EFFECT OF NITROGEN LEVELS AND INHIBITORS ON THE SOIL NITROGEN AVAILABILITY, UPTAKE AND YIELD OF *KHARIF* MAIZE IN INCEPTISOL

By

Mr. Koramaina Santhosh Kumar
(Reg. No. 014/098)

A thesis submitted to the

**MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST.AHMEDNAGAR,
MAHARSHTRA, INDIA**

In the partial fulfilment of the requirements for the degree

Of

MASTER OF SCIENCE IN (AGRICULTURE)

In

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

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MAHARASHTRA, INDIA
2016

CANDIDATE'S DECLARATION

I, hereby declare that this thesis or part thereof has not been submitted by me or other person to any other University or Institute for a Degree or Diploma

Place: MPKV., Rahuri

Date: / /2016 (K. Santhosh Kumar)

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C E R T I F I C A T E

This is to certify that the thesis entitled, **"EFFECT OF NITROGEN LEVELS AND INHIBITORS ON THE SOIL NITROGEN AVAILABILITY, UPTAKE AND YIELD OF KHARIF MAIZE IN INCEPTISOL"** submitted to The Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**, embodies the results of piece of *bonafide* research work carried out by **Mr. Koramaina Santhosh Kumar,** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

Place: MPKV , Rahuri **(R. B. Nazirkar)**
Date: / / 2016 Chairman & Research Guide

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Place : MPKV., Rahuri **(B. R. Ulmek)**
Dated : / /2016

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Date:

Place: M.P.K.V., Rahuri (*K. Santhosh kumar*)

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LIST OF ABBREVIATIONS

AE	:	Agronomic efficiency
ANPU	:	Agro-N-Protect coated urea
ANR	:	Apparent nutrient recovery efficienct
B:C	:	Benefit : cost
CD	:	Critical Difference
cm	:	Centimeter
Cu	:	Copper
cv.	:	Cultivar
^{o}C	:	Degree Celsius
DAI	:	Days after incubation
dSm^{-1}	:	Desi simens per meter
DTPA	:	Diethylene Triamine penta acetic acid
DAS	:	Days after sowing
EC	:	Electrical conductivity
et al.	:	*Et alia,* and others
Fe	:	Iron
Fig.	:	Figure
FYM	:	Farm yard manure
g	:	Gram
GRDN	:	General recommended dose of nitrogen
GRDF	:	General recommended dose of fertilizer
Ha	:	Hectare (s)
i.e.	:	that is
K	:	Potassium
K_2O	:	Potash

Kg	:	Kilogram
kg ha^{-1}	:	Kilogram per hectare
M	:	Meter
me L^{-1}	:	Miliequivalent per liter
Mg	:	Magnesium
mg kg^{-1}	:	Milligram per kilogram
mm	:	Milimeter
Mn	:	Manganese
N	:	Nitrogen
NS	:	Non significant
NU	:	Neem coated urea
NUE	:	Nitrogen use efficiency
O.C	:	Organic carbon
P	:	Phosphorus
P_2O_5	:	Phosphorus pentaoxide
p^H	:	Puissance de hydrogen
Q	:	Quintal (s)
RDN	:	Recommended dose of nitrogen
%	:	Per cent
S.E	:	Standard error
SCU	:	Sulphur coated urea
SRF	:	Slow release fertilizers
TPF	:	Triphenyl Furmazon
t ha^{-1}	:	tonns per hectare
viz.,	:	Vide licet, namely
Zn	:	Zinc

ABSTRACT

EFFECT OF NITROGEN LEVELS AND INHIBITORS ON THE SOIL NITROGEN AVAILABILITY, UPTAKE AND YIELD OF *KHARIF* MAIZE IN INCEPTISOL

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Research Guide	**:**	**Dr. R. B. Nazirkar**
Department	**:**	**Soil Science and Agril. Chemistry**

The field experiment was conducted at Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, during 2015-16 to study the "Effect of nitrogen levels and inhibitors on the soil nitrogen availability, uptake and yield of *kharif* maize in Inceptisol" the periodical soil enzyme activity was also observed by conducting laboratory incubation study.

The experiment was laid out in randomized block design with three replications and nine treatments which comprised T_1: GRDF (120:60:40 Kg ha^{-1} N, P_2O_5 and K_2O + 10 t ha^{-1} FYM), T_2: 85 % N-GRDF-Agro-N-Protect coated urea, T_3: 70 % N-GRDF-Agro-N-Protect coated urea, T_4: 85 % N-GRDF-Neem coated urea, T_5: 70% N-GRDF-Neem coated urea, T_6: 85% N-GRDF-Agro-N-Protect coated urea + Neem coated urea, T_7: 70 % N-GRDF-Agro-N-Protect coated urea + Neem coated urea, T_8: 0 % N-GRDF and T_9 : Absolute Control.

In order to study the efficiency of applied nitrogen the recommended dose of nitrogen (120 kg ha^{-1}) is reduce at rate of 15% to obtain the graded levels of nitrogen i.e 100%, 85% and 70% of recommended dose nitrogen.

The P and K fertilizers were applied as per the treatments at sowing and the nitrogen was applied in three splits (0, 30, 45 DAS). The plant observations like plant population, (grain yield and stover) yield were recorded at proper stage. Plant samples (grain and stover) taken at harvest were analysed for total plant nutrient concentration. Soil samples taken at sowing and harvest were analysed for pH, EC, organic carbon, available N, P and K and also for DTPA-extractable Fe, Mn, Zn, Cu by adoption standard analytical methods. Soil in pots were incubated by giving the similar treatments like field experment under ambient condition for the period of 75 days.

To synchronize the field condition and abserve the activities of urease and dehydrogenase enzymes the incubation study was carried out. the maize grain and stover yields were significantly highest in treatment T_2 i.e. 85% N-GRDF-Agro-N-Protect coated urea which was at par with 85% N-GRDF-Agro-N-Protect coated urea + Neem coated urea.

The application of 85% N-GRDF-Agro-N-Protect coated urea significantly recorded highest concentration and uptake of total plant nutrients (N, P, K, Fe, Mn, Zn, and Cu).

The soil pH and Ec did not affected significantly due to different treatments. However, application of 85 % N-GRDF-

Neem coated urea recorded significantly highest organic carbon and application of 85% N-GRDF-Agro-N-Protect coated urea available nutrients (N, P, K, Fe, Mn, Zn and Cu).

The application of nitrogen through urea coated with inhibitors Agro-N-protect as well as neem coated urea were found beneficial to mineralize the fertilizer N slowly and subsequently providing nitrogen periodically in available form to maize crop saved 15% N could have of GRDF.

Urease activity was (85% N) decreased in the treatments receiving higher dose of nitrogen along with inhibitor upto 60 days of incubation as compared to GRDF treatment. The dehydrogenase activity was found decreased in the treatments receiving higher dose of nitrogen (85% N) along with inhibitor upto 30 days of incubation as compared to GRDF.

Thus it can be concluded from the above finding that the application of 85 % N (102 kg ha^{-1} N) through Agro-N protect coated urea to maize was beneficial for increasing yield, total nutrient uptake and improves soil fertility of medium deep black soil. However, this treatment was at par with the treatment of application of 85 % N (102 kg ha^{-1}) through Agro-N-protect coated urea + Neem coated urea

It is possible to reduce 15 % N for maize crop due to use of nitrogen inhibitor (Agro-N-Protect coated urea or/and Neem coated urea) and get higher benefit by achieving higher yield as well as saving in Nfertilizer as compared to GRDF.

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1. INTRODUCTION

Maize (*Zea mays* L.) belongs to family of grasses (poaceae) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. In India it is cultivated in all the seasons *viz., kharif*, *rabi* and summer. The final estimates of 2014-15 have indicated an increase in of maize production over last two years and it has touched 24.35 million tonnes of maize production in India. It play key role in human diet, animal feed and provides adequate amount of energy and protein (Ipperissiel *et al.* 1989). It is most important constituent of cattle fodder and poultry feed. Maize is an important staple food crop and provides raw materials for the livestock and agro-allied industries in the world (Bello, 2010). Integration of organic and inorganic nitrogen sources is important for maize crop to have easy access to nitrogen whenever is needed throughout all growth stages. Increase in grain protein content of maize as a result of application of slow release source of nitrogen was reported by Amany *et al.* (2006).

Nitrogen is an essential nutrient for the plant growth and development (Simpson, 1987) as it plays a key role in the synthesis of protein and chlorophyll. Nitrogen is the primary nutrient and is commonly found in urea, ammonium, nitrate, ammonium sulphate, di-ammonium phosphate and potassium nitrate. Nitrogen is essential and primary nutrient, required by all the crops in large amount. However, nitrogen fertilizer added in soil get leached or washed out. It not only causes economic loss but also gives invitation to soil, water and environmental pollution. It causes harm to soil health as well as human health. The use of slow release fertilizer to some extent is useful and ecofriendly option to overcome these problems. The use of chemical fertilizers would remain the mainstay of agricultural production in future as well, given the increasing food demands of growing population and insufficient of food availability to feed around 1.4 billion populations. This would necessitate the use of about 45 million tonnes of nutrients.

Urea is the widely used nitrogenous fertilizer in agriculture because of its high nitrogen content (46.6 %). However, 50-70 per cent of the applied nitrogen is lost via volatilization and leaching reducing the use efficiency of applied fertilizers (Shaviv and Mikkelsen, 1993). This reduces the productivity and increases the cost of cultivation besides, polluting the environment. Increasing the nitrogen use efficiency will lead to increase productivity substantially. Various methods recommended to increase fertilizer use efficiency are increasing the organic matter content of soil through application of organic manures, split application of fertilizers and application of coated or slow release fertilizers. In this context, the controlled release technology by coating urea with different materials such as phospho gypsum, sulphur, resin polymers, Dicyclo-pentadiene (DCPD) and neem using different techniques of rotating drum, fluidized bed and spouted bed to increase the efficiency of urea fertilizer has been investigated (Susherman and Anggoro., 2011). The wide application of urea is done as its N content (46.6 % N) is high and cheapest one. The amide form (NH_2-N) of N is further converted to NH_4^+ form by the activity of urease enzyme. Regulation of nitrification can be done by substrate (NH_4^+-N) limiting mechanism. There is also loss through NH_3 emission. Hence it is required to regulate the activity of urease, so as to get limited supply of NH_4-N. It can be done by the use of urease inhibitor. Ingle *et al.* (2010) showed that the slow release fertilizers are slow acting and facilitate long term availability of the N, P, K nutrients often synchronized with the physiological need of plants and are considered as one of the most viable alternative for the sustainable plant productivity. Use of nitrogen inhibitors is demonstrated to have effectiveness in increasing crop nitrogen uptake, soil inorganic nitrogen stock and reducing N_2O and NO emissions, with the effect of nitrogen inhibitors on NH_3 volatilization Liu *et al.* (2013).

Studies of enzyme activities in soil are important as they indicate the potential of the soil to support biochemical processes which are essential for the maintenance of soil. Soil dehydrogenase activity is often used as a measure of any disruption caused by pesticides, trace elements or management (Frank and Malkomes 1993). Dehydrogenases play a significant role in the biological oxidation of soil organic matter by transferring hydrogen from organic substrates to inorganic acceptors Zhang *et al.* (2010)

Grant (2005) suggested one of the most important challenges facing humanity today is that of increasing food production while avoiding environmental degradation. As the world's population grows, the crop yield on land currently under production must be increased to maintain food security without converting marginal land or natural ecosystems to agriculture. This increase in production will require an adequate supply of plant-available N to support both crop yield potential and nutritional quality. Therefore, N fertilization will play a critical role in improving crop yields and ensuring food security (Mosier *et al.,* 2004). There is also a need for data on the effects of nitrification and urease inhibitors over a period of several years to prove that these compounds have no adverse effects on the soil microbial population and on crop productivity.

Thus, keeping this in view present study was undertaken on "Effect of nitrogen levels and nitrogen inhibitors on the soil nitrogen availability, uptake and yield of *kharif* maize in Inceptisol", during *kharif* of year 2015-16 at the Department of Soil Science and Agricultural Chemistry, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri with the following objectives.

1. To study the effect of N levels and nitrogen inhibitors on the available nitrogen, urease and dehydrogenase activity.
2. To observe the effect of N levels and N inhibitors on the nutrient uptake and yield of maize.
3. To study the economical viability of N inhibitors.

2. REVIEW OF LITERATURE

It is now fully realized that the native fertility of the soil cannot be relied upon and fertilizers have to be applied. Therefore fertilizer are indispensable in maintaining soil fertility and reducing the unit cost of production of crops. They are equally important to grow improved varieties more profitably. Thus, fertilizers are inseparable from modern and more productive systems of agriculture and constitute the key input in stepping up and stimulating agricultural production. Among fertilizers, urea is the single largest source of nitrogen used in the country constituting nearly 85 per cent of the total nitrogen conumpstion. Urea being the most concentrated solid nitrogenous fertilizer and comparatively the cheapest source, it dominate the fertilizer scence in the country. The nitrogen use efficiency of urea is very low ranging from 30-60 per cent. Urea fertilizer has its own characteristics and its relative efficiency depends upon the rate of its availability, susceptibility to leaching and other losses, effect on soil reaction, its chemical reaction with the soil constituents, cost involved etc.

The availability of nutrient present in the soil or applied as fertilizers is governed by the net effect of a series of physical, chemical and biological reactions in the soil is it undergoes many chemical and biological changes like mineralization and ammonification. Nitrification is rapid while denitrification is little under aerobic condition. The extent and form of nitrogen present in soil during the growth period of any plant species will, thus affect the absorption of nitrogen by plants. There are large number of factors which affect the fertilizer use efficiency and consequently the crop response to fertilizer or fertilizer characters and fertilizer manipulation such as quantity of fertilizer, time of application, method of application use of nitrification inhibitors and use of chelating substances. Among the various factors for increasing the efficiency of fertilizer nitrogen the split application of fertilizer or by using slow release nitrogen fertilizers and nitrification inhibitors were tried in the presented investigation.

The applied urea treated with urease or nitrification inhibitors and reported that helps to control on N losses into air and ground with improvement in crop yield (Dawar *et al.,* 2011).

2.1 Effect of nitrogen levels and nitrogen inhibitors on soil chemical properties

Dixit and Gupta (2000) observed that there was little variation in soil pH of inceptisol which ranged from 7.70 to 7.80 under different NPK combinations along with FYM, blue green algae as against initial soil pH of 7.80.

Sofi *et al.* (2004) reported that nitrogen and potassium nutrition, increased soil available N, P and K, where as pH, EC and organic carbon content did not influence.

Selvi *et al.* (2004) indicated the gradual increase in the biomass carbon content of the soil with the treatment of graded levels of NPK from 50 to 150 per cent. However, application of 100 per cent NPK + FYM recorded significantly the highest biomass C followed by 150 per cent NPK application.

Deshmukh *et al.* (2005) carried out a field experiment in *kharif* (2000) on mixed red and black soil on farmer's field at Rewa, (M.P). They reported that organic carbon increased from 0. 56 % at initial to 0.69 % after harvest of soybean due to the application of 75 % NPK + FYM @ 2.5 t ha^{-1} + PSB and 75 % NPK + FYM @ 2.5 t ha^{-1} + crop residue.

Kemmitt *et al.* (2006) reported that the application of chemical N fertilizers (ammonium sulphate and urea) resulted in a significant lowering of soil pH. This can attributed to the acidification effect of ammonium ions during their transformation in the soil.

Aggarwal *et al.* (2015) urease enzyme is responsible for the hydrolysis of urea fertilizers applied to the soil in to NH_3 and CO_2 with the rise in soil pH.

2.2 Effect of nitrogen levels and nitrogen inhibitors on soil available N, P & K

2.2.1 Soil available nitrogen

Joseph *et al.* (1994) reported that the application of nitrogen was significantly increased in ammonical-N and nitrate-N in soil as compared to the control and more so at 120 N kg than 60 kg ha^{-1}

Xu *et al.* (2000) observed that for increasing N-use efficiency, one must minimize the N losses and increase its consumption by the crop. The combined application of hydroquinone (HQ) and dicyandiamide (DCD) inhibitors to spring wheat had minimized gaseous N losses compared to HQ or DCD alone, which showed that the combination of HQ and DCD is an efficient way to increase N use efficiency, quality of wheat crop and ultimately reduces nitrogen losses from the soil environment.

Boyer *et al.* (2002) reported that the presently intensive agricultural systems are quite fertilizer based demanding high inputs with more chances of N losses resulting into huge economic loss. To utilize the maximum N content of commercial urea fertilizer by application of inhibitors is considered best strategy.

Tiwari *et al.* (2002) reported after twenty eight years of continuous intensive cropping along with organic and inorganic fertilization resulted in increased available nitrogen. The highest value of available nitrogen (290 kg ha^{-1}) was recorded by integrating the use of recommended dose of fertilizer with FYM.

