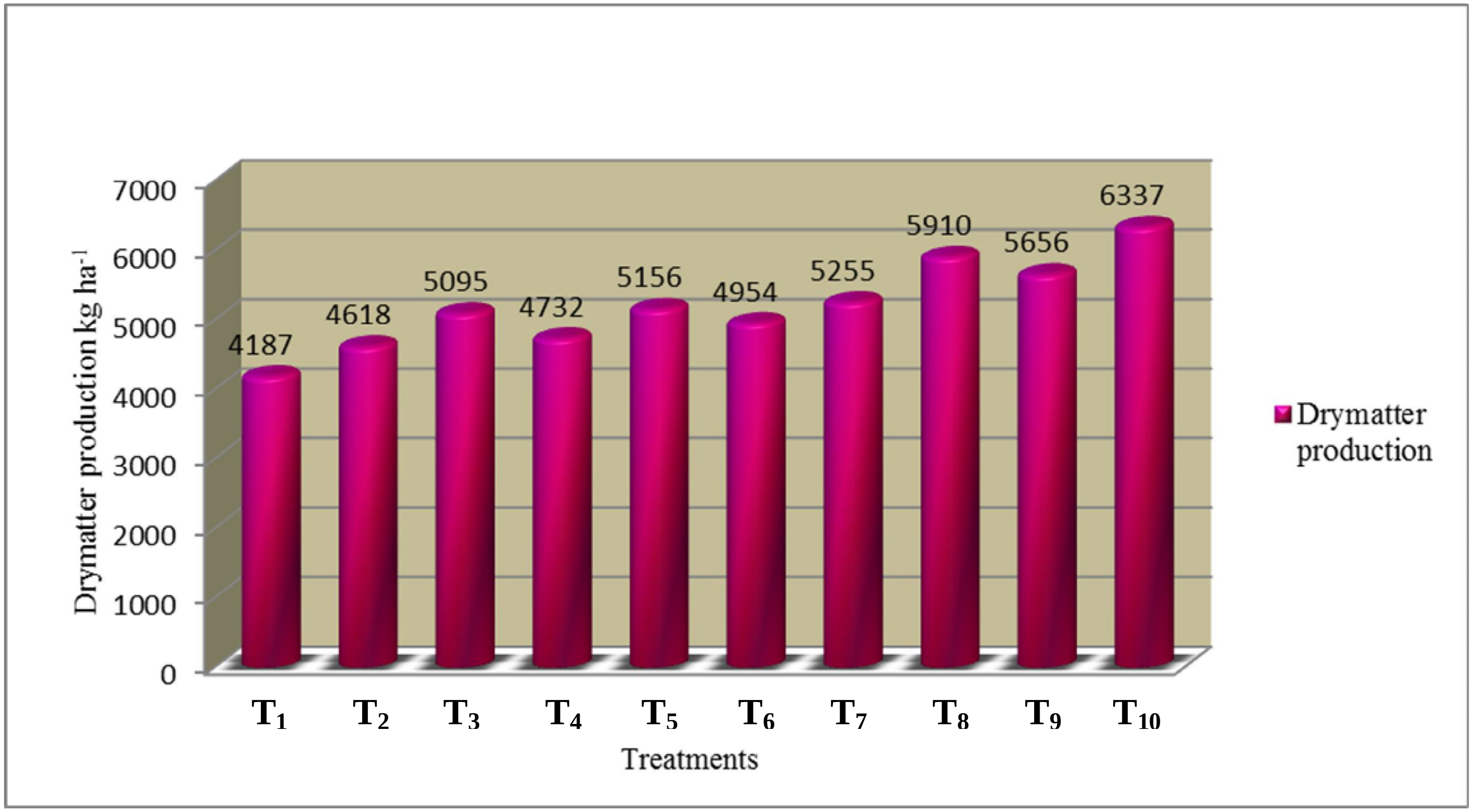


Figure 4.1. Drymatter production of maize at tasseling as influenced by various treatments

