RESPONSE OF NITROGEN EFFICIENCY BIO-AVAILABILITY (NEB) ON GROWTH, YIELD AND QUALITY OF MAIZE

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CERTIFICATE

*This is to certify that the thesis titled, "**RESPONSE OF NITROGEN EFFICIENCY BIO-AVAILABILITY (NEB) ON GROWTH, YIELD AND QUALITY OF MAIZE** submitted to the **DEPARTMENT OF AGRONOMY, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka** in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS)** in **AGRONOMY** embodies the result of a piece of bona fide research work carried out by **CHITRA SARKER, Reg. No. 11-04643** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated:
Place: Dhaka, Bangladesh

(Professor Dr. Tuhin Suvra Roy)
Supervisor

Dedicated to

"My Beloved Parents and well wishers"

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The Author

RESPONSE OF NITROGEN EFFICIENCY BIO-AVAILABILITY (NEB) ON GROWTH, YIELD AND QUALITY OF MAIZE

ABSTRACT

Production of maximum quantity and good quality maize grain are the main bottleneck in Bangladesh, due to its sub-optimal management strategies aside of inorganic environment. From this perspective a field experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during November, 2015 to April, 2016 to find out the response of nitrogen efficiency bio-availability (NEB) on growth, yield and quality of maize (*Zea mays* L. cv. ACI Hybrid DON 111). The experiment consisted of eight different combinations of NEB with inorganic fertilizers namely, T_1= 50% recommended urea (RU) + 500 ml NEB ha^{-1} along with other fertilizers, T_2= 50% RU + 750 ml NEB ha^{-1} along with other fertilizers, T_3= 50% RU + 1000 ml NEB ha^{-1} along with other fertilizers, T_4= 50% RU + 1250 ml NEB ha^{-1} along with other fertilizers, T_5= 50% RU and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% RU and 25% reduction of P, K, S + 1000 ml NEB ha^{-1}, T_7= 50% RU and 25% reduction of P, K, S + 1250 ml NEB ha^{-1} and T_8= 100% recommended chemical fertilizer fertilizer (255-55-140-40-2-6 kg ha^{-1} of N-P-K-S-B-Zn). The experiment was laid out in a randomized complete block design with three replications. Results demonstrated that NEB in combination with chemical fertilizers had significant effects on most of the growth, yield and quality contributing parameters studied in this experiment. Among the eight treatments, the combination of NEB at the rate of 1250 mL ha^{-1} and 50% recommended urea along with other fertilizers at conventional rate showed better performance on number of cobs $plant^{-1}$, number of rows cob^{-1}, shelling (%), grain yield, seed grading, germination (%) and also on popping recovery (%) of maize which was statistically similar to the combination of NEB at the rate of 1000 mL ha^{-1} and 50% recommended urea along with other fertilizers at conventional rate. On the other hand; days to tassel initiation and full tassel emergence, days to silk initiation showed the delayed performance when the crop was managed by T_8 (100% recommended chemical fertilizers). The maximum yield of maize was found from T_4 (13.51 t ha^{-1}) which was statistically similar to T_3 (12.61 t ha^{-1}) where as the application of 100% recommended chemical fertilizers exhibited the worst one (4.10 t ha^{-1}) for grain yield of maize. From this study, it may be concluded that NEB had significant positive response for the improving of grain yield and quality of maize when applied at the rate of 50% urea and 1000 ml of NEB per hectare. Finally, NEB may put remarkable contribution for improving the quantity and quality of maize grain by reducing the application of chemical fertilizers.