Teyker (2006) the increased uptake by corn was due to increased N supply and improved physiological capacity of corn to absorb nutrients.

Majumdar (2007) obtained results in respect of preponderance of NH_4^+ over NO_3^- in the soil and root zone, since NH_4^+ gets fixed in the cation exchange complex. Thatinfluence N uptake by plants, N nutrition and yield.

Chen *et al.* (2008) found enhanced nitrogen availability from fertilizers due to the use of inhibitors, which ultimately improved the crop yield.

Zaman *et al.* (2009) reported that encapsulating of urea with inhibitors improved N availability and increased the crop yield. They also observed that the efficiency of both nitrification and urea inhibitors in soils is very dependent on the water-filled pore space of the soil during the period after application.

Sharma and Singh (2010) reported that ammonium was available for longer duration that synchronized with the nitrogen demand of the *Brassica* plants due to the slow release property of organic matrix based slow release fertilizer granules.

Nasima *et al.* (2010) showed that Agrotain and dicyandiamide (DCD) in combination were more effective in minimizing NH_3 losses and N_2O emission, and in controlling urea hydrolysis, improving pasture production and retaining N in NH_4^+ form.

2.2.2 Soil available phosphorus

Gaur *et al.* (1984) reported that manure blocks specific adsorption sites and forms organic P compounds in the manure, which is subsequently mineralized, when added to the soil. The increase in uptake of P with increase in FYM and NPK treatments may be attributed to P solubilization by P solubilizing bacteria from the organic FYM source.

Mathur (1997) reported that there was a significant increase in the available P status of the soil in plots receiving fertilizer P in both the seasons and in those getting FYM application over the rest of the treatments.

Gupta *et al.* (2004) the increase in N, P and K uptake due to the addition of the NC may be attributed to the increased availability of N, P and K and improved soil physical condition.

Ingle *et al.* (2010) showed that the slow release fertilizers are slow acting and facilitate long term availability of the of the N, P and K nutrients often synchronized with the physiological need of plants and are considered as one of the most viable alternatives for the sustainable plant productivity.

2.2.3 Soil available potassium

Suresh and Hasan (2002) reported that noticeable changes occurred in available soil K due to the application of different levels of N and K to banana crop. They recorded the highest soil available K at vegetative stage and thereafter, decreased gradually during shooting and harvest.

Dahiya *et al.* (2004) showed that the slow release fertilizers (Urea formaldehyde, Sulphur coated urea and Polymer coated urea) are slow acting and facilitate long term availability of the of the N, P, K nutrients often synchronized with the physiological need of plants and are considered as one of the most viable alternative for the sustainable plant productivity.

Pettigrew (2008) observed part of the maize yield enhancement from K fertilization was because of a reduction in stalk lodging with the K fertilization, particularly when higher N rates were applied.

Bhatt and Sharma (2011) reported that Phosphorus and potassium application was given on the soil test basis. In most of the cases, soil was high in available-K.

2.3 Effect of nitrogen levels and nitrogen inhibitors on soil available micronutrients

Madhavi *et al.* (1995) reported that higher availability of these micronutrient cations in soil due to the application of organic manures was ascribed to the mineralization of organic manure, reduction in fixation and complexing properties of these manures with the action of micronutrients.

Marschner (1995) found most of N is contained in its organic fraction a large reservoir of forms more readily available, such as nitrate and ammonium, and these mineral forms, despite responding for a small portion of the total N, are of utmost importance from the nutritional viewpoint because they are absorbed by plants and microorganisms.

Bellakki and Badanur (1997) concluded that incorporation of organic sources of nutrients either alone or in combination with fertilizers recorded higher DTPA-extractable micronutrients (Zn, Fe, Mn and Cu) in surface and sub-surface soils. Addition of organic manure might enhanced the microbial activity in the soil and consequent release of complexed organic substances could have prevented micronutrients from precipitation, fixation, oxidation and leaching. Application of recommended NPK along with FYM (10 t ha^{-1}) significantly increased the available DTPA-Zn and Mn over inorganic fertilizers.

Selvi *et al.* (1997) the cationic micronutrients in the soil showed a build up with the application of FYM. The increased availability may be due to the chelation process.

Singh *et al.* (1999) reported that the fertilizer treatment increased the DTPA - Cu over control. The DTPA - Cu level was high in NPK + FYM and NPK + FYM + Zn treatments. The application of fertilizer treatments either alone or with FYM (NPK + FYM and NPK + FYM + Zn) showed significantly higher DTPA-Fe content than other treatments. Further significant increase in DTPA-Fe with SSP application was also noticed.

Prakash *et al.* (2002) reported that the micronutrients like Fe, Cu and Zn availability was significantly higher in FYM treatment.

Kadam *et al.* (2010) reported that whenever the soil nutrient status was influenced by the application of organic nitrogen sources the soil available N, P_2O_5 and K_2O buildup was higher in all the treatments over the initial whereas, the DTPA-extractable micronutrients were also enhanced due to the application of organic nitrogen source.

2.4 Effect of nitrogen application on plant growth parameters

Singh *et al.* (1997) reported that dry matter production at 90 and 120 days after sowing (DAS) increased significantly with an increase in population levels from 55556 plants ha^{-1} to 111111 plants ha^{-1} on silty loam soils of during winter season.

Ameta and Dhakar (2000) reported that increasing the nitrogen dose beyond 120 kg ha^{-1} was not significant with lower plant populations of maize (65000 plants ha^{-1} and 75000 plants ha^{-1}) whereas, with higher plant populations (85000 plants ha^{-1}

and 95000 plants ha^{-1}) while a significant response up to 150 kg N ha^{-1} was noticed in respect of grain and stover yields on clay loam soils at Banwara, Rajastan during *rabi* season.

Hani *et al.* (2006) from Sudan reported that plant height, stem diameters, LAI (leaf area index) increased significantly with an increase in levels of nitrogen from 0 to 80 kg N ha^{-1}. However 40 and 80 kg N ha^{-1} remained at par with each other in fodder maize.

Palled and Shenoy *et al.* (2006) studied the possible reason for the increase in the growth parameters by three split application of nitrogen might be due to more accumulation of nitrogen content in a plant which in turn resulted in more synthesis of nucleic acids, amino acids, amide substances in growing regions of meristematic tissues ultimately enhanced multiplication of cell division and thereby increased in the maize growth attributes.

Chaudhari *et al.* (2006) observed the growth parameters, *viz.*, plant height, number of leaves per plant, fresh and dry weight per plant and chlorophyll content were significantly higher with the application of nitrogen through neem coated urea than the granular urea and P prilled urea. This may be due to the fact that the coating of urea decreases the leaching losses and provide more nitrogen to the plant.

Dawar *et al.* (2011) used nitrogen inhibitors coated N and found better crop growth and yield during their research.

Mercy *et al.* (2012) conducted an experiment and found that nitrogen uptake was more with lower planting density of 66666 plants ha^{-1} than that with higher plant densities (88888 plants ha^{-1} and 133333 plants ha^{-1}) on clay loam soils at Bapatla.

Kaur *et al.* (2012) observed the increase in growth parameters with increasing levels of nitrogen. Scheduling of nitrogen significantly affected the most of the growth parameters at all growth stages of the crop.

2.5 Effect of nitrogen levels on yield of maize

Misra *et al.* (1994) found that increasing levels of nitrogen from 100 to 200 kg ha^{-1} resulted in increased maize yield.

Banerjee *et al.* (2006) reported that higher productivity levels of soil series of vertisols and Inceptisols under integrated nutrient management could be due to fact that organic source might have enhanced the efficient utilization of native as well as added fertilizer nutrients with the receipt of *kharif* rains which maintained the balance between growth, yield attributes and yield.

Bindhani *et al.* (2007) conducted the experiment during the rainy season at Bhubaneshwar in Orissa to study the effect of nitrogen levels on baby corn. They noticed that application of nitrogen at a higher level (120 kg ha) has significantly obtained higher yield

Almodares *et al.* (2008) reported that total biomass yield of sorghum and sweet corn increased significantly with increase in levels of nitrogen fertilizer.

Carvalho *et al.* (2012) reported that the nitrogen fertilization at 100 kg ha^{-1} brought significant improvement in yield attributing traits as compared to 75 kg N ha^{-1}. The overall improvement in crop growth was reflected into better development of sink i.e. yield attributes. The excellent utilization of growth resources, particularly nitrogen in absolute amount on account of better availability in well supplied plots (100 kg N ha^{-1}) and later their translocation to sink during the course of grain filling stage might have caused superiority in aforesaid yield attributing characters as compared to plots supplied with sub-optimal level of nitrogen (75 kg N ha^{-1}). Adequate supply of N might have caused increase in grains per cob. Higher accumulation of photosynthates at 100 kg N ha^{-1} resulted in relatively higher accumulation of photosynthates in individual grain and thereby also increased the 100 grain weight (seed index) and ultimately weight of cob at higher level of N (100 kg ha^{-1}). Application of nitrogen at 100 kg ha^{-1} increased the seed yield by 4.78 per cent over 75 kg N ha^{-1}. A similar trend was observed for straw yield.

2.6 Effect of nitrogen inhibitors on yield of maize

Vyas *et al.* (1991) obtained similar yields of rice with 70 kg Nha^{-1} in the form of NCU with 100kg N ha^{-1} applied as unammended urea.

Havlin *et al.* (2007) reported that the low N use efficiency of crops due to N dynamics seriously undermined the attainment of maximum yield potential by field crops. The low N efficiency is attributed to rapid nitrification and subsequent loss of N by leaching and denitrification

Virendra (2014) reported the effect of different organic manure and fertilizers on yield and nutrient uptake of maize and concluded that fertilizer combination with neem coated urea increased availability of nutrient yield and nutrient uptake by maize crop

Arun *et al.* (2014) found that the application of neem coated urea was significantly superior for production of straw yield (9231.24 kg ha^{-1}) over granular urea (8734.76 kg ha^{-1}).

2.7 Effect of nitrogen levels and nitrogen inhibitors on concentration of nutrient in plant

Yu *et al.* (2007) observed that the positive effect of N fertilization on nutrient concentration and uptake by maize.

Mukhopadhyay and Das (2001) recorded the higher amount of extractable Fe and Mn in Inceptisol and alfisol with the application of organic matter. The magnitude was more with the levels of organic matter indicated its positive relationship with the extractability of Fe and Mn in the soils.

Hao *et al.* (2007) indicated that the concentrations of Fe, Mn, Cu, and Zn in rice increasing N fertiliser application.

Hussaini *et al.* (2008) found that fertilization with nitrogen increased concentration of N and P in the plant system.

Shi *et al.* (2010) reported that the N fertilisation increased Fe, Zn, and Cu density in wheat grain compared to the control (0 kg N ha^{-1}).

Borgognone *et al.* (2012) Form of N supplied to the plants greatly influenced the absorption of other ions particularly micronutrients like Fe, Cu, Mn and Zn.

Mehdi *et al.* (2012) revealed that in fodder maize, zinc application at the rate of 10 kg ha^{-1} significantly increased plant height, N and Zn content and their uptake.

Ali *et al.* (2014) reported that nitrogen concentration increased with increasing rates of N applied especially 200 kg N ha^{-1}. The increment is due to hydrolysis of urea applied.

2.8 Effect of nitrogen levels on N P K uptake

Pawar S.D. *et al.* (1991) Nitrogen uptake by grain and stover of maize significantly increased with increasing level of N from 0 to 100 kg ha^{-1}.

Bhaskaran *et al.* (1992) also reported a positive trend in NPK uptake with increase in N application at all growth stages of maize.

Vimala and Subramanian (1994) observed that the nitrification inhibitor applied treatments showed higher N, P and K uptake by rice than untreated urea treatments.

Selvaraju and Iruthayaraju (1995) noticed that an increase in N, P and K uptake with increased level of N application from 75 to175 kg ha^{-1}, irrespective of the season.

Padmaja M. (1999) reported that the highest level of N (150 kg ha^{-1}) resulted in significantly the maximum uptake of N by the maize crop. Nitrogen application at this rate also increased P and K uptake by both the grain and stover.

Shivay and Sing (2000) observed nitrogen application increased rate also increased P and K uptake by both the grain and stover significant increase in N uptake with each successive increase in level of nitrogen application from 0 to 120 kg ha^{-1}.

Fageria (2003) reported that cereals including rice, N accumulation is associated with dry matter production and yield of shoot and grain. Nitrogen uptake in the straw differs significantly between 0 and 90 (kg N ha^{-1}), and straw N-uptake increased significantly with N. Similarly, N (90 kg N ha^{-1}) caused the highest content of N uptake (57.16 kg ha^{-1}).

Siam *et al.* (2008) reported that increase in level of N up to 140 kg N/fed significantly increased plant height, fresh and dry weight, weight of leaf, ear weight, 100 grain weight, yield and N, P and K uptake of maize plant.

Sawargaonkar and Shinde (2009) observed profound influenced the different doses of fertilizer application as regards to fertilizers doses from 75 % -100 % RDF significantly increased N, P and K uptake of maize.

Singh *et al.* (2010) reported a significant increase in carbohydrate, sugar, starch, protein, N, P and K content and uptake with increase in N + P + K from 60 + 12.9 + 24.9 ha^{-1} to 120 + 25.8 + 49.8 ha^{-1}.

2.9 Effect of nitrogen inhibitors on N, P and K uptake

Muneshwar and Singh (1986) reported that neem cake blended urea reduces the leaching loss NO_3^--N and NH_4^+- N, significant increase in the nitrogen concentration and uptake by the grains and straw, were observed on application of neem cake blended urea as compared with the urea alone.

Aggarwal *et al*. (1998) observed that N uptake was highest in plots with nimin coated urea followed by urea + DCD, which were significantly higher than plots with urea alone, neem coated urea and urea + thiosulphate. The N recovery was appreciable in all the treatments and was highest in plots with nimin coated urea. The loss of soil nitrogen through leaching during the crop growth period may not be very high as it is considered to be negligible in wheat crops in Indian condition (no rain in winter).

Srinivas *et al*. (1999) reported that dicyandiamide (DCD) is another nitrification inhibitor and is shown effective in slowing nitrification process, potentially increase autumn forage production and N uptake when DCD was applied in combination with urea.

Wen *et al*. (2001) found that coated urea performed better than commercial fertilizers by increasing grain yield and N uptake in maize.

Eltelib *et al*. (2006) reported the result on the main effects of nitrogen and neem seed crush (NSC) on nutrient concentration of maize grain. The result shows that there was a significant effect of N treatment levels on the nutrient concentration. N levels at 150 kg N ha^{-1} recorded an increase in N, P, K, Ca and Mg content of 138.4, 239.0, 28.0, 67.0 and 30.0 %, respectively over the control. At the 100 kg N ha^{-1} level increase in nutrient contents were 69.0, 115, 68, 100 and 35 %

over the control for N, P, K, Ca and Mg, respectively. The N level at 50 kg ha^{-1} which was also significantly higher than the control, recorded N, P, K, Ca and Mg content of 67.0, 108.0, 43.0, 67 and 15 per cent, respectively increase over the control. The results clearly showed that great degree of synergy existed between N application and accumulation of other mineral nutrients in maize grain.

Kurumthottical and Jose (2007) reported that the prolonged availability of N in soil from slow release fertilizers must have favoured high N uptake.

Majumdar (2007) reported that the factors and treatments comprised four levels of nitrogen (0, 50, 100 and 150 kg N ha^{-1}) in form of urea and three levels of neem seed crush (0, 15 and 30 % by weight of urea-N applied). The results indicated that fertilizer N singularly or in combination with neem seed crush (NSC) significantly influenced the concentration and uptake of N, P, K and Ca both in maize grain and stover.

Sujatha *et al.* (2008) reported the primary nutrient concentration in maize grain and stover showed variable response to different types of organic manures and fertilizers. The treatment 100 % RDN through neem coated urea (4 ml neem oil/100g urea) recorded significantly higher value of N (0.79 and 1.55 % stover and grain concentration respectively), P (0.36 and 0.38 % stover and grain concentration respectively) and K (1.44 and 0.53 % stover and grain concentration respectively) concentration in grain and stover over the other treatments except the treatment 100 % RDN through neem coated urea (2 ml neem oil/100 g urea).

2.10 Effect of nitrogen levels and nitrogen inhibitors on micronutrient uptake

Singh *et al* (1998) reported the improvement in Zn content with increased levels of N, suggesting a synergistic effect of N on Zn uptake.

Salam and Subramanian (1988) studied the interaction between N and Zn rates on the uptake and concentration of N and Zn appears to be synergetic effect that is, soil application of N in combination with Zn increased concentration and uptake of these two nutrients.

Duhan and Singh (2002). reported that application of N through chemical fertilizer significantly improved the Fe uptake in grain and stover. Increasing rate of N increased the Fe uptake in rice.

Ghosh *et al.* (2001) reported that application of farm yard manure 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 recommended dose of fertilizer treatment.