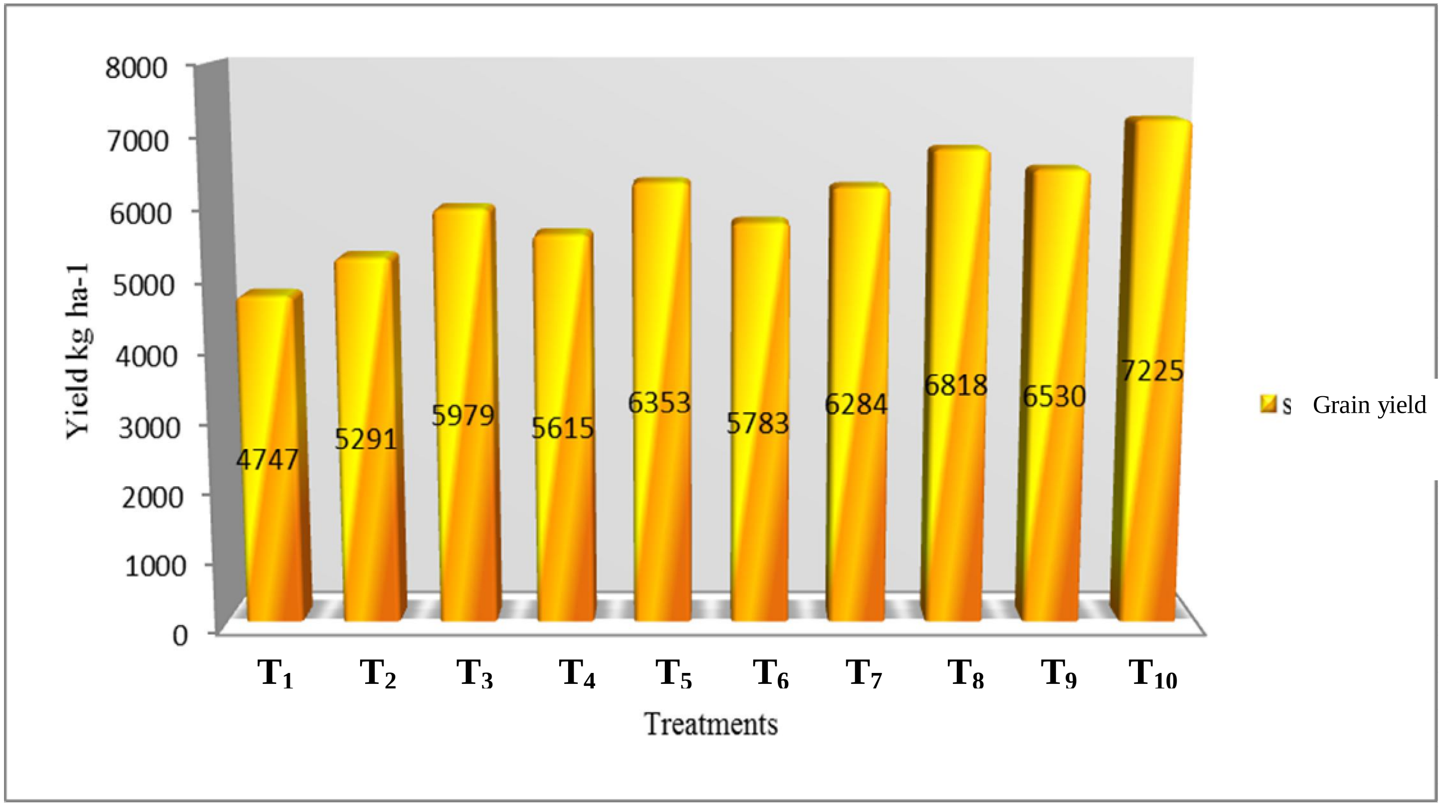


Figure 4.2. Grain yield of maize as influenced by various treatments.