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LIST OF ACCRONYMS AND ABBREVIATIONS

AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
Appl.	Applied
Biol.	Biology
Chem.	Chemistry
Cm	Centi-meter
CV	Coefficient of Variance
DAS	Days After Sowing
Ecol.	Ecology
Environ.	Environmental
et al	et alii, And Others
Exptl.	Experimental
FLP	Final Land Preparation
G	Gram
i.e.	*id est* (L), that is
J.	Journal
Kg	Kilogram
LSD	Least Significant Difference
M.S.	Master of Science
m^2	Meter squares
Mg	Milligram
NEB	Nitrogen Efficiency Bio-availability
NRE	Natural Root Exudates
Nutr.	Nutrition
Physiol.	Physiological
Res.	Research
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
Soc.	Society
t ha^{-1}	Ton per hectare
Viz	*videlicet* (L.), Namely
%	Percentage
@	At the rate of

CHAPTER I

INTRODUCTION

Maize (*Zea mays* L.) is the second most important cereal crop in the world after wheat and rice with respect to area and productivity (Akande and Lamidi, 2006; Olakojo *et al.*, 2007; Mboya *et al*, 2011). There is no cereal on the earth which has so immense potentiality and that is why it is called “Queen of Cereals”. It has a great significance as human food, animal feed and diversified uses for large number of industrial products. It is a productive food plant and has the highest potential for carbohydrate accumulation per unit area per day (Seran and Brintha, 2010). Maize is a long duration, quick growing crop and has potential to produce high quantity grains per unit area (Majid *et al.*, 2017). Maize is grown for grain as well as fodder in tropical, sub-tropical and temperate regions of the world. Maize as a cereal, has multiple uses such as bread making, corn flakes, corn syrup, corn starch, textile, paper making and in other food industries (Kumar and Jhariya, 2013). Corn oil is suitable for human consumption due to the presence of unsaturated fatty acids (Khan *et al.*, 2013).

The total area under maize cultivation in Bangladesh is 0.334 million hectares (ha), producing 2.44 million tons with yield of 7.30 t ha^{-1} in the year 2015 (FAOSTAT, 2016) while 161,765,388 ha with an annual production of 840,308,214 tons worldwide (Anthony, 2014) which is discouraging farmers, due to the big gap exists between the actual and potential yield per unit area of the crop (AIS, 2017). Day by day the production of maize is increasing due to the demand and low production cost resulting higher economic return per unit areas. But the quality of maize is not good. Due to some important bottleneck *viz.*, soil factors, climatic factors, nutritional factors and plant uptake of nutrients from soil by roots. Among these the root nutrients uptake by roots is the most probably important for the growth, yield and quality of maize cob.

The Maize farmers used huge amount of chemical fertilizers, as a result, production cost is increasing and at same time quality is decreasing. So, maize production and its quality may be increase by application of NEB (Nitrogen Efficiency for Bio-availability) which is natural root exudates. NEB is an organic product with mineral or other components. NEB is a natural origin product, in liquid and dry forms, that are non-toxic and non-hazardous. NEB influences microbial populations which makes nutrients more available. It influences mycorrhizae which collect, store and deliver nutrients directly to the plants. Plant root exudates constitute up to 30 to 40% of the plants photosynthetic productivity (Samtsevich, 1965).

NEB product contain a small amount of nutrients but NEB is an additive that allows more of the nutrients supplied by fertilizer to be used which results in superior yields. It increases yields at an economic cost which results in greater profits. Root exudates are known to enhance growth rates of bacteria (Hartwig *et al*., 1994). Plant roots release as much as 20% of their assimilates as root exudates in the form of organic acid, amino compounds, sugars and phosphate esters (Uren, 2001; Whipps, 1990). Unseen part of the plant secretes chemical compounds which acts as communication signal between the adjacent plant and microbial community present in the rhizosphere of the root. The main functions of the 'hidden' part of the plant, its root system, have traditionally been thought to be anchorage and uptake of nutrients and water. However, roots secrete an enormous range of compounds into the surrounding soil. This area, called the rhizosphere. Root exudation is part of the rhizodeposition process, which is a major source of soil organic carbon released by plant roots (Hutsch *et al*., 2000). Root exudates correspond to an important source of nutrients for microorganisms in the rhizosphere and seem to participate in early colonization inducing chemotactic responses of rhizospheric bacteria (Bacilio *et al*., 2004).
Rhizosphere is defined as a zone of most intense bacterial activity around the roots of plant (Badri and Vivanco, 2009).). Root exudate is one of the ways for

plant communication to the neighboring plant and adjoining of microorganisms present in the rhizosphere of the root. The chemicals ingredients of the root exudates are specific to a particular plant species and also depend on the nearby biotic and abiotic environment. The chemical ingredient exuded by plant roots include amino acids, sugars, organic acids, vitamins, nucleotides, various other secondary metabolites and many other high molecular weight substances as primarily mucilage and some unidentified substances. Root exudate helps the plant to form partnerships with beneficial microbes and mycorrhiza. Plant encourages this partnership by secreting root exudates, which finally stimulate microbes and mycorrhiza. Root exudates mediate various positive and negative interactions like plant-plant and plant-microbe interactions. But research works on NEB with maize are very scarce in Bangladesh. Therefore, the study was aimed a field experiment with the following objectives:

1. To explore the role of NEB on growth, yield and quality of Maize.
2. To determine the optimum rate of NEB along with other chemical fertilizers for maximizing yield and improving the quality of Maize.

CHAPTER II

REVIEW OF LITERATURE

Maize contributing a major part as a cereals crops in many developed country mostly also in Bangladesh. Improvement of growth, yield and quality attributes of maize is much more important for growing hungry people around the world through processing and exporting industry related to especially poultry sector. In Bangladesh the yield of quality maize is much lower than other major maize growing developed countries. But, the yield potential of maize is plastic nature those could be changed by nutritional management including mediated new cultivation systems with organic agriculture instead of total chemical inorganic fertilizers. The research on quality maize with organic root exudates are more or less availed in our country but the optimum cultivation systems with root exudates for better quality maize is not well known to us. Some more related research findings regarding production of maize against root exudates/root hormones/root enhancer have been reviewed in this chapter.

Balendres *et al*. (2016) reported that, root exudation has importance in soil chemical ecology influencing rhizosphere microbiota. Prior studies reported root exudates from host and nonhost plants stimulated resting spore germination of *Spongospora subterranea,* the powdery scab pathogen of maize, but the identities of stimulatory compounds were unknown. This study showed that maize root exudates stimulated *S. subterranea* resting spore germination, releasing more zoospores at an earlier time than the control. They detected 24 low molecular weight organic compounds within maize root exudates and identified specific amino acids, sugars, organic acids, and other compounds that were stimulatory to *S. subterranea* resting spore germination. Given that several stimulatory compounds are commonly found in exudates of diverse plant species, they supported observations of nonhost-specific stimulation.

They provided knowledge of *S. subterranea* resting spore biology and chemical ecology that may be useful in formulating new disease management strategies.

Naqqash *et al*. (2016) carried out an observation to overcome high fertilizer demand (especially nitrogen), five bacteria, i.e., *Azospirillum* sp. TN10, *Agrobacterium* sp. TN14, *Pseudomonas* sp. TN36, *Enterobacter* sp. TN38 and *Rhizobium* sp. TN42 were isolated from the maize rhizosphere on nitrogen-free malate medium and identified based on their 16S *rRNA* gene sequences and also reported thatrRhizosphere engineering with beneficial plant growth promoting bacteria offers great promise for sustainable crop yield such as maize. Maize is an important food commodity that needs large inputs of nitrogen and phosphorus fertilizers. Inoculation with these bacteria under axenic conditions resulted in differential growth responses of maize. *Azospirillum* sp. TN10 incited the highest increase in maize fresh and dry weight over control plants, along with increased N contents of shoot and roots. All strains were able to colonize and maintain their population densities in the maize rhizosphere for up to 60 days, with *Azospirillum* sp. and *Rhizobium* sp. showing the highest survival. Plant root colonization potential was analyzed by transmission electron microscopy of root sections inoculated with *Azospirillum* sp. TN10. *Azospirillum* sp. TN10 has the greatest potential to increase the growth and nitrogen uptake of maize. Hence, it is suggested as a good candidate for the production of maize biofertilizer for integrated nutrient management as organic root exudates.

Shehata *et al*. (2016) pointed out that bio-stimulant as natural root exudates may enhance the yield and improve crop quality and their study aimed to evaluate the use of two bio-stimulants for reducing the nitrate content and improving the commercial quality of head lettuce. This study was arranged in a split plot experiment in three replications. The treatments included two nitrogen sources (ammonium nitrate and ammonium sulfate) as main plot and two bio-stimulants, FZB 24 and Actiwave as sub-plot.