Ashoka *et al.* (2008) reported that Zn applicationat 10 mg kg-1 soil caused significant increase in the Zn content and uptake by sorghum over application of 5 mg kg-1 soil and control.

Debiprasad *et al.* (2010) application of N through chemical fertilizers induced significant improvement on Mn content over rest of the treatments. Application of urea enhanced the content Mn by the plant and the interaction between Mn and N was found to be positive also observed significantly increased Mn content in rice straw and grain with the application of fertilizer N.

Keram *et al.* (2012) conducted experiment on wheat crop and observed that yield, harvest index, nutrient (N, K, Zn) uptake and quality increased significantly with the application of recommended dose of N, P, K and Zn @ 20 kg ha^{-1} by wheat as compared to N, P and K alone.

2.11 Effect of nitrogen on nitrogen use efficiency

McCarty *et al.* (1990) reported nitrification inhibitor, such as dicyandiamide (DCD), have been effectively used to reduce N_2O, NO and NO_3 losses from urea fertilized soil.

Majumdar (2002) was shown among the non-edible oil seeds, *neem* (*Azadirachta indica* L.) and *Karanja* (*Pongamia pinnata,* Pierre) and their isolates have been evaluated and found to be effective in retarding nitrification in soil.

Tilman *et al. (*2002) reported the comparisons of maize grain yields and N fertilizer usage on a global basis lead to estimates of maize NUE ranging from 25–50 per cent, indicating that more than half the fertilizer N applied in maize crop production is lost to the environment. They suggested, there is considerable opportunity for enhancing maize NUE.

Bernard *et al.* (2012) reported the effect of urea fertilizer forms on grain corm yield and nitrogen use efficiency. They observed that the corn grain yield increased linearly with increasing rates of urea and polymer coated urea in all years, but magnitude of the response varied with years.

Sanz-Cobena *et al.* (2012) reported that agrotain treated urea reduced the emission of N_2O by 54 per cent under irrigated maize crop.

Hayat and Khan (2013) shown that sulphur and urease (agrotain) coated urea fertilizers have slower dissolution rate and thus slower nitrification making less susceptible to NO_3 leaching. The effectiveness of sulphur and urease inhibitor coated urea over granular urea in coarse textured soils under leaching conditions.

2.12 Effect of N inhibitor along with nitrogen fertilizer on economic viability

Thakur *et al.* (2000) reported that increased level of nitrogen application, cost of cultivation and average net returns increases significantly

Dadarwal *et al.* (2009) observed an increase in net returns and B:C ratio with increasing dose of fertilizer application.

Singh *et al.* (2010) reported that application of 120 Kg N ha^{-1} markedly improved crop profitability (Rs. 635.9 ha^{-1}day), Net returns (Rs.65.49 x 10^3 ha^{-1}) and net returns per rupee invested (Rs. 6.35) over preceded levels. However it was at par with 150 kg N ha^{-1}.

2.13 Effect of nitrogen on enzyme activity in incubation study

2.13.1 Urease activity

Sonar and Kamire (1979) conducted laboratory incubation study reported that application of urea to a verticustropepts soil released more NH_4^+-N and NH_3^--N than with 25, 50 and 100 per cent of urea-N replaced by neem cake or Karanj cake. The NH_4^+-N concentration in the soil increased up to 10 days and decreased thereafter while, NO_3^--N concentration continuously increased throughout the period of 60 days of incubation. The rate of mineralization (ammonification and nitrification) to applied urea-N in the soil decreased with increase in the proportion of neem or karanj cake added, thereby increasing the available urea-N over a longer time.

Sarkunan and Biddappa (1980) reported that in an incubation study the transformation of nitrogen from urea blended with coaltar, in moist soil the production of NH_4^+ and NO_2^- increased, whereas NO_3^- formation was significantly inhibited. The study indicated that there is considerable scope for increasing efficiency of urea under moist aerobic situation by coating with neem cake or coaltar.

Watson *et al.* (1990) reported that whenever addition of urea-based N products, slowing down the activity of urease enzyme and slows the conversion of NH_4^+ to gaseous NH_3 reducing volatilization loss of nitrogen.

Vyas *et al.* (1991) reported that urea fertilized plots recorded highest NO_3^- content throughout the study period due to quick release of ammonium and its subsequent nitrification. Nimin coated urea was most efficient in reducing nitrification, while urea

+ DCD was better than neem coated urea. Up to 51 DAS, urea + thiosulphate had more nitrification inhibition than urea + DCD, but subsequently urea + DCD had slightly more nitrification inhibition. Nimin coated urea has shown nitrification inhibition to the extent of 46.2 and 39.7 per cent during a period of 30 days in laterite (Ultisol) and black (Vertisol) soils, respectively, under aerobic condition.

Joseph *et al.* (1994) reported that urea nitrification inhibitor as soil well as higher levels of N maintained significantly more ammonium N in soil for a period of 60 days.

Salam *et al.* (1999) observed that the changes in enzymatic activities including urease showed a significant relationship with the contents of soil organic C and total N.

Deepanjan *et al.* (2002) reported that soil ammonium was highest (20.7 mg kg^{-1} soil) immediately after the application of urea, which decrease afterwards due to quick nitrification. Nimin coated urea maintained highest soil ammonia up to 33 DAS (8.8 mg NH_4^+-N kg^{-1} soil). After top dressing also, nimin coated urea maintained highest soil ammonia until the end (on 95 DAS).

Srinivas *et al.* (2004) conducted a pot culture experiment and laboratory incubation studies to evaluate the addition of different organic manures on soil urease activity. They were reported that the urease activity increased during the active growth period of rice (from 1.8 mg NH_4^+-N 5 g^{-1} $2h^{-1}$ to 27.2 mg NH_4^+-N 5 g^{-1} $2h^{-1}$ at 60^{th} days after transplanting). Among the organic manure FYM @ 10 t ha^{-1} recorded the highest urease activity (3.1 mg NH_4^+-N 5 g^{-1} 2h at 60^{th} day of incubation).

Edmeades (2004) reported that the nitrification inhibitor by delaying the conversion of ammonium to nitrate avoid undesirable high nitrate levels in plants used for human and animal nutrition. Inhibiting nitrification, however, will not prevent mineral N from entering water bodies by way of direct N application of fertilizers and by runoff.

Kissel *et al.* (2008) studied on nitrogen fertilizer in the form of urea is subject to ammonia volatilization through the activity of the urease enzyme found ubiquitously in soil. Nitrogen volatilization was especially prevalent when urea is applied to the soil surface, as in no-till systems when growers have not invested in sub-surface application tools. They suggested to decrease possible ammonia volatilization losses a number of slow release products have been developed to delay urease activity.

Sanz-Cobena *et al.* (2008) reported urease inhibitors compounds effectively abate NH_3 emissions by slowing the hydrolysis of urea, which limits the pool of NH_4^+ potentially lost through volatilization.

Albert *et al.* (2008) studied the hydrolysis of urea, with the highest NH_4^+ concentration (10.1 mg NH_4^+-N kg^{-1}) observed on the 3rd day for this treatment NBPT. Thereafter, the NH_4^+-N concentration declined slowly to 0.8 and 1.9 mg NH_4^+-N kg^{-1} respectively, for urea and urea + NBPT after 27 days of fertilizer application.

Dawar *et al.* (2010) who applied agrotain coated urea to crops and found improved crop productivity and reduced N losses. Urea fertilizer coated with urease inhibitor (Agrotain) improved bioavailability of N, resulting in increased crop biomass and yield.

They opined that increase may be due to the delayed urea hydrolysis by inhibiting compounds and reduced losses of nitrogen.

2.13.2 Dehydrogenase activity.

Perucci (1992) reported that soil dehydrogenase activity reflects the total range of oxidative activity of soil microflora and is consequently used as an indicator of microbial activity.

Goyal *et al.* (1992) reported the increase in dehydrogenase activity of sandy loam texture, soil (Typic *Ustochrept*) with inorganic fertilizers and organic amendments. The highest dehydrogenase activity (218 g TPF g^{-1} soil 24 hr^{-1}) was recorded in the wheat straw amended soil than FYM amended soil (195 g TPF g^{-1} soil 24 hr^{-1}). They were reported positive significant correlation among dehydrogenase activity and bacterial counts with microbial biomass carbon.

Singaram and Kamalakumari (1995) reported that summarized from a long term effect of FYM and fertilizers on activities of dehydrogenase in *Typic Ustropept* and reported that the dehydrogenase activity was maximum in FYM treatment. The higher rates of N, P and K fertilization were enhanced the enzyme activity and the effect was more pronounced with FYM in combination with fertilizer.

Goutami *et al.* (2015) showed that the soil dehydrogenase activity increased with addition of organic carbon through FYM. The dehydrogenase activity maximum at flowering (72.89 µg g^{-1} 24 hr^{-1}) and decline at time of harvest (49.78 µg g^{-1} 24 hr^{-1}) and highest when the treatment received combined application of 150 kg N ha^{-1} + FYM + Biofertilizers.

3. MATERIAL AND METHODS

The present investigation was carried out by conducting a field experiment entitled "Effect of nitrogen levels and nitrogen inhibitors on the soil nitrogen availability, uptake and yield of *kharif* maize in Inceptisol" during *kharif* in the year 2015-16 at the Department of Soil Science and Agricultural Chemistry, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri.

The details of material used, for experimentation and analytical techniques adopted for this investigation were presented in this chapter under different heads and subheads.

3.1 Location

Geographically the central campus of Mahatma Phule Krishi Vidyapeeth, Rahuri is situated 38 km away from Ahmednagar, on Ahmednagar-Manmad State Highway. It lies between 19^0 48' N to 19^0 57' N latitude and 74^0 19' E to 74^0 23' longitude. This tract is lying on the eastern side of western ghat and falls under rain shadow area. The experiment was carried out at post graduate institute, farm Dept. of SSAC, M.P.K.V., Rahuri.

3.2 Climatic condition

The prevailing weather condition during the field experimentation season is presented in table 1. It indicates that the weather conditions were suitable for normal growth of maize crop.

Table 1. Meteorological data

MW No.	Date	Temp (^0C)		RH (%)		Sunshine (hrs)	Wind speed (km hr^{-1})	Rainfall (mm)	No. of rainy days
		Max	Min.	Morn.	Even.				
June 15									
23	04 to 10	38.7	24.5	71	33	07.2	05.7	2.6	-
24	11 to 17	36.7	24.7	65	36	09.8	07.8	18.8	1
25	18 to 24	33.4	24.7	66	46	03.6	10.3	22.4	1
26	25 to 01	35.9	22.5	66	35	08.1	06.1	-	-
July 15									
27	02 to 08	34.4	23.3	72	52	05.2	04.7	11.8	1
28	09 to 15	32.7	23.4	73	52	03.8	06.0	16.8	2
29	16 to 22	30.8	24.0	72	64	01.1	09.8	0.0	-
30	23 to 29	29.1	22.3	76	63	04.1	05.5	23.4	3
31	30 to 05	29.0	22.6	75	68	02.2	07.0	13.2	2
August 15									
32	06 to 12	30.5	21.9	72	57	05.1	05.6	1.6	-
33	13 to 19	31.7	21.9	70	50	04.8	05.6	34.0	1
34	20 to 26	32.7	22.6	79	51	05.3	02.0	44.4	2
35	27 to 02	28.6	21.8	81	72	01.4	02.3	13.0	3
September 15									
36	03 to 09	29.5	22.2	75	66	03.7	05.9	15.8	1
37	10 to 16	30.7	21.0	71	57	05.2	03.0	0.0	-
38	17 to23	31.9	21.0	71	71	08.0	02.9	4.0	1
39	24 to 30	33.6	20.0	70	70	08.7	00.5	-	-
October 15									
40	01 to 07	34.1	22.2	70	40	07.5	01.2	0.0	-
41	08 to 14	34.0	19.6	64	33	8.0	2.5	7.4	1
42	15 to21	33.7	20.9	72	43	8.1	1.1	13.4	2
43	22 to 28	29.4	16.1	72	57	4.9	1.4	1.0	-
44	29 to 04	32.0	14.0	56	36	9.8	1.9	0.0	-
November 15									
45	05 to 11	31.8	15.9	57	33	9.1	1.2	0.0	-
46	12 to 18	29.7	20.1	81	63	5.3	1.0	9.56	2
47	19 to 25	29.8	15.2	69	41	9.1	0.4	0.0	-
48	26 to 02	29.6	12.1	57	29	9.1	0.5	0.0	-
December 15									
49	03 to 09	29.1	10.9	55	32	9.5	00.5	0.0	-
50	10 to 16	29.2	14.6	67	47	7.0	01.3	0.0	-

3.3 Experimental site

The soil of the experimental site of the present investigation was grouped under Inceptsols order belong to Sawargaon soil series which comprises of fine montmorillionitic isohyperthemic family of *Vertic Haplustepts.*

Table 2. Chemical properties of initial experimental soil

Sr. No.	Soil properties	Value
A.	**Chemical properties**	
1.	pH (1: 2.5)	8.11
2.	EC (dS m^{-1})	0.33
4.	Organic carbon (%)	0.41
5.	Available N (kg ha^{-1})	260
6.	Available P (kg ha^{-1})	16.84
7.	Available K (kg ha^{-1})	463
8.	DTPA Fe (mg kg^{-1})	4.7
9.	DTPA Mn (mg kg^{-1})	7.2
10.	DTPA Zn (mg kg^{-1})	0.56
11.	DTPA Cu (mg kg^{-1})	3.10

3.4 Details of field experiment

3.4.1 Layout and experimental design

The layout of experiment showing replication wise treatment allotment is given in Fig. 1. The experiment was laid out in a randomized block design with 9 treatments and 3 replications. The gross plot size was 6 m × 4 m and net plot size was 4.5 m × 3.6 m.

3.5 Method

3.5.1 Experimental details

Field experiment on "Effect of nitrogen levels and nitrogen inhibitors on the soil nitrogen availability, uptake and yield of *kharif* maize in Inceptisol" maize crop was conducted at PGI Farm of Department of Soil Science and Agricultural Chemistry, M.P.K.V., Rahuri during 2015-16.

1.	Location	:	PGI Research Farm M.P.K.V Rahuri.
2.	Crop	:	Hybrid Maize
3.	Soil type	:	Inceptisol (*Vertic Haplustept*)
4.	Season	:	*Kharif* 2015
5.	Variety	:	*Rajarshi*
6.	Treatments	:	9
7.	Replications	:	3
8.	Design	:	RBD
9.	Spacing	:	75 × 20 cm
10.	Plot size	:	Gross: 6.0 m ×4.0 m Net: 4.5 m × 3.6 m

3.5.2 Treatment details

T_1 : GRDF(120:60:40 kg ha^{-1} N, P_2O_5 and K_2O +10 t ha^{-1} FYM)
T_2 : 85 % N-GRDF-Agro-N-Protect coated urea
T_3 : 70 % N-GRDF-Agro-N-Protect coated urea
T_4 : 85 % N-GRDF-Neem coated urea
T_5 : 70 % N-GRDF-Neem coated urea
T_6 : 85 % N-GRDF-Agro-N-Protect coated urea + Neem coated urea
T_7 : 70 % N-GRDF-Agro-N-Protect coated urea + Neem coated urea
T_8 : 0 % N-GRDF
T_9 : Absolute Control

NOTE

1. The nitrogen as per treatments (T_1 to T_8) was applied in splits 1/3 at sowing, 1/3 30 DAS and remaining 1/3 after 45 days of sowing DAS.
2. The recommended dose of P_2O_5, K_2O and FYM was applied as basal dose for treatment T_1 to T_8 at sowing.
3. Urea was coated by Agro-N-protect @ 3 ml kg^{-1} of urea by weight.
4. Limiting micronutrient (Zinc) (T_1 to T_8) was applied in soil at the time of sowing @ 20 kg ha^{-1}

3.6 Detailed field operation

3.6.1 Seeds and sowing

Healthy viable seed of hybrid maize variety Rajarshi was obtained from the Chief Scientist, Central Seed Cell, M.P.K.V., Rahuri for the experiment.

3.6.2 Fertilizers application

Neem coated urea, Agro-N-protect coated urea, urea, single superphosphate, muriate of potash and zinc sulphate was used as a source of N, P_2O_5, K_2O. The treatment-wise quantity of nutrients applied through chemical fertilizer added is presented in (Table 3).