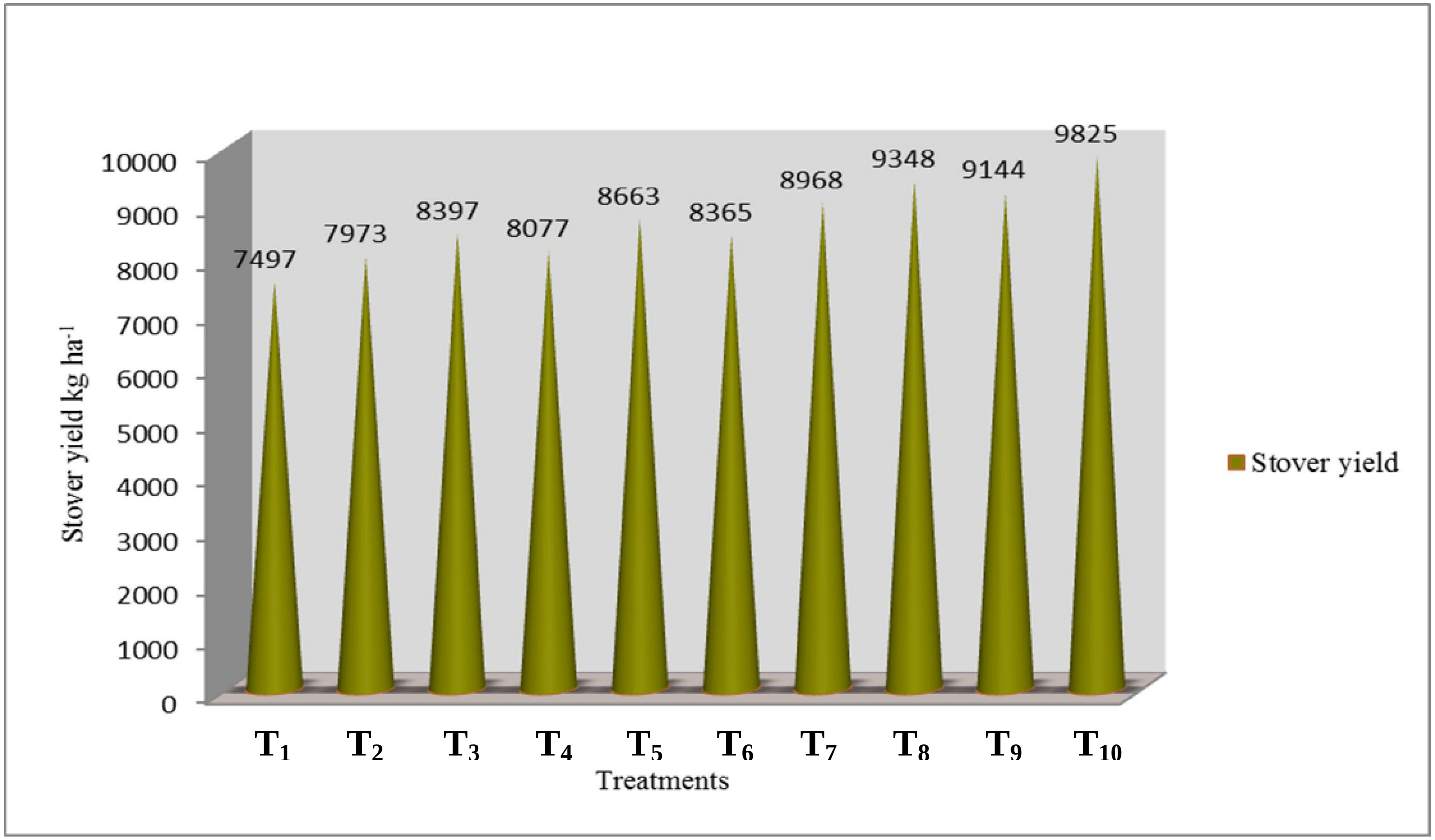


Figure 4.3. Stover yield of maize as influenced by various treatments.