The criteria measured were fresh and dry weights of leaves, number of leaves, yield and the contents of nitrogen, nitrate total sugars as well as chlorophyll and carotenoid contents. Results obtained showed that regardless of the nitrogen source, the FZB 24 and Actiwave at both rates significantly increased the leaf number, fresh and dry weights of leaves and the total yield. The highest contents of chlorophyll, total sugars, carotenoids and lower nitrate contents were found in lettuce leaves treated with FZB 24 and Actiwave at the increased rates. The nitrogen source application did not affect the fresh and dry weight of leaves, the yield, the total sugars and chlorophyll contents. Whereas, ammonium sulfate as a nitrogen source significantly increased the leaf number and decreased the nitrate content. Biostimulants exerted a positive role with regard to yield and quality of head lettuce.

Wierzbowska *et al*. (2015) reported that growth regulators stimulate life processes in plants, improving their stress resistance and health, which translates into higher and better quality yield. Growth regulators can improve biochemical parameters of cob of maize and enhance the maize resistance to adverse environmental conditions or pathogens. The purpose of this research was to examine the effect of biostimulators on yield and selected chemical properties of maize cob. Four maize cultivars were grown in a field experiment: very early Volumia and medium early Irga, Satina and Sylvana. Starting from stage 39 on the BBCH scale (crop cover complete), maize plants were treated thrice, in 10- to 14-day intervals, with the growth regulators Asahi SL, Bio-Algeen S90 and Kelpak. The reference treatment was composed of maize untreated with the bioregulators. The growth regulators, especially Bio-Algeen S90 (6.3-16.3%) and Kelpak SL (14.2-24.7%) raised the cob of maize yield, but the effect was statistically verifiable only in the second year, with less precipitation and lower temperature of the vegetation period. The quality of maize cob of maizes was more strongly dependent on the cultivar-specifc traits than on the applied biostimulators. In the second year, too, maize cob of maize contained on average 34% more N-total than in the first year.

During storage, the content of N-total in cob of maize increased by 35-50%. After a five-month storage period, maize cob contained more NO3- abut less N-NH4+.

Huang *et al*. (2014) studied the interactions between plants and their microbial communities in the rhizosphere are important for developing sustainable management practices and agricultural products such as biofertilizers and biopesticides also act as natural root exudates. Plant roots release a broad variety of chemical compounds to attract and select microorganisms in the rhizosphere. In turn, this plant associated microorganisms, via different mechanisms, influence plant health and growth. In this review, we summarize recent progress made in unraveling the interactions between plants and rhizosphere microbes through plant root exudates, focusing on how root exudate compounds mediate rhizospheric interactions both at the plant–microbe and plant–microbiome levels. We also discuss the potential of root exudates for harnessing rhizospheric interactions with microbes that could lead to sustainable agricultural practices.

Doornbos *et al*. (2012) conducted a study to assess better implications of shifts in the rhizosphere microflora and reviewed the effects of root exudates on soil microbial communities. They reported that current knowledge on inducible defense signaling in plants is discussed in the context of recognition and systemic responses to pathogenic and beneficial microorganisms resulting more nutrients will be available to the plant. Plants affect their rhizosphere microbial communities that can contain beneficial, neutral and pathogenic elements. Interactions between the different elements of these communities have been studied in relation to biological control of plant pathogens. Such applications may however affect microbial communities associated with plant roots and interfere with the functioning of the root microbiota. Here, they reviewed the possible impact of plant defense signaling on bacterial communities in the rhizosphere resulted from action of microflora acted as natural root exudates.