Table 3. Treatment wise nutrient organic and inorganic fertilizer application for plot to maize crop

Tr. No	Treatment	FYM Kg plot^{-1}	N g plot^{-1}	P_2O_5 g plot^{-1}	K_2O g plot^{-1}	Urea g plot^{-1}			ANPU g plot^{-1}			NU g plot^{-1}			SSP g plot^{-1}	MOP g plot^{-1}
						0	30	45	0	30	45	0	30	45		
T_1	GRDF	24	288	144	96	206	206	206							900	160
T_2	85%N-GRDF-ANPU	24	244	144	96	-	-	-	175	175	175				900	160
T_3	70%N-GRDF-ANUP	24	201	144	96	-	-	-	144	144	144				900	160
T_4	85%N-GRDF-NU	24	244	144	96	-	-	-				175	175	175	900	160
T_5	70%N-GRDF-NU	24	201	144	96	-	-	-				144	144	144	900	160
T_6	85%N-GRDF-ANPU+NU	24	244	144	96	-	-	-	87.5	84.5	87.5	87.5	87.5	87.5	900	160
T_7	70%N-GRDF-ANPU+NU	24	201	144	96	-	-	-	72	72	72	72	72	72	900	160
T_8	0%N-GRDF	24		144	96	-	-	-							900	160
T_9	Absolute control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

3.7 Cultural operations

The periodical cultural operations carried out for the field experiment is shown in Table 4.

Table 4. Periodical cultural operations

Sr. No.	Field operations	Date of operations
	Experimental crop (Maize crop)	
1.	Ploughing	5/6/2015
2.	Rotavator	25/6/2015
3.	Lay out	21/7/2015
4.	Soil sample collection	23/7/2015
5.	Sowing	25/7/2015
6.	Application of FYM & NPK	25/7/2015
7.	Gap filling	3/8/2015
8.	Irrigations	25/7/2015, 31/7/2015 3/8/2015 , 24/8/2015
9.	Fertilizer application in 3 split at regular interval	25/07/2015, 24/8/2015, 8/9/2015
11.	Weeding	19/8/2015, 5/9/2015
12.	Harvesting of maize crop	3/11/2015

3.7.1 Pre-sowing operation

3.7.1.1 Ploughing

Ploughing was done at once by tractor plough.

3.7.1.2 FYM

Well decomposed farm yard manure was procured from Cattle Project, M.P.K.V., Rahuri.

3.7.1.3 Fertilizer application

Nitrogen in the form of urea either coated or non coated as per treatment were applied in three equal split at interval of 0, 30, 45 DAS and other nutrients P_2O_5 and K_2O were applied once at the time of sowing through SSP and MOP respectively. The limiting micronutrient Zn was applied through zinc sulphate @ 48 g plot^{-1} at sowing.

3.7.2 Sowing

The seeds were treated with thiram. At field capacity of soil, sowing was done by dibbling at a distance of 75 x 20 cm putting one seeds per whole at about 5 cm depth and then covered with soil. Eight rows and 20 hills per row were planted through dibbling of seed.

3.7.3 Post sowing cultural operations

3.7.3.1 Irrigation

All plots were irrigated uniformly when required to maintain soil moisture at optimum for normal plant growth.

3.7.3.2 Inter cultivation

Hand weeding and stirring of surface soil was done two times to remove weeds and for facilitating aeration to growing root system.

3.7.3.3 Plant protection measures

The sprays of pesticide chemicals were given at specific time interval to protect crop from attack of insect, pest and diseases.

3.7.3.4 Harvesting and threshing

Maize plants from all net plots were harvested after removing the two guard rows from two sides of the plot and two plants from both the ends of each row. The corn cobs produce from each plot were threshed after drying with the help of threshing tool and kept in separate bags and was labeled properly. The grain weight and stover weight of plants per plot were recorded on air dry basis.

3.7.4 Yield

Yields of maize for grain and stover were recorded by weighing grains and obtained separately, the stover weights obtained from the plants in the net plot area. These grain and stover weights were converted into respective yields expressed in (q ha^{-1})

3.8 Details of laboratory analysis

3.8.1 Laboratory material

3.8.1.1 Glass wares

The necessary glassware *viz.*, beaker, conical flask, volumetric flask, pipette, glass rod, burette, funnel, measuring cylinder, digestion tubes etc. were used for analytical work in the laboratory.

3.8.1.2 Equipments

The equipments *viz.,* kelplus digestion and distillation unit, hot air oven, weighing balance, grinding machine, mechanical shaker, kelplus auto N analyser, flame photometer, atomic absorption spectrophotometer, pH meter, conductivity meter, spectro photometer and hot plate etc. were used during the chemical analysis of soil and plant for various estimations.

3.8.1.3 Chemicals

High purity (AR grade) chemicals such as sulphuric acid, sodium hydroxide, hydrogen peroxide, hydrochloric acid, potassium permanganate, sodium bicarbonate, ammonium acetate, ammonium molybdate, ammonium vanadate, boric acid, phenolphthalein, methyl red, bromocresol green etc. were used.

3.8.2 Methods

3.8.2.1 Analysis of soil

Representative surface soil sample of the experimental site were collected up to 22.5 cm depth at intial and harvesting stage of maize from each plot to know the fertility status of soil. The collected soil samples were dried under shade, grinded in wooden mortar and pestel, sieved through 2 mm sieve and were analyzed for pH, EC, available N, P, K and DTPA extractable micronutrients viz, Fe, Zn, Mn, Cu. For organic carbon estimation soil was sieved from 0.5 mm sieve. The analysis of soil was done by adopting standard methods given in table 7.

3.8.2.2 Total plant analysis

The stover and seed samples were collected at harvest of maize. The samples were air dried and then dried in oven at 70^{0}C till constant weight. The whole plant sample of each treatment was grinded through a Willey grinding mill after oven drying. Digestion of plant sample was done and used for estimation of nutrient concentration *viz.,* N, P, K and micronutrients Fe, Zn, Mn and Cu as per the specified methods given in table 7.

Apparent nutrient recovery efficiency (ANR) was calculated by following formulae

$$\text{ANR}\ \% = \frac{(\text{Nutrient uptake F, Kg} - \text{Nutrient uptake C, Kg})}{\text{Quantity of nutrient applied, Kg}} \times 100 \quad \dots 3.1$$

$$\text{AE}\ (\text{kg kg}^{-1}) = \frac{(\text{Total yield F, Kg ha}^{-1} - \text{Total yield C, kg ha}^{-1})}{\text{Quantity of nutrient applied kg ha}^{-1}} \quad \dots 3.2$$

Where, F = plants receiving fertilizer and C = plants receiving no fertilizer.

3.9 Incubation study

In order to study the effect of treatments on enzyme activity under ambient condition the incubation study was carried out there were 9 treatments same as that of field experiment with three replications. The details of the treatment and fertilizer applied for these are given in Table 5.

The soil samples were sieved through 2 mm sieve. The air dry soil sample of 2000 g was placed in each of plastic bowl. Neem coated urea and Agro-N-protect and urea were applied to the soil in pot (capacity 2 kg soil) for studying the mineralization of nitrogen at soil moisture equivalent. The soil was moistened to field capacity and was maintained by adding appropriate quantity of distilled water after alternate day. The soil samples were incubated in triplicate for 75 days at room temperature ($26^{0}C \pm 2$). The soil sampling from each pot was done at interval for urease activity i.e. 0, 8, 14, 30, 45, 60 and 75 days and for dehydrogenase activity i.e. 0, 30, 75 days. The soil samples were analyzed for urease activity and dehydrogenase activity as per the methods specified in Table 7.

Table 5. Nutrient and Fertilizers applied in the pots for incubation study

Tr. No	Treatment	FYM g pot-1	N g pot-1	P_2O_5 g pot-1	K_2O g pot-1	Urea g pot-1			ANPU g pot-1			NU g pot-1			SSP g pot-1	MOP g pot-1
						0	30	45	0	30	45	0	30	45		
T_1	GRDF	8.9	0.18	0.04	0.02	0.15	0.15	0.15							0.66	0.11
T_2	85%N-GRDF-ANPU	8.9	0.16	0.04	0.02	-	-	-	0.13	0.13	0.13				0.66	0.11
T_3	70%N-GRDF-ANPU	8.9	0.12	0.04	0.02	-	-	-	0.10	0.10	0.10				0.66	0.11
T_4	85%N-GRDF-NU	8.9	0.16	0.04	0.02	-	-	-				0.13	0.13	0.13	0.66	0.11
T_5	70%N-GRDF-NU	8.9	0.12	0.04	0.02	-	-	-				0.10	0.10	0.10	0.66	0.11
T_6	85%N-GRDF-ANPU+NU	8.9	0.16	0.04	0.02	-	-	-	0.06	0.06	0.06	0.06	0.06	0.06	0.66	0.11
T_7	70%N-GRDF-ANPU+NU	8.9	0.12	0.04	0.02	-	-	-	0.05	0.05	0.05	0.05	0.05	0.05	0.66	0.11
T_8	0%N-GRDF	8.9		0.04	0.02	-	-	-	-	-	-	-	-	-	0.66	0.11
T_9	Absolute control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6. Incubation study operations

Sr. No.	Incubation study	Date of operations
	Experiment in soil	
1.	Soil sample collection	23/07/2015
2.	Incubation	20/8/2015
3.	Application of FYM & NPK	20/8/2015
4.	Nitrogen application in 3 split at regular interval	20/8/2015 20/9/2015 5/10/2015
5.	Soil sample collection to measure the urease activity	20/8/2015 28/8/2015 4/9/2015 20/9/2015 5/10/2015 25/10/2015 5/11/2015
9.	Soil sample collection to measure the dehydrogenase activity	20/8/2015 20/9/2015 5/11/2015

3.10 Methods used for soil and plant analysis

The standard methods used for soil and plant sample for field and incubation study analysis were presented in Table 7.

Table 7.a. Standard analytical methods for soil

Sr. No.	Particular	Method	References
A.	**Soil analysis**		
1.	p^H (1:2.5)	Potentiometric	Jackson (1973)
2.	EC (1:2.5)	Conductometric	Jackson (1973)
3.	Organic carbon	Wet oxidation	Nelson and Sommer (1982)
4.	Available N	Alkaline permanganate	Subbaih and Asija (1956)
5.	Available P	0.5 *M* $NaHCO_3$ at pH 8.5 Ascorbic acid	Olsen *et.al* (1954)
6.	Available K	N *N* NH_4OAc	Knudsen and Peterson (1982)
7.	NH_4^+-N & NO_3^--N	Steam distillation	Bremner and Keeney (1965)
8.	Available Fe, Mn, Cu, Zn	DTPA-extract (Atomic Absorption Spectrophotometer)	Lindsay and Norvell (1978)
9.	Urease activity	Titrimetric	Tabatabai and Bremmer (1972)
10.	Dehydrogenase activity	Spectrophotometry	Casida *et al.* (1964)

Table 7.b.Standard analytical methods for plant

Sr. No.	Plant Analysis	Method Used	Reference
1.	Total N	Microkjeldahl Wet digestion, (H_2O_2:H_2SO_4 1:1)	Jackson (1973)
2.	Total P	Vanadomolybdate phosphoric acid yellow colour method (Diacid digestion 9:4 mixture of HNO_3:$HClO_4$).	Jackson (1973)
3.	Total K	Flame Photometery, (Diacid digestion 9:4 mixture of HNO_3:$HClO_4$).	Chapman and Pratt (1961)
4.	Micronutrients (Fe, Mn, Zn and Cu)	Atomic absorption spectrophotometery	Zososki and Burau (1977)

3.11 Statistical analysis

The field experiment was conducted by using Randomised block design and Laboratory incubation styudy was conducted by using Factorial completely randomised block design. The data obtained was analysed as per the methods described by Panse and Sukhatme (1985).

4. RESULTS AND DISCUSSION

The field experiment entitled "Effect of nitrogen levels and nitrogen inhibitors on the soil nitrogen availability, uptake and yield of *kharif* maize in Inceptisol" was conducted during the year 2015-16 in the Department of Soil Science and Agricultural Chemistry, at Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri. The laboratory incubation study was conducted at ambient conditions simultaneously during crop period. The results obtained in field experiment in respect maize yield, nutrient uptake, residual soil properties and enzymatic activity (Incubation study) are presented and discussed here in the chapter under different heads and subheads.

4.1 Chemical properties of soil

4.1.1 Soil p^H

The data pertaining to p^H of soil after harvest of maize is presented in table 8. The p^H was recorded highest in T_4 and T_6 (8.16) due to application of 85 % N-GRDF - Neem coated urea and 85 % N-GRDF-Agro-N-protect coated urea + neem coated urea.

From the present data, it can be seen that the treatments comparing of nitrogen levels and N inhibitors were non-significant in respect of the soil p^H. These results are in close conformity with the observations of Dixit and Gupta (2000).

Table 8. Soil chemical properties as influenced by treatments at harvest of maize

Tr. No.	Treatment	p^H (1:2.5)	EC (dSm^{-1})	Org. C (%)
T_1	GRDF	8.08	0.32	0.42^a
T_2	85 % N-GRDF- ANPU	8.14	0.35	0.43^a
T_3	70 %N-GRDF- ANPU	8.13	0.34	0.40^b
T_4	85 % N- GRDF – NU	8.16	0.35	0.45^a
T_5	70 % N- GRDF –NU	8.10	0.33	0.42^a
T_6	85 % N- GRDF- ANPU + NU	8.16	0.35	0.44^a
T_7	70 % N- GRDF- ANPU + NU	8.12	0.33	0.41^b
T_8	0 % N- GRDF	8.05	0.32	0.39^b
T_9	Absolute Control	8.04	0.31	0.37
	Initial	8.11	0.33	0.41^b
	S.E. $\pm$	0.043	0.002	0.011
	CD at 5 %	NS	NS	0.030

4.1.2 Electrical conductivity

The data in respect of electrical conductivity of soil at harvest of maize crop presented in table 8.

The EC was highest in T_2 (0.35), T_4 (0.35) and T_6 in (0.35) dsm^{-1} and lowest in T_9 (0.31). Numerically lower EC was recorded in the absolute control. The slight increase in EC might be due to application of fertilizers for various treatments increased the salt load of soil.

Sofi *et al.* (2004) reported that nitrogen and potassium nutrition increased soil available N, P and K, as pH, EC and organic carbon content did not influence.

The soil electrical conductivity did not influenced by the use of nitrogen inhibitor or levels of nitrogen at harvest of maize crop.

4.1.3 Organic carbon

The soil organic carbon at harvest of crop was significantly influenced by the treatments presented in table 8.

The organic carbon content was in range between 0.37 and 0.45 %. The organic carbon content was observed significantly higher in treatment (T_4) 85 % N-GRDF neem coated urea (0.45 %) and statistically on par with 85 % N-GRDF-Agro-N-protect coated urea+ neem coated urea (0.44 %) and 85 % GRDF-Agro-N-protect coated urea (0.43 %), 70 % N GRDF-neem coated urea (0.42 %) and GRDF (0.42 %).

The increase in organic carbon was due to the application of FYM to all plots except absolute control. Organic treatments and nitrogen inhibitors might have influenced to raise the organic carbon levels and organic matter in soil might have increased the soil microbial biomass.

Deshmukh *et al.* (2005) reported the increase in organic carbon of soil due to application of 75 % NPK + 2.5 t ha^{-1} FYM + crop residues, confirming the present results.

Inference of the present investigation can be stated as the application of FYM or FYM + N-inhibitor can increase the organic carbon in soil which might have useful for development of soil micro-organisms and enzyme activities.

4.2 Soil available N, P and K at harvest stage

4.2.1 Available nitrogen

The residual soil available nitrogen at harvest of maize was significantly influenced by the coating of urea with Agro-N protect over the neem coated urea applied to maize crop (Table 9).

It was observed that the available nitrogen was significantly increased by the applications of urea coated with nitrogen inhibitors over T_1, T_8 and T_9. The highest value of available nitrogen was under the treatment (T_2) of urea blending with 85 % N-GRDF-Agro-N-protect coated urea (251.50 kg ha^{-1}). The available N found increased with nitrogen levels applied and nitrogen inhibitor used.

Variations in N availability of the treatments might be due to variations in applied levels of N. Similarly there might be effect due to N inhibitors responsible for avoiding N losses.

Increased availability of N was reported due to use of organic nutrient sources in (Prakash *et al.* 2002) intensive use of organic and inorganic resources (Tiwari *et al.,* 2002) and reducing N losses by N inhibitors (Xu *et al.,* 2000) and also conformity with observations (Chen *et al.,* 2008).

The use of nitrogen inhibitors might have better utility in enhancing the N availability use efficiency of nitrogenous fertilizer.