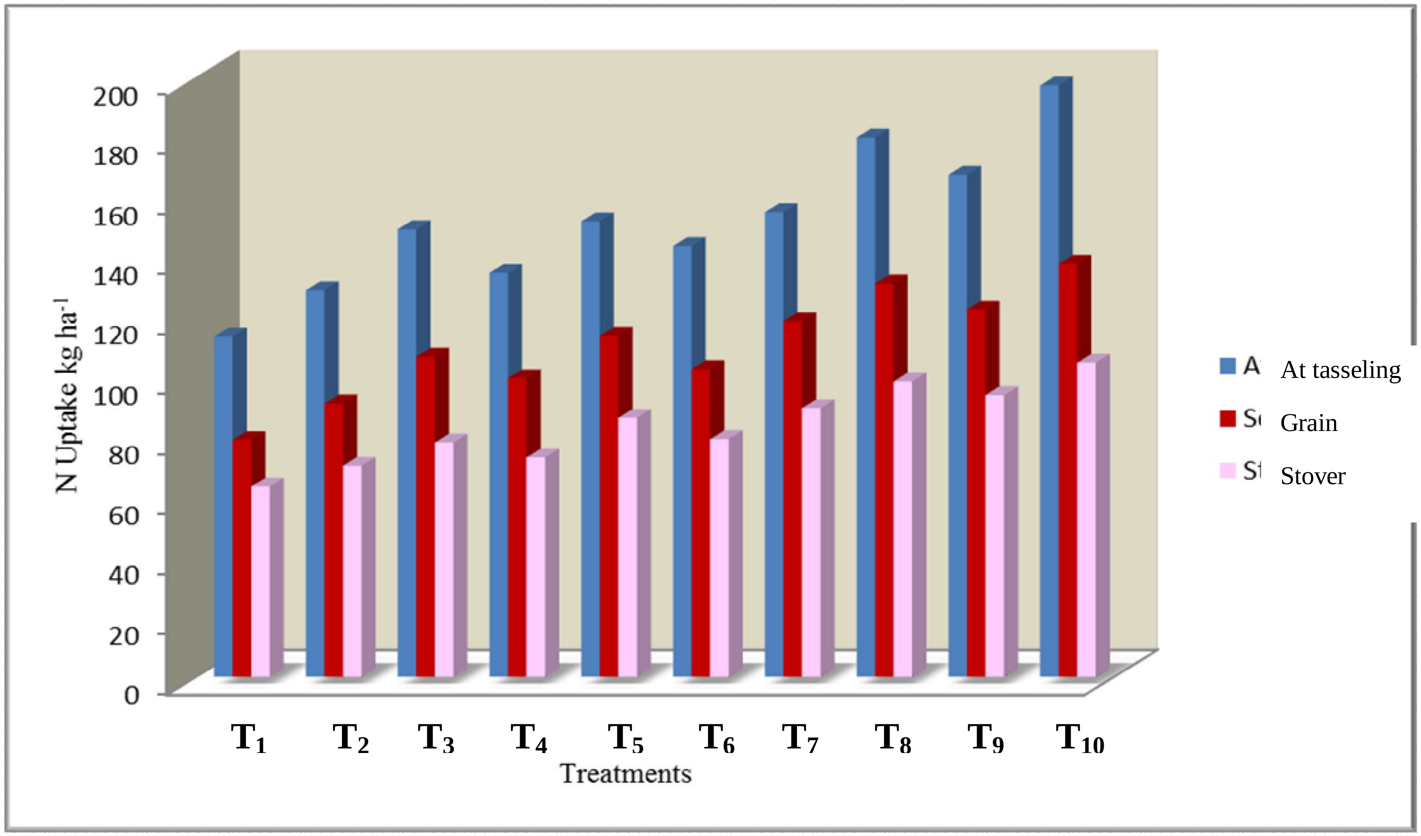


Figure 4.4. Nitrogen uptake (kg ha^{-1}) by maize as influenced by various treatments.