Table 9. Residue Soil fertility as influenced by different treatments at harvest of maize

Tr. No.	Treatment	Soil available nutrients (kg ha^{-1})				
		N	P	K	NH_4^+N	NO_3^-N
T_1	GRDF	191.29	14.84^{b}	377.2^{b}	147.39	37.63
T_2	85 % N-GRDF- ANPU	251.50^{a}	16.63^{a}	410.5^{a}	185.00^{a}	59.58^{a}
T_3	70 %N-GRDF- ANPU	210.11	14.42^{c}	369.6^{b}	159.93	43.90
T_4	85 % N- GRDF – NU	233.11^{b}	15.80^{a}	387.6^{a}	181.88^{a}	53.31^{b}
T_5	70 % N- GRDF –NU	205.97	13.49	351.9	156.80	40.76
T_6	85 % N- GRDF- ANPU + NU	241.40^{a}	16.08^{a}	403.2^{a}	181.88^{a}	56.44^{a}
T_7	70 % N- GRDF- ANPU + NU	206.65	14.14^{c}	362.1^{b}	163.07	37.63
T_8	0 % N- GRDF	183.98	11.27	339.7^{c}	141.12	34.49
T_9	Absolute Control	167.85	9.86	318.2	128.57	31.36
	Initial	260.21	16.84	463.3	191.29	59.58
	S.E. $\pm$	3.92	0.41	9.45	3.12	1.96
	CD at 5 %	11.85	1.24	28.57	9.35	5.89

4.2.2 Available phosphorus

The residual soil available phosphorus at harvest of maize was significantly influenced by the treatments of nitrogen inhibitors and nitrogen levels to maize crop (Table 9).

The data indicated that phosphorus increased significantly in all treatments of urea blending with nitrogen inhibitors. The range was between 9.86 to 16.63 kg ha^{-1}.

The highest available phosphorus was recorded in treatment of application of urea blending with 85 % N through Agro-N-protect (16.63 kg ha^{-1}). Treatment T_6 consists of 85 % N through Agro-N-protect + neem coated urea (16.08 kg ha^{-1}) was at par with (T_4) 85 % N through neem coated urea (15.80 kg ha^{-1}). It might be due to microbial solubilization of P in presence of organic matter in applied FYM and availability of N (Gaur *et al.* 1984) and similar results were also reported by Ingle *et al* (2010).

Thus it can be concluded that availability of increased with N levels and use of N inhibitors.

4.2.3 Available potassium

The residual soil available potassium at harvest of maize was significantly influenced by the coating of urea with Agro-N-protect and neem coated urea applied to maize crop table 9.

The significantly highest available potassium was recorded in treatment of application of urea blending with (T_2) 85 % N through Agro-N-protect (410 kg ha^{-1}) and was at par with (T_6) 85 % N through Agro-N-protect + neem coated urea (403 kg ha^{-1}) and (T_4) 85 % N-neem coated urea (388 kg ha^{-1}). The lowest available potassium was recorded in control treatment (318.2 kg ha^{-1}).

The availability of K might have improved due to native K, application of K through FYM along with N, P and K fertilizer. The availability of NH_4^+ ion in soil might have presented K fixation helpful for increased K availability in soil.

The increase in available K was reported by Mathur (1997) due to NPK + FYM application, Suresh and Hasan (2002) due to N and K application.

The availability of K increased because of more availability of N through applied N inhibitors.

4.2.4 Available form of NH_4^+-N and NO_3^--N

The residual soil available NH_4^+-N and NO_3^--N at harvest of maize was significantly influenced by the coating of urea with Agro-N protect and neem coated urea applied to maize crop (Table 9).

The nitrogen application to the maize @ 85 % N-GRDF-Agro-N-protect coated urea recorded significantly highest value for NH_4^+-N (185.0 kg ha^{-1}) and NO_3^--N (59.58 kg ha^{-1}). The treatment (T_6) 85 % N through Agro-N-protect + Neem coated urea (181.88 and 56.44 kg ha^{-1} for NH_4^+-N and NO_3^--N respectively. it was at par with in respect of NH_4^+-N with T_4 (85 % N neem coated urea). The values of NH_4^+-N were higher than NO_3^--N in all treatments and also NH_4^+-N was at par with (T_4) 85 % N through neem coated urea (181.88 kg ha^{-1}).

It might be due to N application through coated of urea with the Agro-N-protect and neem coated urea increased availability of N in the form of NH_4^+-N and NO_3^--N. Hence inhibitors will useful for slow release N to crop as per its requirement. Similar results are also obtained by Majumdar (2007).

4.3 Soil available micronutrients at harvest

4.3.1 Available Fe

The residual soil available Fe at harvest of maize was significantly influenced by nitrogen inhibitors and nitrogen levels to maize crop (Table 10).

The application of 85 % N-GRDF with Agro-N-protect recorded significantly high amount of Fe (3.75 mg kg^{-1}). It was par with 85 % N through Agro-N-protect coated urea + neem coated urea (3.65 mg kg^{-1}).

The application of fertilizer treatments either alone or with FYM (NPK + FYM and NPK + FYM + Zn) showed significantly higher DTPA - Fe content than other reported by Singh *et al.* (1999).

It was observed that the available Fe was significantly increased by the application of urea coated with nitrogen inhibitors over control.

4.3.2 Available Mn

The residual soil available Mn at harvest of maize was significantly influenced by nitrogen inhibitors and nitrogen levels to maize crop (Table 10).

The data recorded indicated that the available Mn was significantly increased (6.31 mg kg^{-1}) in treatment of (T_2) 85 % N Agro-N-protect coated urea over all the treatments except T_6 (6.10 mg kg^{-1}) and T_4 (6.00 mg kg^{-1}).

It was revealed that available Mn increased significantly with application of urea treated with nitrogen inhibitors. Similar results are also obtained by Kadam *et al.* (2010).

Table 10. Residue Soil fertility as influenced by different treatments at harvest of maize

Tr. No.	Treatment	DTPA-Micronutrient (mg kg^{-1})			
		Fe	Mn	Zn	Cu
T_1	GRDF	3.13	5.47[c]	0.53[a]	2.40
T_2	85 % N-GRDF- ANPU	3.75[a]	6.31[a]	0.54[a]	2.71[a]
T_3	70 %N-GRDF- ANPU	3.32	5.70[b]	0.51[c]	2.51
T_4	85 % N-GRDF –NU	3.54[b]	6.00[a]	0.52[b]	2.58[b]
T_5	70 % N-GRDF –NU	3.12	5.44[c]	0.48	2.46
T_6	85 % N-GRDF- ANPU + NU	3.65[a]	6.10[a]	0.53[a]	2.62[a]
T_7	70 % N-GRDF- ANPU + NU	3.22	5.50[c]	0.50	2.45
T_8	0 % N- GRDF	3.02	5.02	0.47	2.37
T_9	Absolute Control	2.85	4.81	0.44	2.10
	Initial	4.7	7.2	0.56	3.10
	S.E. $\pm$	0.064	0.139	0.003	0.032
	CD at 5 %	0.19	0.41	0.01	0.09

4.3.3 Available Zn

The residual soil available Zn at harvest of maize was significantly influenced by nitrogen inhibitors and nitrogen levels to maize crop (Table 10).

The highest available Zn was recorded in treatment of application of urea coated with 85 % Agro-N-protect coated urea (0.54 mg kg^{-1}) and it was at par with 85 % N-Agro-N-protect coated urea + neem coated urea , treatment of GRDF (0.53 mg kg^{-1}) and (85 % N-GRDF-Neem coated urea).

The results indicated that Zn increased significantly in all treatments of urea coated with nitrogen inhibitors and due to supply of high nitrogen dose. Similar results were also reported by Prakash *et al.* (2002).

4.3.4 Available Cu

The residual soil available Cu at harvest of maize was significantly influenced nitrogen inhibitors and nitrogen levels to maize crop (Table 10).

It is observed from the data that the available Cu was significantly increased in treatment (T_2) of 85 % N-GRDF-Agro-N-protect coated urea (2.71 mg kg^{-1}). and was at par with treatment of 85 % N-GRDF-Agro-N-protect coated urea + Neem coated urea (2.62 mg kg^{-1})

This might be because of 85 % N application to maize through Agro-N-protect coated urea or NU release the nitrogen slowly to nitrogen which fulfill nitrogen requirement as per physiological growth stages of maize crop.

Thus the application of nitrogen to the maize crop @ 85 % N through Agro-N-protect coated urea alone or 85 % through Agro-N-protect and neem coated urea are most beneficial for improving the DTPA-Cu status in soil. These results are inclose conformity with observations of Singh *et al.* (1999).

4.4 Plant Population

The data obtained for plant population of gross plot size converted on hector basis and per cent basis is presented in Table 11.

Table 11. Plant population of maize as influenced by different treatments

Tr. No.	Treatment	Plant population (ha^{-1})	Population (%)
T_1	GRDF	61510^a	92.26
T_2	85 % N-GRDF- ANPU	61943^a	92.91
T_3	70 %N-GRDF- ANPU	61249^a	91.87
T_4	85 % N- GRDF – NU	61665^a	92.49
T_5	70 % N- GRDF –NU	60832^b	91.24
T_6	85 % N- GRDF- ANPU + NU	61804^a	92.70
T_7	70 % N- GRDF- ANPU + NU	60693^b	91.04
T_8	0 % N- GRDF	60138^c	90.20
T_9	Absolute Control	58332	87.49
	S.E. $\pm$	354	
	CD at 5 %	1063	

It is observed that there was significant influence of treatments on plant population. It was range between 58332 to 61943 plant ha^{-1}. It was found significantly highest in T_2 over rest of the treatments. It was followed by T_6, T_4, T_1 and T_3. This might be associated with release of nitrogen in treatment 85 % N through Agro-N-protect coated urea and 85 % N through Agro-N-Protect coated and neem coated urea sufficient for maize and no any adverse or toxic effect on maize crop. Hence, there was maintained the plant population as compare to other treatments. (Chaudhari *et al.,* 2006) observed the growth parameters as number of leaves, number of tillers, chlorophyll content was significantly higher with the application of nitrogen through neem coated urea. Use neem coated urea found better for crop growth (Dhawar *et al.,* 2011; Kaur *et al.*, 2012) observed that increase in growth parameters with levels of nitrogen.

Thus addition of nitrogen to maize @ 85 % N through Agro-N-protectcoated urea or 85 % N through Agro-N-protect urea + neem coated urea are useful for optimizing the maize plant population.

4.5 Yield of maize

4.5.1 Grain yield

The data regards grain yield as affected due to various treatments for N-levels and nitrogen inhibitors presented in Table 12.

The treatment differences due to N application and N inhibitors were found significant. It has range between 28.18 to 58.84 q ha^{-1}. The application of 85 % N-GRDF coated with ANPU recorded significantly highest grain yield (58.84 q $ha-^{1}$) and was at par with T_6 (57.29 q ha^{-1}) and T_4 (58.84 q ha^{-1}). The treatment of GRDF (T_1) recorded (52.17 q ha^{-1}).

Increase in grain yield of maize with increase in N level was reported by Carvalho *et al.* (2012).

Virendra (2014) reported the neem coated urea significantly increased grain yield in maize crop.

Table 12. Grain and stover yield of maize as influenced by different treatments

Tr. No.	Treatment	Yield (q ha^{-1})	
		Grain	Stover
T_1	GRDF	52.17	88.16
T_2	85 % N-GRDF- ANPU	58.84[a]	116.44[a]
T_3	70 %N-GRDF- ANPU	53.00	95.65
T_4	85 % N- GRDF NU	56.43[a]	109.59[a]
T_5	70 % N- GRDF –NU	48.51	81.48
T_6	85 % N- GRDF- ANPU + NU	57.29[a]	112.91[a]
T_7	70 % N- GRDF- ANPU + NU	50.13	87.41
T_8	0 % N- GRDF	41.03	69.22
T_9	Absolute Control	28.18	55.47
	S.E. $\pm$	1.06	3.85
	CD at 5 %	3.21	11.65

The increase in grain yield might be due to supply of higher dose of nitrogen is (85 % as compressed to 70 % N) and action of nitrogen inhibitor to prevent loss of N. It might have supplied higher nitrogen as and when required, during the crop growth period, ultimately responsible for increase in grain yield.

There was increase in grain yield of maize due to reduction of N levels (15 %) with use of N inhibitors over GRDF.

4.5.2 Stover yield

The data regards fodder yield as affected due to various treatments for N-levels and nitrogen inhibitors is presented in (Table 12).

The urea blended with nitrogen inhibitors significantly increased the fodder yield over control. The fodder yield of treatments range between (55.47 to 116.44 q ha^{-1}).

Among the treatment T_2 (116.44 q ha^{-1}) was found significantly higher for fodder yield of maize and it was at par with T_6 and T_4. The increase in stover yield due to N (85 to 70 % N) and action of nitrogen inhibitors.

Nitrogen application through urea treated with urease or nitrification inhibitors helps to control N losses helps to improve yield (Dhawar *et al.* 2011).

Thus results showed that addition of nitrogen to maize crop coating with Agro-N-Protect and neem with 70 to 85 % levels of nitrogen was found beneficial for enhancing the stover yield of maize over GRDF and control. Similar results were also reported by Arun *et al.* (2014).

4.6 Concentration of N, P and K in maize grain

4.6.1 Concentration of N

The concentration of nitrogen in maize grain as influenced by N levels and nitrogen inhibitors were analysed and presented here with (Table 13).

Concentration of nitrogen in maize grain significantly higest (2.11 %) in treatment of T_2 (85 % N-Agro-N-protect coated urea) over all the treatments except treatment T_6 (2.0 %) and T_4 (1.96 %).

It was revealed that concentration of nitrogen in grain increased significantly with application of urea treated with Agro-N-protect. It also found not affected due to level increased nitrogen (70 to 85 %) dose over GRDF in maize grain. Similar results were also reported by Muneshwar and Singh (1986)

Table 13. The nutrient concentration in maize grain as influenced by treatments

Tr. No.	Treatment	nutrient concentration (%)		
		N	P	K
T_1	GRDF)	1.87[b]	0.68	0.47[b]
T_2	85 % N-GRDF- ANPU	2.11[a]	0.84[a]	0.57[a]
T_3	70 %N-GRDF- ANPU	1.96[a]	0.73	0.45[b]
T_4	85 % N- GRDF – NU	1.91[b]	0.80[a]	0.50[b]
T_5	70 % N- GRDF –NU	1.87[b]	0.69	0.40[c]
T_6	85 % N- GRDF- ANPU + NU	2.00[a]	0.82a	0.55[a]
T_7	70 % N- GRDF- ANPU + NU	1.91[b]	0.70	0.47[b]
T_8	0 % N- GRDF	1.77	0.62	0.38
T_9	Absolute Control	1.73	0.60	0.37
	S.E. $\pm$	0.051	0.013	0.025
	CD at 5 %	0.15	0.04	0.07

4.6.2 Concentration of P

The phosphorus concentration in maize grain as influenced by application of urea treated with nitrogen inhibitors were analysed and presented herewith (Table13).

The concentration of phosphorus in maize grain significantly increased in treatment T_2 (0.84 %) and was par with T_4 (0.80 %) and T_6 (0.82 %). The concentration of phosphorus might have increased due to more availability of nitrogen throughout growing period in the presence of N inhibitor and having synergistic interaction among N and P. These results are in close conformity with observation of Singh *et al.* (2010).

4.6.3 Concentration of K

The concentration of potassium in maize grain as influenced by application of urea treated with nitrogen inhibitors were assessed and presented here with (Table 13).

The potassium concentration was the highest in treatment T_2 (0.57 %) which was at par with treatment T_4 (0.50 %) and T_6 (0.55 %). The lowest potassium was recorded in control treatment (0.37 %).

Total potassium concentration in grain was increased significantly in the treatment receiving of urea blended with Agro-N-Protect coated urea and increased rate (70 to 85 % of RDN) of nitrogen application. Similar results were also reported by Sujatha *et al.* (2008).

4.7 Concentration of micronutrient in maize grain

4.7.1 Concentration of Fe

The concentration of Fe in maize grain as influenced by application of urea treated with nitrogen inhibitors were analysed and presented here with (Table 14).

The application of 85 % N-GRDF with Agro-N-protect recorded significantly high amount of Fe (210 ppm). It was par with 85 % N through Agro-N-protect coated urea + neem coated urea (203 ppm) and 85 % N neem coated urea (201 ppm)

It was observed that the concentration Fe was significantly increased by the application of urea coated with nitrogen inhibitors over control. Similar results were also reported by Mukhopadhyay and Das (2001).

Table14. Micronutrient concentration in maize grain as influenced by treatments.

Tr. No.	Treatment	DTPA-Micronutrient Grain concentration (ppm)			
		Fe	Mn	Zn	Cu
T_1	GRDF	159	62[c]	38	3.28
T_2	85 % N-GRDF- ANPU	210[a]	71[a]	58[a]	5.20[a]
T_3	70 %N-GRDF- ANPU	184	61[c]	42	4.05
T_4	85 % N-GRDF –NU	201[a]	67[a]	52[b]	4.48
T_5	70 % N-GRDF –NU	168	63[b]	39	3.23
T_6	85 % N-GRDF- ANPU + NU	203[a]	67[a]	54[a]	4.65
T_7	70 % N-GRDF- ANPU + NU	181[c]	61[c]	41	3.63
T_8	0 % N- GRDF	150	58	38	2.75
T_9	Absolute Control	133	52	34	2.09
	S.E. $\pm$	3.52	1.44	1.17	0.15
	CD at 5 %	10.57	4.32	3.51	0.47

4.7.2 Concentration of Mn

The data regardind concentration of Mn as affected due to various treatments for N-levels and nitrogen inhibitors is presented in Table 14.