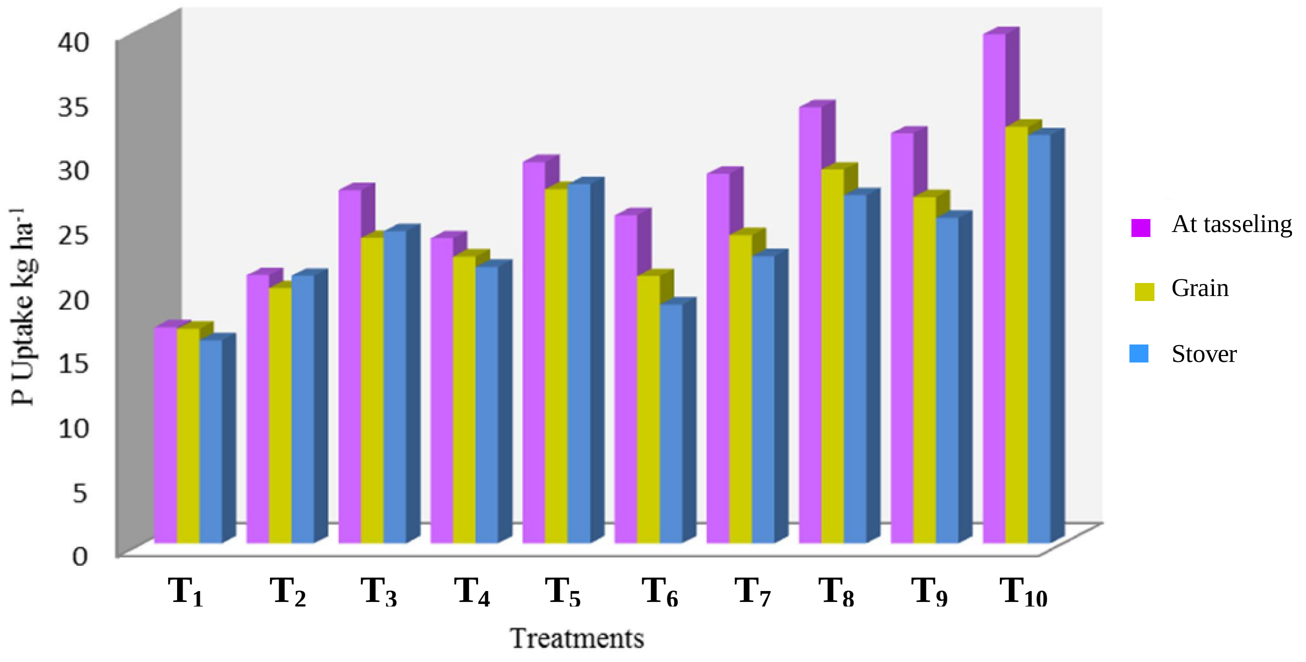


Figure 4.5. Phophorus uptake by maize as influenced by various treatments.

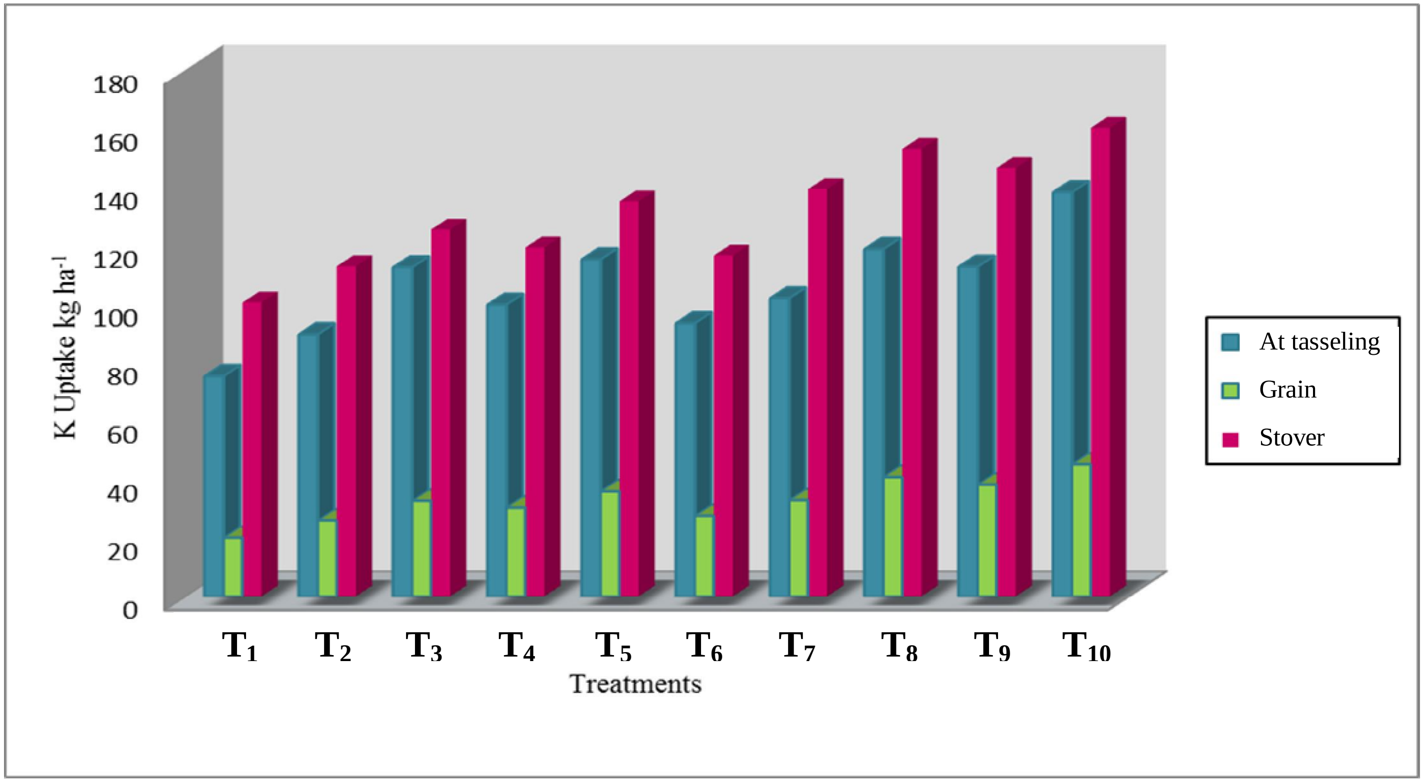


Figure 4.6. Potassium uptake by maize as influenced by various treatments.

Chapter V

SUMMARY AND CONCLUSION

A field experiment was conducted to study the effect of different levels of recommended dose of fertilizer nitrogen either alone or in combination with FYM/ poultry manure on soil properties, yield and nutrient uptake by maize during *kharif*, 2011 at Agricultural College Farm, Bapatla with ten treatments replicated thrice and laid out in RBD. The treatments comprised of two levels of fertilizer nitrogen *i.e.*, 100 and 125 per cent RDN alone and in combination with FYM/ poultry manure at 25 and 50 per cent extra RDN.

The experimental soil and manures used in the study were analysed before the initiation of experiment. Organic manures viz., FYM and poultry manure were applied to the respective plots ten days before sowing. Recommended dose of fertilizer nitrogen 120 kg ha^{-1} was applied in three equal split doses as per the treatments. Entire quantity of P_2O_5 (60 kg ha^{-1}) was applied as basal, while K_2O (40 kg ha^{-1}) in two equal splits.

The influence of various treatments on drymatter production at tasseling, yield components viz., 1000 grain weight, no. of grains per cob, weight of grains per cob, shelling percentage and harvest index and grain and stover yields were recorded. The contents and uptake of macro and micro nutrients by maize crop at tasseling, in grain and stover at harvest were determined. Soil samples collected at tasseling and at harvest were analysed for organic carbon, available macro and micro nutrient status and urease activity, while samples at harvest of maize were analysed for physical and physico- chemical properties also. The findings of the investigation are summarized below.

Integrated application of increased level of fertilizer nitrogen along with FYM/ poultry manure significantly influenced the drymatter production over sole application of 100 and 125 per cent RDFN. The 1000 grain weight, no. of grains per cob, weight of grains per cob and grain and stover yields were also increased significantly by supplementing inorganic fertilizers with different levels of FYM/ poultry manure.

The result indicated that all the yield attributes and yield of grain and stover were higher in the treatments which received 175 per cent recommended dose of fertilizer nitrogen (125 per cent through urea and 50 per cent through FYM/ poultry manure). However, the poultry manure combinations performed better than their corresponding combinations of FYM in all aspects. The lowest was recorded in treatments which received only inorganic fertilizers @ 100% RDFN. There was no significant difference in harvest index and shelling percentage among different treatments.