The application of nitrogen to maize crop @ 85 % N through Agro-N-Protect coated urea was found significantly superior for Mn Concentration (71 ppm) over other treatments and statistically on par with treatment (T_4) 85 % N neem coated urea (67 ppm) and (T_6) 85 % N through Agro-N-protect and neem coated urea (67 ppm).

Form of N supplied in available form to the plants greatly influenced the absorption of other ions particularly micronutrients. These results are in close conformity with observation of Borgognone *et al.* 2012).

4.7.3 Concentration of Zn

The concentration of Zn in maize grain as influenced by application of urea treated with nitrogen inhibitors were assessed and presented here with (Table 14).

The application of 85 % N-GRDF with Agro-N-protect recorded significantly high amount of Fe (58 ppm) and was at par with 85 % N through Agro-N-protect coated urea + neem coated urea (54 ppm).

The interaction between N and Zn on the uptake and concentration of N and Zn appears to be synergetic, that is, soil application of N in combination with Zn increased concentration and uptake of these two nutrients. Similar results were also reported by Salam and Subramanian (1988).

4.7.4 Concentration of Cu

The data regards concentration of Cu as affected due to various treatments for N-levels and nitrogen inhibitors is presented in Table 14.

The highest concentration of Cu was recorded due to application of urea coated with 85 % Agro-N-protect coated urea (5.2 ppm) over rest of the treatments

The results indicated that Cu increased significantly in all treatments of urea coated with nitrogen inhibitors and due to supply of high nitrogen dose. These results are in close conformity with observation of Shi *et al.* (2010).

4.8 Concentration of N, P and K in maize stover

Table 15. The nutrient concentration by maize stover as influenced by treatments

Tr. No.	Treatment	nutrient concentration (%)		
		N	P	K
T_1	GRDF	0.89[b]	0.30	0.93
T_2	85 % N-GRDF- ANPU	1.09[a]	0.36[a]	1.25[a]
T_3	70 %N-GRDF- ANPU	0.98[a]	0.31	1.03
T_4	85 % N- GRDF – NU	1.03[a]	0.34[a]	1.15[b]
T_5	70 % N- GRDF –NU	0.89[b]	0.30	0.95
T_6	85 % N- GRDF- ANPU + NU	1.07[a]	0.34[a]	1.22[a]
T_7	70 % N- GRDF- ANPU + NU	0.93[b]	0.31	1.03
T_8	0 % N- GRDF	0.84[c]	0.30	0.83
T_9	Absolute Control	0.75	0.26	0.72
	S.E. $\pm$	0.04	0.009	0.02
	CD at 5 %	0.13	0.02	0.07

4.8.1 Concentration of N

The concentration of nitrogen in maize stover as influenced by N levels and nitrogen inhibitors were assessed and presented here with (Table 15).

Concentration of nitrogen in maize grain significantly increased (1.09 %) in treatment of T_2 (Agro-N-protect coated urea) over all the treatment except treatment T_6 (1.07 %) and T_4 (1.04 %).

It was revealed that concentration of nitrogen increased significantly with application of urea treated with nitrogen inhibitor and also increased with increased nitrogen concentration (70 to 85 %) dose over GRDF. Similar results were also reported by Ali *et al.* (2014).

4.8.2 Concentration of P

The phosphorus concentration in maize stover as influenced by application of urea treated with nitrogen inhibitors were assessed and presented herewith (Table15).

The concentration of phosphorus in maize grain significantly increased in treatment T_2 (0.36%) and was par with T_4 (0.34%) and T_6 (0.34%). The concentration of phosphorus might have increased due to more availability of nitrogen throughout growing period and having synergistic interaction among N and P. Similar results were also reported Majumdar (2007).

4.8.3 Concentration of K

The concentration of potassium stover in maize as influenced by application of urea treated with nitrogen inhibitors were assessed and presented here with (Table 15).

The potassium concentration was the highest in treatment T_2 (1.25 %) which was at par with treatment T_6 (1.22 %). Concentration of potassium in stover was increased significantly in the treatment receiving of urea blended with Agro-N-Protect coated urea. Similar results were also reported Singh *et al.* (2010).

4.9 Concentration of micronutrient in maize stover

4.9.1 Concentration of Fe

The concentration of Fe in maize stover as influenced by application of urea treated with nitrogen inhibitors were assessed and presented here with (Table 16).

The data observed that the concentration of Fe in stover was significantly increased in treatment (T_2) of 85 % N-GRDF-Agro-N-protect coated urea (270 ppm) and was at par with treatment (T_6) of 85 % GRDF-Agro-N-protect coated urea + Neem coated urea (264 ppm) and treatment 85 % Neem coated urea (259 ppm).

This might be because 85 % N application to maize through Agro-N-protect coated urea or NU release the nitrogen slowly to soil solution which fulfill nitrogen requirement as per physiological growth stage of maize. These results are in close conformity with observation of Shi *et al.* (2010).

4.9.2 Concentration of Mn

The data regards concentration of Mn as affected due to various treatments for N levels and nitrogen inhibitors is presented in Table 16.

The concentration of Mn was significantly increased (129 ppm) in treatment of (T_2) 85 % N Agro-N-protect coated urea over all the treatment except T_6 (126 ppm).

It was revealed that concentration of Mn increased significantly with application of urea treated with nitrogen inhibitors. It might be due to synergistic interaction between

N & Mn. These results are in close conformity with observation of Debiprasad *et al*. (2010).

Table 16. Micro nutrient concentration in maize stover as influenced by treatments

Tr. No.	Treatment	DTPA-Micronutrient stover concentration (ppm)			
		Fe	Mn	Zn	Cu
T_1	GRDF	237[c]	91	29	3.76
T_2	85 % N-GRDF- ANPU	270[a]	129[a]	45[a]	5.75[a]
T_3	70 %N-GRDF- ANPU	231[c]	102	39[b]	4.16
T_4	85 % N-GRDF –NU	259[a]	120	42[a]	4.80
T_5	70 % N-GRDF –NU	234[c]	95	33	3.84
T_6	85 % N-GRDF- ANPU + NU	264[a]	126[a]	43[a]	5.28
T_7	70 % N-GRDF- ANPU + NU	244[b]	95	35[b]	4.03
T_8	0 % N- GRDF	211	84	31	3.31
T_9	Absolute Control	203	77	27	2.76
	S.E. $\pm$	5.56	2.26	1.10	0.08
	CD at 5 %	16.68	6.79	3.31	0.25

4.9.3 Concentration of Zn

The data regards concentration of Zn as affected due to various treatments for N-levels and nitrogen inhibitors is presented in Table 16.

The highest concentration of Zn was recorded in treatment of application of urea coated with 85 % Agro-N-protect coated urea (45 ppm) and was par with 85 % N-Agro-N-protect coated urea + neem coated urea (43 ppm) and 85% N by Neem coated urea (42 ppm).

The results indicated that Zn concentrtion increased significantly in all treatments of urea coated with nitrogen inhibitors and due to supply of high nitrogen dose. Similar results were also reported by Hao *et al.* (2007).

4.9.4 Concentration of Cu

The concentration of Cu in maize stover as influenced by application of urea treated with nitrogen inhibitors were assessed and presented here with (Table 16).

The data recorded that application of nitrogen to maize crop @ 85 % N through Agro-N-Protect coated urea was found significantly superior for Cu concentration (5.75 ppm). The lowest value was in control (2.76 ppm).

FYM application as the source of Cu and presence of some native Cu might have get chelated and become the source for supply of Cu. These results are in close conformity with observation of Borgognone *et al.* (2012).

4.10 Uptake of N, P and K by maize

4.10.1 Uptake of N

The nitrogen uptake by maize as influenced by N levels and nitrogen inhibitors were assessed and presented in (Table 17).

Total uptake of nitrogen by maize crop significantly increased (250.72 kg ha^{-1}) in treatment of T_2 (Agro-N-protect coated urea) over all the treatment except treatment T_6 (235.47 kg ha^{-1}). The lowest total nitrogen uptake (90.57 kg ha^{-1}) was recorded in control.

The use of N inhibitors have effectiveness in increasing crop nitrogen uptake (Liu *et al.,* 2013) and also similar results are also reported by Siam *et al.* (2008).

Apparent nutrient recovery efficiency (ANR) significantly increased in treatment T_2 (157 %). It was significantly increased with application of urea with ANPU and NU.

It was revealed that uptake of nitrogen increased significantly with application of urea treated with nitrogen inhibitor and also increased with increased nitrogen (70 to 85 %) dose over GRDF in maize.

4.10.2 Uptake of P

The phosphorus uptake by maize as influenced by application of urea treated with nitrogen inhibitors were assessed and presented herewith (Table17).

The total uptake of phosphorus by maize crop was significantly superior in treatment (T_2) of 85 % N Agro-N-protect coated urea (90.82 kg ha^{-1}) over other treatments and statistically on par with treatment (T_6) of 85 % N through Agro-N-protect + neem coated urea (85.13 kg ha^{-1}). The total phosphorus uptake might have increased due to more availability of nitrogen throughout growing period and having synergistic interaction among them.

The combined application of N:P:K levels increased the uptake of P was reported by Singh *et al.* (2010).

Table 17. Total nutrient uptake by maize as influenced by treatments

Tr. No.	Treatment	Total nutrient uptake (kg ha^{-1})			
		N	ANR %	P	K
T_1	GRDF)	175.46	71	61.38	106.60
T_2	85 % N-GRDF- ANPU	250.72[a]	157	90.82[a]	178.72[a]
T_3	70 %N-GRDF- ANPU	198.18	128	68.06	122.96
T_4	85 % N- GRDF – NU	220.32[b]	127	82.05	154.30
T_5	70 % N- GRDF –NU	168.56	93	59.18	103.15
T_6	85 % N- GRDF- ANPU + NU	235.47[a]	142	85.13	168.81[a]
T_7	70 % N- GRDF- ANPU + NU	170.93	96	60.79	106.86
T_8	0 % N- GRDF	131.18[c]		46.16	73.28
T_9	Absolute Control	90.57		30.95	50.45
	S.E. $\pm$	6.12		1.02	4.65
	CD at 5 %	18.53		3.09	14.07

*ANR : Apparent nutrient recovery efficiency

4.10.3 Uptake of K

The uptake of potassium by maize as influenced by application of urea treated with nitrogen inhibitors were analysed and presented here with (Table 17).

The potassium with 85 % N-GRDF Agro-N-protect coated urea found higher over rest of the treatments. The potassium uptake was the highest in treatment T_2 (178.72 kg ha^{-1}) which was at par with treatment T_6 (168.81 kg ha^{-1}). The lowest potassium was recorded in control treatment (50.45 kg ha^{-1}). Total potassium uptake in grain was increased significantly in the treatment receiving of urea blended with Agro-N-Protect coated urea and increased rate (70 to 85 % of RDN) of nitrogen application.

The total uptake of K was increased due to increase in levels of N (70 to 85 % of RDN) along with N inhibitors (ANPU and or NU). Similar results were also reported by Sawargaokar and Shinde (2009).

4.11 Micronutrient uptake by maize crop

4.11.1 Uptake of Fe

The data regards uptake of Fe as affected due to various treatments of N-levels and nitrogen inhibitors presented in (Table 18).

The total Fe uptake by maize crop significantly increased (4387 g ha^{-1}) in treatment of T_2 (85 % Agro-N-protect coated urea) over all the treatment except treatment T_6 (4153 g ha^{-1}). The lowest total uptake (1502 g ha^{-1}) was recorded in control.

The application of FYM and continues supply of N to plants due to N inhibitors might have responsible for availability of Fe in soil and its subsequent accumulation in plant.

Duhan and Singh (2002) reported that application of N through chemical fertilizer significantly improved the Fe uptake.

The uptake of Fe increased significantly with application of urea with nitrogen inhibitors and also increased with increase nitrogen dose (70 to 85 % RDN) over GRDF.

4.11.2 Uptake of Mn

The data regards uptake of Mn as affected due to various treatments for N-levels and nitrogen inhibitors presented in (Table 18).

The data recorded that uptake of Mn by maize crop @ 85 % N through Agro-N-protect coated urea was found significantly increased (1933 g ha^{-1}). It was par with T_6 treatment (1811 g ha^{-1}).

Table 18. Total micronutrients uptake by maize as influenced treatments.

Tr. No.	Treatment	Total micro nutrient uptake(g ha^{-1})			
		Fe	Mn	Zn	Cu
T_1	GRDF	2922	1134	459	50
T_2	85 % N-GRDF- ANPU	4387^a	1933^a	876^a	97^a
T_3	70 %N-GRDFANPU	3195	1311	601	61
T_4	85 % N- GRDF – NU	3972^b	1693^b	756^c	77
T_5	70 % N- GRDF –NU	2873	1077	489	49
T_6	85 % N- GRDF- ANPU + NU	4153^a	1811^a	798^c	86
T_7	70 % N- GRDF- ANPU + NU	2888	1153	490	50
T_8	0 % N- GRDF	2075	823	374	34
T_9	Absolute Control	1502	573	247	21
	S.E. $\pm$	118.2	54.42	21.06	1.84
	CD at 5 %	354.3	163.1	63.16	5.53

It might be due to application of FYM causing chelation of Mn for its easy availability in soil and get accumulated with increase in biomass of maize in the presence of adequate N supply.

Application of urea enhanced the content Mn by the plant and the interaction between Mn and N was found to be positive also observed significantly increased Mn uptake (Debiprasad *et al.*, 2010).

The Mn uptake of maize increased with increase in levels of N (70 to 85 % RDN) along with use of N inhibitors.

4.11.3 uptake of Zn

The data regards uptake of zinc as affected due to various treatments of N-levels and nitrogen inhibitors is presented in table 18.

The total zinc uptake by maize crop was significantly superior in treatment (T_2) of 85 % N Agro-N-protect coated urea (876 g ha^{-1}) over other treatments and statistically on par with treatment (T_6) of 85 % N through Agro-N-protect + neem coated urea (798 g ha^{-1}) and treatment T_4 (756 g ha^{-1}).

As the soil was deficient for Zn, it was applied through $ZnSO_4$ for correcting the deficiency. The synergistic effect of N on Zn uptake might be responsible for increase in Zn uptake in the treatments of N levels along with N inhibitors.

The application of FYM and the doses of N (70 to 85 % RDN) along with N inhibitors increased the uptake of Zn by maize crop. Similar results were also obtained by Singh *et al* (1998) and Keram *et al.* (2012).

The increase of micronutrient uptake also production of high biomass reflected in more micronutrient uptake.

4.11.4 Uptake of Cu

The data regards uptake of Cu as effected due to various treatments of N-levels and nitrogen inhibitors is presented in table 18.

The data recorded the application of nitrogen to maize crop @ 85 % N through Agro-N-Protect coated urea was found significantly superior for Cu uptake (97 g ha^{-1}) over other treatments and statistically on par with treatment (T_6) 85 % N through Agro-N-protect and neem coated urea (86 g ha^{-1}).

FYM application as the source of Cu and presence of some native Cu might have get chelated may be become the source for ample supply of Cu in the increased biomass of maize.

The application of FYM along with the levels of N (70 to 85 %) and N inhibitors increased Cu uptake of maize plants. Similar results were also obtained by Ghosh *et al.* (2001).

4.12 Economic viability for N inhibitors

4.12.1 Benefit : cost ratio

The data with respect to cost of cultivation, gross return, net return and B:C ratio were influenced by various treatments were presented in Table 19.

There was significantly increase in benefit cost (B:C) ratio in treatment (T_2) 85 % N-Agro-N-protect coated urea T_2 (2.85). It was closely followed by T_6 (2.78) and treatment T_4 (2.72). It is clearly seen that benefit cost ratio was highest in treatment T_2 (2.85) and significantly higher over the GRDF. Same trend was also noticed in case of net return and nitrogen efficiency of these treatments. It could be interred that application of nitrogen inhibitor as urea coated with Agro-N-Protect significantly increased the yield, monetary return and benefit cost ratio in maize. Agronomic efficiency was also increased due to reduction in RDN (15 to 30 %) in the presence of N inhibitors. We can save the cost of fertilizer and getting more yield with help of use of N inhibitors.

Table 19. Economics of maize

Tr. No.	Treatment	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	Agronomic efficiency (kg kg^{-1})	B:C ratio
T_1	GRDF	35000	85401	50401	47	2.44
T_2	85 % N-GRDF- ANPU	34967	99870	64903	89	2.85[a]
T_3	70 %N-GRDF- ANPU	34701	88000	53299	77	2.54
T_4	85 % N- GRDF – NU	34967	95254	60287	80	2.72[c]
T_5	70 % N- GRDF –NU	34701	78701	44000	55	2.27
T_6	85 % N- GRDF- ANPU + NU	34967	97021	62054	85	2.78[b]
T_7	70 % N- GRDF- ANPU + NU	34701	82673	47972	64	2.38
T_8	0 % N- GRDF	33552	67177	33625		2.00
T_9	Absolute Control	19493	47896	28403		2.46
	S.E. ±					0.04
	CD at 5 %					0.12

Rates (Rs. kg^{-1})

Fertilizer	Rate	Fertilizer	Rate
Urea	5.2	ANPU	6.0
NU	6.0	SSP	7.8
$ZnSO_4$	32.0	MOP	17.0
Grain	13.0	Straw	2.0

4.13 Incubation study

The laboratory incubation experiment was conducted at Department of Soil Science and Agril. Chemistry, M.P.K.V., Rahuri, during 2015-16. The results obtained in respect to soil urease and dehydrogenase enzyme activity as influenced by the use of GRDF of maize crop with nitrogen inhibitors *viz.,* Agro-N-protect coated and neem coated urea. The moisture content of soil was maintained at field capacity the enzymatic activities were assessed periodically. The results were presented and discussed below.

4.13.1 Urease activity

The soil urease activity in an incubation study was conducted under ambient condition of laboratory. The urease enzyme activity was significantly influenced by the coating of urea fertilizer with Agro-N-protect and neem coated urea as nitrogen inhibitor at various proportion of recommended dose of nitrogen *viz.,* 85 and 70 % RDN were represented in (Table 20).

The urease enzyme activity was increased with an increased period of incubation and it was the highest at 60 DAI irrespective of the treatments and decreased at 75 DAI in GRDF and increased in rest of the treatments. This result revealed that the rate of mineralization of nitrogen was prolonged because of coating of urea with Agro-N-protect and neem coated urea.

The general recommended dose of 85 and 70 % nitrogen coated with Agro-N-protect to release the nitrogen slowly for a longer period which was most useful for field crops to provide the nitrogen in an available form during their physiological growth stages. It was significantly on par with 85 % N-GRDF with neem coated and 85 % N-GRDF coated with Agro-N-protect + neem coated urea. The least release of nitrogen observed in 70 % N-GRDF with neem coated urea (T_5), 70 % N-GRDF with Agro-N-protect + neem coated urea and 70 % N GRDF with neem coated urea (T_7).

Thus, coated of 85 % N-GRDF with Agro-N-protect coated urea was beneficial to mineralize the nitrogen slowly and provide the nitrogen in an available form as per physiological growth period of crops. Similar results were also reported by Majumdar *et al.* (2002).

Urease activity (graph)

The urease activity in an incubation study significantly influenced by the coating of urea fertilizer with Agro-N-protect and neem coated urea is graphically shown in fig.5.

The urease activity is significantly influenced by the coating of 85 % and 70 % N-GRDF with Agro-N-protect and neem coated urea range between (R^2=0.837 to 0.993). The urease activity is significantly higher in treatment T_2 (R^2=0.993). It was closely followed by T_6 (R^2=0.982) and T_4 (R^2=0.971). The lowest value is treatment T_9 (R^2=0.837)

It was shown 85 % N Agro protect coated urea higher due to affected by Agro-N-protect. This result revealed that the rate of mineralization of nitrogen was prolonged because of coating with nitrogen inhibitor

Table 20. Effect of nitrogen inhibitors on soil urease enzyme activity under incubation study

Tr. No.	Treatment	Urease enzyme activity (µg NH_4^+-N 100 g^{-1} soil hr^{-1})							Mean
		0 DAI	8 DAI	14 DAI	30 DAI	45 DAI	60 DAI	75 DAI	
T_1	GRDF	21.93	27.40	33.67	41.07	48.83	54.83	52.03	39.97
T_2	85 % N-GRDF- ANPU	19.13	25.67	31.27	38.20	44.33	51.80	54.60	37.86
T_3	70 %N-GRDF- ANPU	16.10	22.17	27.30	27.80	34.07	40.40	43.87	30.24
T_4	85 % N- GRDF – NU	17.97	24.30	30.10	32.33	38.27	48.33	51.57	34.70
T_5	70 % N- GRDF - NU	14.93	19.37	23.07	26.13	30.50	37.80	40.13	27.42
T_6	85 % N- GRDF- ANPU + NU	17.73	25.20	30.80	34.30	40.33	50.87	52.73	35.99
T_7	70 % N- GRDF- ANPU + NU	15.40	21.70	25.43	25.67	32.43	38.73	40.83	28.60
T_8	0 % N- GRDF	13.20	15.87	17.03	22.17	30.80	27.10	25.23	21.63
T_9	Absolute Control	12.60	14.00	16.90	17.50	23.63	20.27	17.73	17.52
	Mean	16.55	21.74	26.17	29.46	35.91	41.13	42.08	30.44
		Days	Treat	Day x Treat					
	S.Em. ±	0.22	0.25	0.67					
	CD at 5 %	0.62	0.71	1.87					

4.13.2 Dehydrogenase activity

The soil dehydrogenase enzyme activity in an incubation study was significantly influenced by the coating of 85 and 70 % N-GRDF with Agro-N-protect and neem coated urea (Table 21).

Table 21. Effect of nitrogen inhibitors on soil dehydrogenase activity under incubation study

Tr. No.	Treatment	Dehydrogenase enzyme activity (µg TPF g^{-1} soil 24 hr^{-1})			Mean
		0 DAI	30 DAI	75 DAI	
T_1	GRDF	27.76	37.15	27.58	30.83
T_2	85 % N-GRDF- ANPU	25.05	35.61	30.22	30.29
T_3	70 %N-GRDF- ANPU	22.28	32.14	27.67	27.36
T_4	85 % N- GRDF – NU	23.10	34.24	28.76	28.70
T_5	70 % N- GRDF –NU	21.67	31.14	26.39	26.40
T_6	85 % N- GRDF- ANPU	24.29	34.42	29.22	29.31
T_7	70 % N- GRDF- ANPU	22.19	31.68	27.48	27.12
T_8	0 % N- GRDF	20.91	24.47	22.55	22.64
T_9	Absolute Control	18.17	21.73	20.54	20.15
	Mean	22.82	31.40	26.71	26.98
		Days	Treat	Day x Treat	
	S.Em. ±	0.22	0.39	0.67	
	CD at 5 %	0.62	1.08	1.87	

The soil dehydrogenase enzyme activity was found significantly higher at 75 DAI in 85 % N – GRDF coated with Agro-N-protect (30.22 µg TPF g^{-1} 24 hr^{-1}) over rest of the treatments. It was followed by 85 % N GRDF with Agro-N-protect coated urea + neem coated urea (29.22 µg TPF g^{-1} soil 24 hr^{-1}).

However, GRDF recorded significantly the highest value of soil dehydrogenase enzyme activity at 30 DAI (37.15 μg TPF g^{-1} soil 24 hr^{-1}).

Due to application of inhibitors along with nitrogen fertilizer decrease the microbial activity. The dehydrogenase activity was lower in the treatments receiving nitrogen inhibitors over GRDF. Similar results were also reported by Singaram and Kamalakumari (1995).

5. SUMMARY AND CONCLUSIONS

The field experiment entitled, "Effect of nitrogen levels and inhibitors on the soil nitrogen availability, uptake and yield of *kharif* maize in Inceptisol" and also on periodical soil enzyme activity in soil by during laboratory study was conducted during the year 2015-2016 in the Department of soil science and agricultural chemistry, at post Graduate Institute M.P.K.V, Rahuri.

Field study

1. The soil pH, EC did not effected significantly due to different treatments. Organic carbon content significantly increased from 0.41% initial to 0.45 % in treatment of T_4 (85% GRDF + NU) which was at par with the treatment of T_1, T_2, T_5 and T_6.

2. The soil available nitrogen significantly in T_2 (85% GRDF + ANPU). which was at par with treatment T_6 (241.40 kg ha^{-1}) in respect of available P and K it was significantly increase in T_2 treatment (16.63 and 410.5 kg ha^{-1}) respectively. However, it was at par with treatment T_4 and T_6. Similar trend was observed in respect of ammonical and nitrate nitrogen.

3. The DTPA micronutrients in soil Fe, Mn, Zn and Cu significantly increased 3.75, 6.31, 0.54 and 2.71 mg kg^{-1} respectively in treatment T_2 which was at par with treatment T_6.

4. The grain yield and stover yield of maize significantly increase 58.84 and 116.44 q ha^{-1} respectively in treatment of T_2 however it was at par with treatment T_4 and T_6.
5. Total N, P and K concentration and uptake by maize was significantly increase 250.72, 90.82 and 178.72 kg ha^{-1} respectively in treatment of T_2 which was at par with treatment T_6.
6. Total Fe, Mn, Zn and Cu concentration and uptake by maize were significantly higher 4387, 1933, 876 and 97 g ha^{-1} respectively in treatment T_2 which was at par with treatment T_6 in respect of total Fe and Mn uptake.
7. Agronomic efficiency was recorded highest in treatment T_2 (89 kg ha^{-1}) followed by treatment T_6 (85 kg ha^{-1}).
8. The gross and net return were significantly recorded higher 99870 Rs ha^{-1} and 64903 Rs ha^{-1} respectively in treatment T_2 which was at par with treatment T_6.
9. There was significantly increase in B:C ratio (2.85) in treatment T_2 which was at par with treatment T_6 (2.78).

Incubation study

1. The soil urease enzyme activity was increased with an increased period of incubation irrespective of the treatments. The highest urease enzyme activity was observed at 60 DAI in General recommended dose of fertilizer (GRDF) treatment (54.83 µg NH_4^+-N g^{-1} soil hr^{-1})

and at 75 DAI in 85% N GRDF-N-Agro-N-protect coated urea 54.60 µg NH_4^+-N g^{-1} soil hr^{-1}).

2. The soil dehydrogenase enzyme activity was significantly higher in General recommended dose of fertiliser (GRDF) in 0 and 30 DAI (27.76 and 37.15 µg TPF g^{-1} soil 24 hr^{-1} respectively). However, at 75 DAI the dehydrogenase enzyme activity was significantly higher in 85% N GRDF-Agro-N-protect coated urea (30.22 µg TPF g^{-1} soil 24 hr^{-1}).

5.2 Conclusions

Thus it can be concluded from the above finding that the application of 85 % N (102 kg ha^{-1} N) through Agro-N protect coated urea to maize was beneficial for increasing yield, total nutrient concentration, uptake and improves soil fertility of medium deep black soil. However, this treatment was at par with the treatment of application of 85 % N (102 kg ha^{-1}) through Agro-N-protect coated urea + Neem coated urea

The application of nitrogen through urea coated with inhibitors like Agro-N-protect as well as neem coated urea were beneficial to mineralize the N slowly, provide the nitrogen in an available form as per physiological growth period of crop, saved 15 % N as well as ecofriendly technique for preventing environment pollution.

The economical aspects of the treatments shown that the agronomic yield was found higher with B:C ratio 2.85 in the treatment 85 % N through ANPU, hence we can save 15 % N with gaining higher yield and monetary returns.

Urease activity was (85% N) decreased in the treatments receiving higher dose of nitrogen along with inhibitor upto 60 days of incubation as compared to GRDF treatment. The dehydrogenase activity was found decreased in the treatments receiving higher dose of nitrogen (85% N) along with inhibitor upto 30 days of incubation as compared to GRDF.

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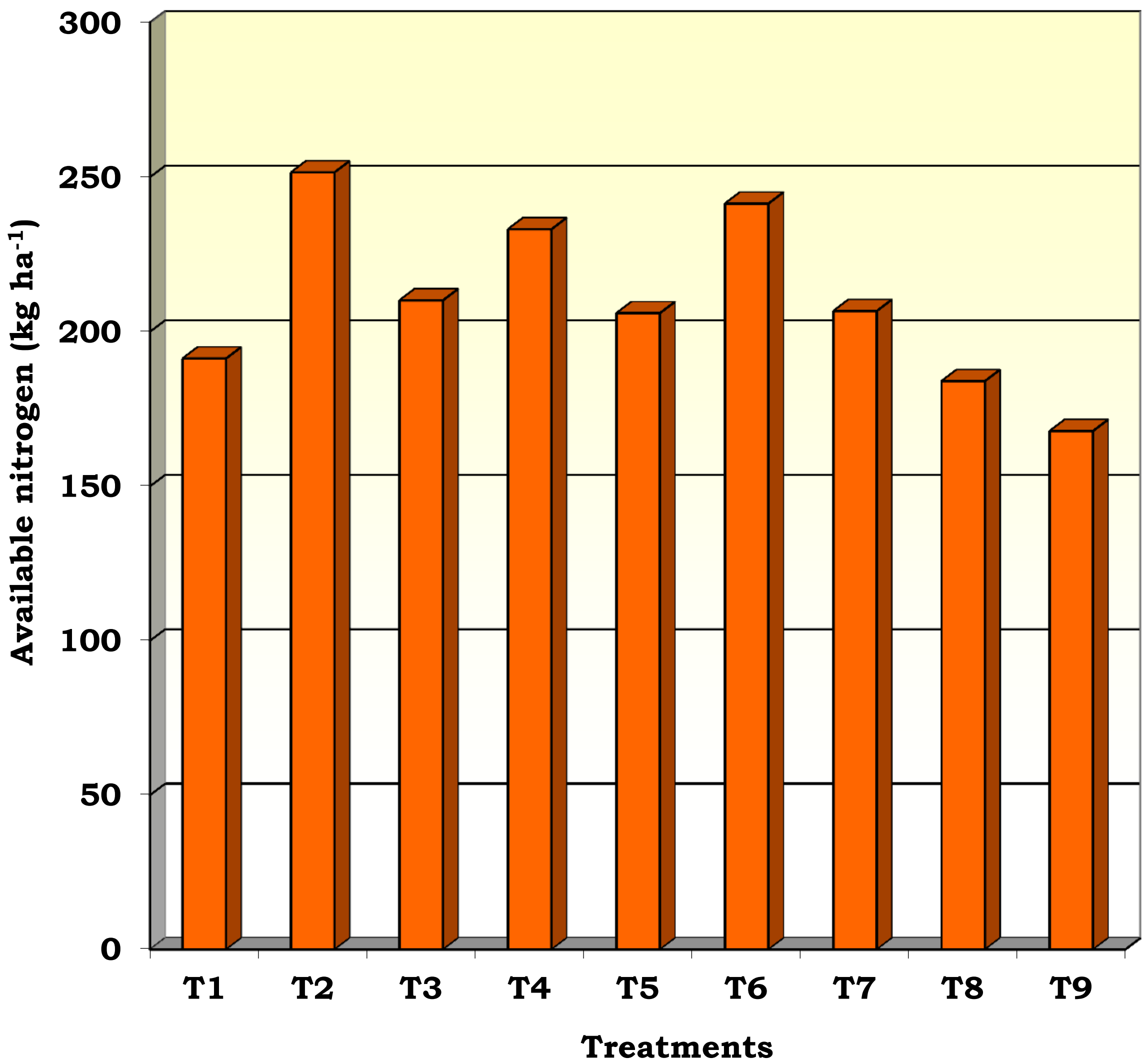

Fig. 2. Effect of nitrogen levels and nitrogen inhibitors on nitrogen availability of soil at harvest