The uptake of macro (N, P and K) and micronutrients (Fe, Cu, Mn and Zn) by maize crop at tasseling and harvest were significantly influenced by various treatments. The highest uptake of all nutrients was observed in T_{10} (125% RDFN + 50% N-PM). At similar doses of recommended nitrogen, higher values of nutrient contents at both the stages of crop growth were recorded in poultry manure treatments compared to corresponding treatments of FYM. Among the sole inorganic treatments T_6 (125% RDFN) recorded the highest values in all the above parameters.

Bulk density, pH and EC of soils were not influenced by increased level of fertilizer nitrogen application along with FYM/ poultry manure, but CEC of soil was significantly improved. Significant variation in organic carbon and available macro and micronutrient status and urease activity in soil was observed among treatments both at tasseling and harvest. At the same level of recommended dose of nitrogen, FYM was superior in maintaining the highest organic carbon (T_8: 125% RDFN + 50% N –FYM) while poultry manure (T_{10}: 125%RDFN + 50% N-PM) reported marked increase in available macro and micronutrient contents and urease activity at both the stages. In all aspects the lowest was recorded in sole inorganic nitrogen treatments.

Though the treatment T_8 (50 per cent RDN through FYM along with 125 per cent RDFN) was on a par with T_{10} (125 per cent RDFN + 50 per cent N as poultry manure) in improving soil properties and performance of maize, its B: C ratio was significantly different to that of T_{10}. This was due to higher cost of FYM. Moreover a higher quantity of FYM is needed to improve yield because of its lower nutrient content.

Keeping in view of the above results, the following conclusions are drawn

- Results indicated that the crop is highly responding to additional dose of nitrogen up to 75 per cent of the recommended dose indicating high nutrient requirement of the crop.

- Supplementation of increased level of nitrogen through fertilizer urea and locally available FYM/ poultry manure performed well in respect to drymatter production, increased yield components, yield and nutrient uptake by maize over sole application of fertilizer nitrogen.

- Substantial improvement in residual soil fertility was recorded as the contents of organic carbon, available nitrogen, phosphorus and potassium and micronutrients viz., Fe, Zn, Mn and Cu were significantly higher in case of the plots which received either FYM or poultry manure in combination with chemical fertilizers than the plots which received chemical fertilizers only.

- Results also suggest that application of 125 per cent nitrogen through urea along with 50 per cent nitrogen through FYM or poultry manure was found to be highly effective for achieving more urease activity at tasseling and at harvest of crop.

- Further, the nutrient balance of soil implied that build up of phosphorus and negative balance of nitrogen and potassium under maize crop in sandy loam soil, calls for refinement of N, P and K level recommendations.

- From the results on yield and nutrient uptake by maize, soil fertility and urease activity it could also be concluded that application of poultry manure was better than FYM and was also found to be economical in maize production.

- Considering the soil health and maize productivity, combined application of poultry manure @ 5 t ha^{-1} and 150 kg of nitrogen ha^{-1} as urea has been suggested for *kharif* maize in sandy loam soils.

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***Original not seen**

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

Appendix -I

CALENDAR OF OPERATIONS

Operation	Date
Spraying of glyphosate	19.07.2011
Ploughing with mould board plough	27.07.2011
Working with blade harrow	30.07.2011
Removal of stubbles & layout of field	07.08.2011
Application of manures	07.08.2011
Leveling manually	16.08.2011
Fertilizer application (basal)and sowing	17.08.2011
Pre-emergence herbicide application (Atrazine)	18.08.2011
Gap filling	26.08.2011
Hand weeding	13.09.2011
First top dressing	20.09.2011
Irrigation	22.09.2011
Phorate application	07.10.2011
Handweeding	20.10.2011
Sample collection	23.10.2011
Second top dressing	24.10.2011
Irrigation	02.11.2011
Irrigation	09.11.2011
Final sample collection	25.11.2011
Harvesting	26.11.2011