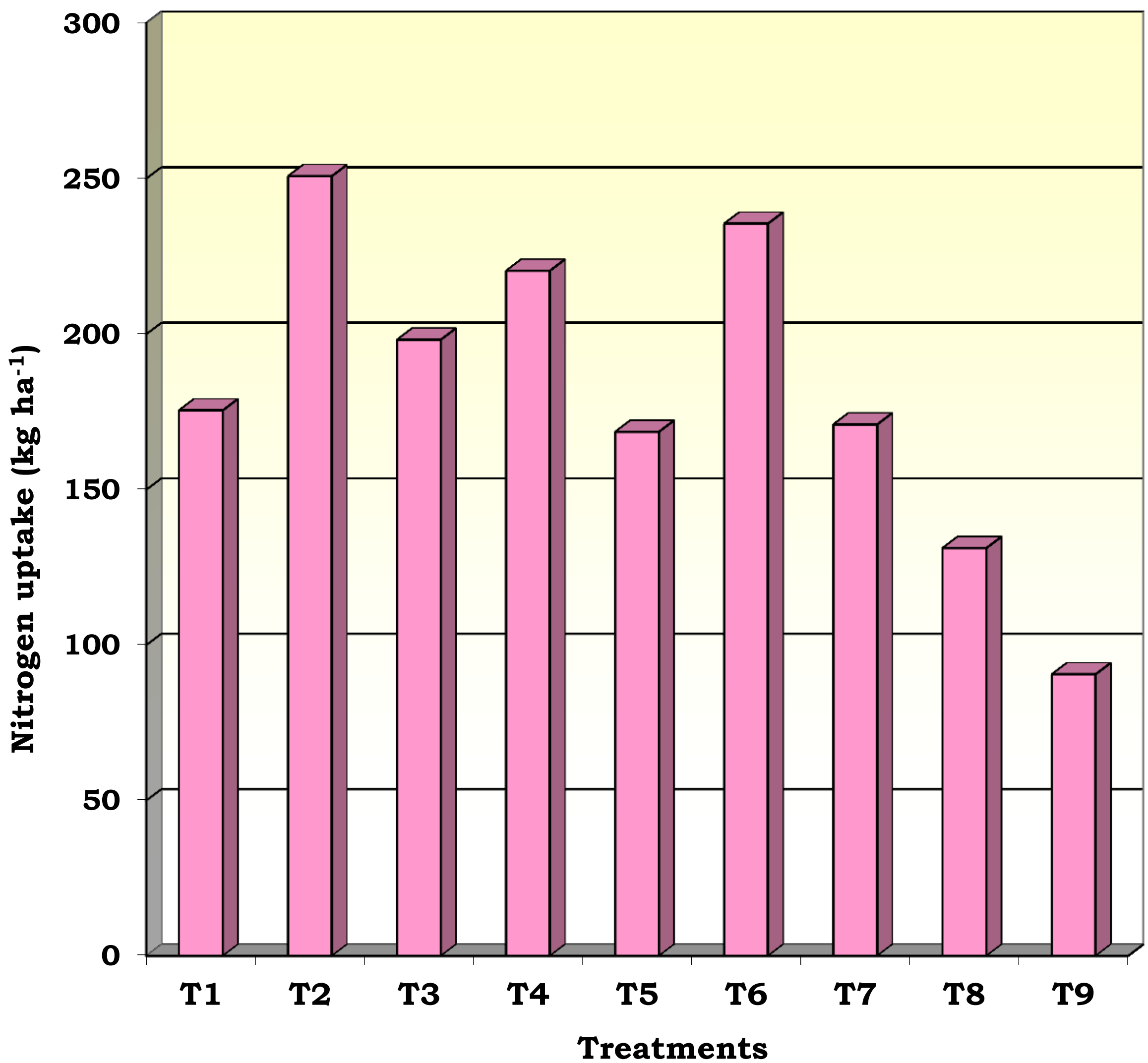

Fig. 4. Effect of nitrogen levels and nitrogen inhibitors on nitrogen uptake in maize

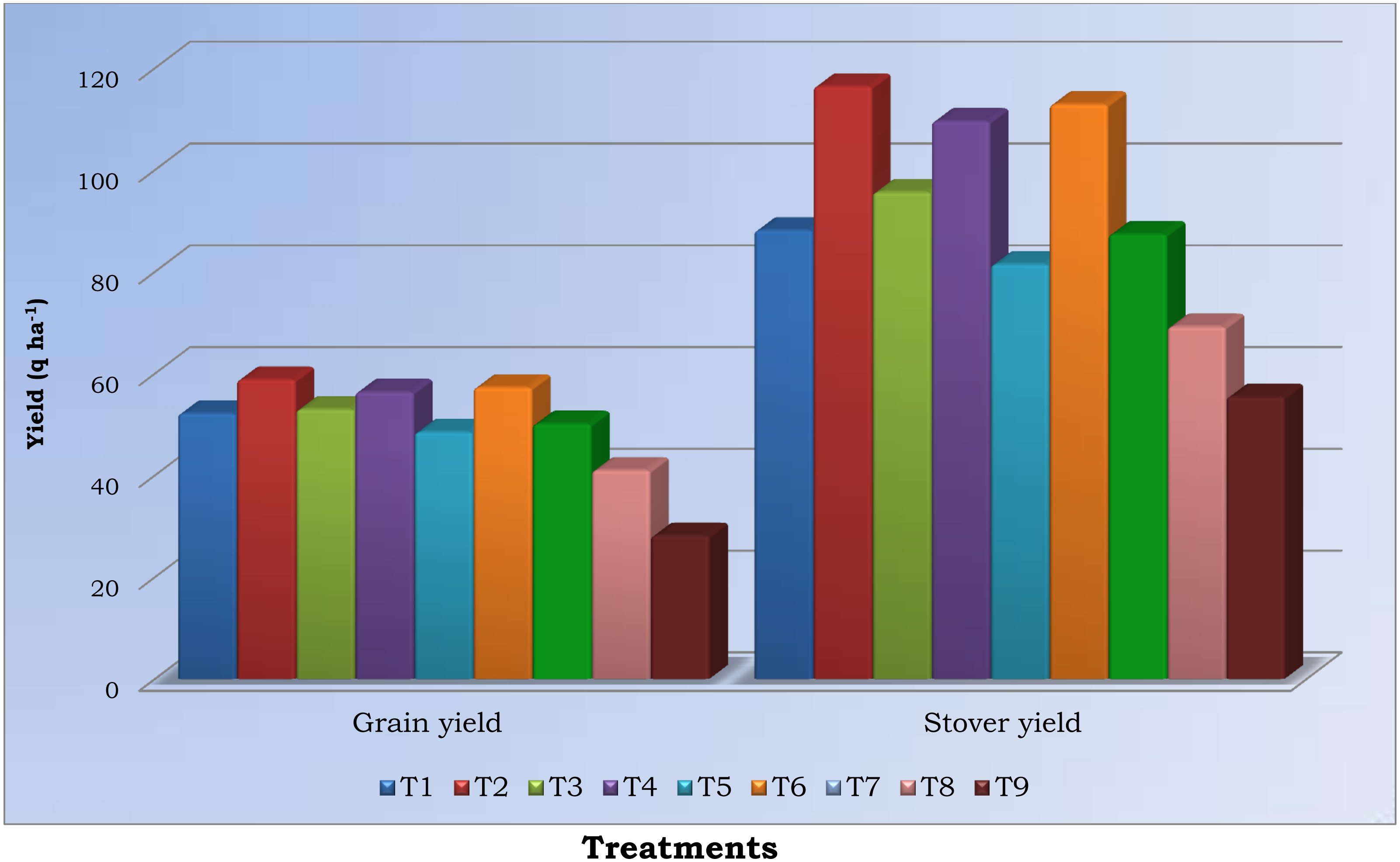

Fig. 3. Effect of nitrogen levels and nitrogen inhibitors on yield of maize

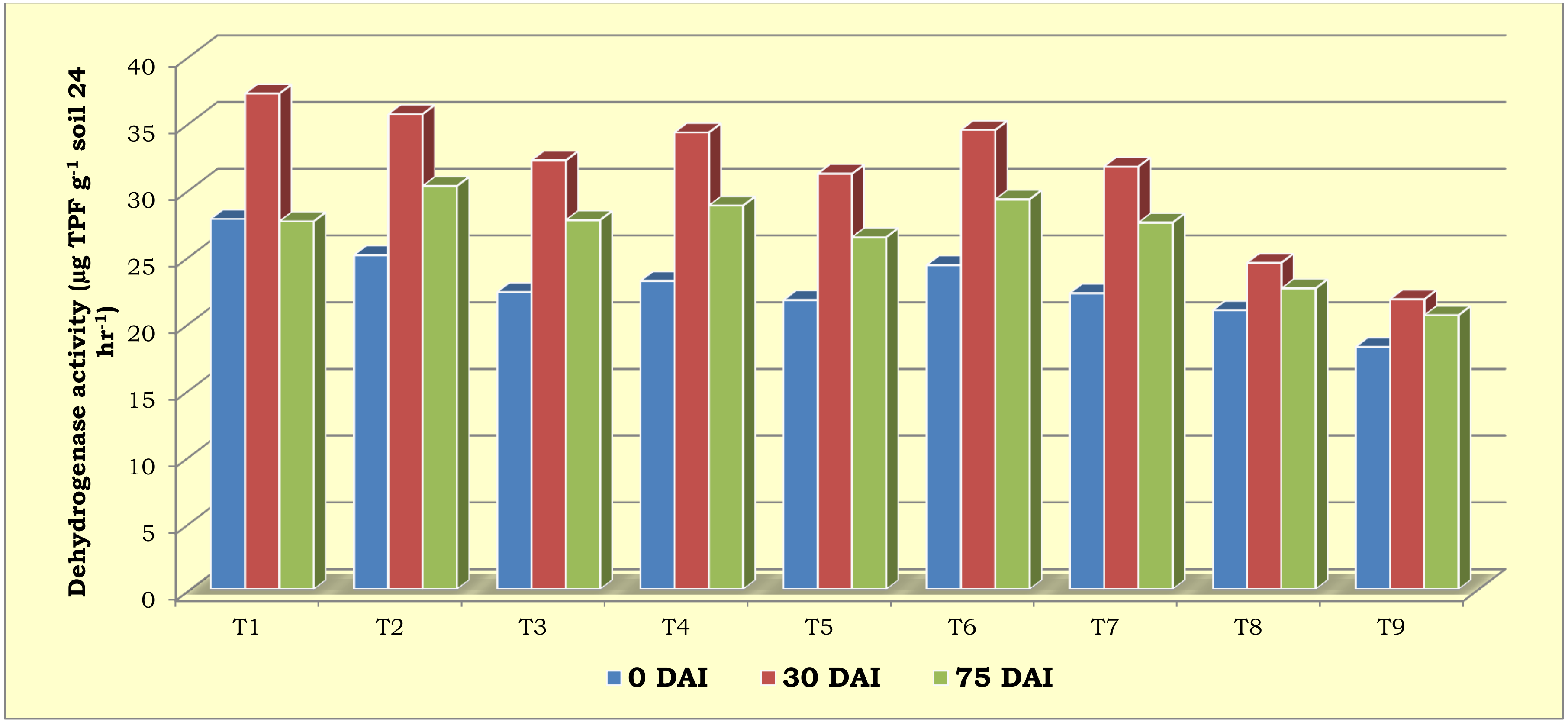

Fig. 6. Effect of nitrogen levels and inhibitors on dehydrogenase activity under incubation

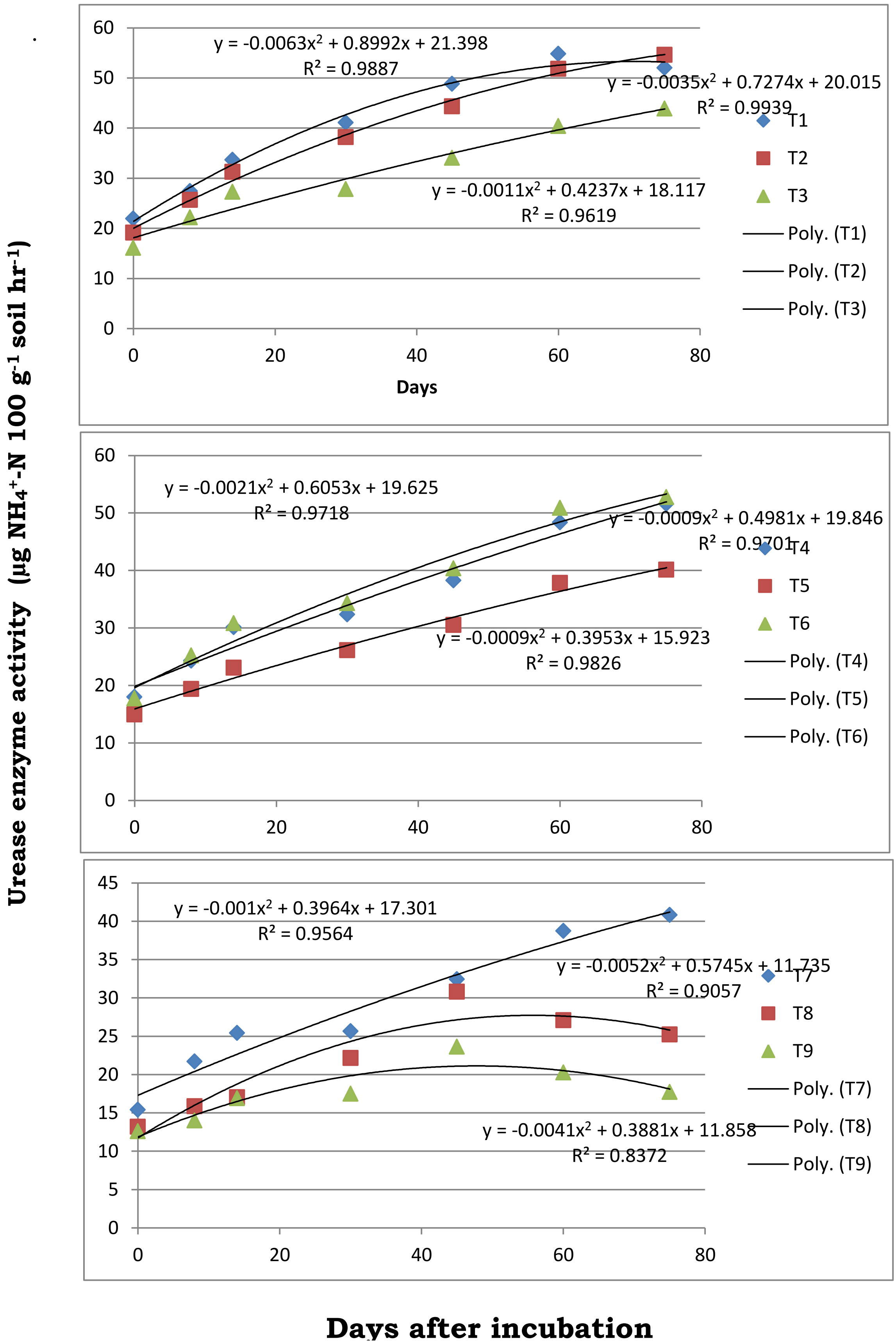

Fig. 5. Effect of nitrogen levels and nitrogen inhibitors on urease activity under incubation

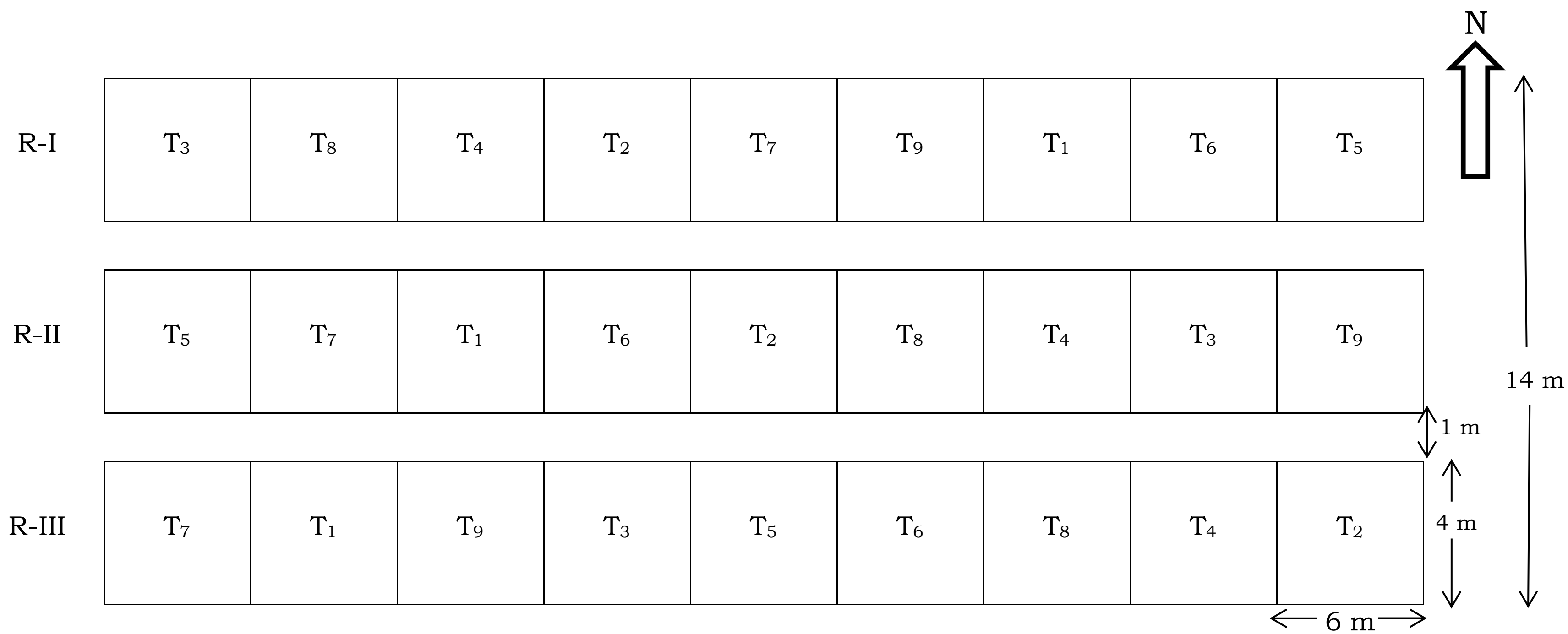

Fig. 1. Layout of field experiment

Plate 1. Over view of field experiment site

Plate 2. Over view of incubated soil pots