Roumeliotis *et al*. (2012) carried out an experiment on various transcriptional networks and plant hormones have been implicated in controlling different aspects of maize cob formation as natural root activity enhancers. Due to its broad impact on many plant developmental processes, a role for auxin in cob of maize initiation has been suggested but never fully resolved. Here, auxin concentrations were measured throughout the plant prior to and during the process of cob formation of maize. Auxin levels increase dramatically in the tasseling prior to cob through silking and remain relatively high during subsequent cob of maize growth, suggesting a promoting role for auxin in cob of maize formation. Furthermore, *in vitro* cob of maizeization experiments showed higher levels of cob of maize formation from axillary buds of explants where the auxin source (shoot tip) had been removed. This phenotype could be rescued by application of auxin on the ablated shoot tips. In addition, a synthetic strigolactone analogue applied on the basal part of the shoot buds resulted in fewer cob of maize. The experiments indicate that a system for the production and directional transport of auxin exists in shhot tips and acts synergistically with strigolactones to control the outgrowth of the axillary shoot buds; similar to the control of above-ground shoot branching resulted into con initiation of maize.

Badri and Vivanco (2009) reported that root-secreted chemicals mediate multi-partite interactions in the rhizosphere, where plant roots continually respond to and alter their immediate environment. Increasing evidence suggested that root exudates initiate and modulate dialogue between roots and soil microbes. For example, root exudates serve as signals that initiate symbiosis with rhizobia and mycorrhizal fungi. In addition, root exudates maintain and support a highly specific diversity of microbes in the rhizosphere of a given particular plant species, thus suggesting a close evolutionary link. In this review, we focus mainly on compiling the information available on the regulation and mechanisms of root exudation processes, and provide some ideas related to the evolutionary role of root exudates in shaping soil microbial communities.

Rawsthorne and Brodie (1986) observed the response of *Globodera rostochiensis* in maize root diffusate (PRD) collected by soaking individual maize, *Zea mays* cob of maize, root systems in water for 2 hours was used to assess the relationship between root growth and PRD production. Resistant Maize cultivars Hudson and Rosa were used as test plants. Maximum hatch occurred in PRD collected 3 weeks after plant emergence (APE) in the greenhouse, and declined after this time. Hatch was positively correlated with increased root weight only during the first 3 weeks AE. Hudson PRD was consistently more active than Rosa PRD in stimulating hatch, except when adjusted for root weight. Although the results indicated that cells at the root tip produced a more active PRD than cells located elsewhere, PRD appeared to be produced along the entire root. Differences in time length of the vegetative growth phase, extent of root growth, and volume of roots, rather than the production of a more active PRD percent in soil.

By reviewing the different sources of information regarding the present experiment it was found and taken that, the application of root exudates has the potentiality to response against different traits of maize and other crops. So, different doses of NEB in combination with different levels of chemical fertilizers were taken for the present study to observe the response on growth, yield and quality attributes of maize.

CHAPTER III

MATERIALS AND METHODS

A brief description about experimental, site, climatic condition, planting materials, treatments, experimental design and layout, crop growing procedure, intercultural operations, data collection and statistical analysis were described in this chapter. The details of experimental materials and methods are described below:

3.1 Experimental period and site

The study was conducted in the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, during November, 2015 to April, 2016. The experimental area was belonged to $23^{o}7'$N latitude and 93^{o}E' longitude at an altitude of 8.6 meter above the sea level (Anon., 2004) and research area was also belonged to agro-ecological zone of “Madhupur Tract”, AEZ-28. The experimental site is shown in the map of AEZ of Bangladesh in (Appendix-I).

3.2 Climate and soil

The experimental site probably most characterized by winter during the months from November, 2015 to April, 2016 (*Rabi* season) with a significant monsoon climate with sub-tropical cropping zone. Top soil was characterized by silty clay in texture, olive- gray whitish with common fine to medium distinct dark whitish brown mottles was seen on the top soil. The soil was also characterized by pH-5.57 and organic carbon-0.462%. The experimental area was flat and medium high topography with available easy irrigation and drainage system. The weather data during the study period at the experimental site including maximum and minimum temperature, total rainfall and relative humidity were shown in (Appendix-II) ans the soil status was shown in (Appendix-XV).

3.3 Planting material

"ACI Hybrid DON 111" was used as planting material under present study which was introduced by ACI Limited (Bangladesh) due to its more suitability as grain crop.

3.4 Treatments

The experiment was comprised of eight different treatments of NEB in combination with urea and PKS fertilizers as follows:

T_1	50% recommended urea (RU) + 500 ml NEB ha^{-1} along with other fertilizers
T_2	50% recommended urea + 750 ml NEB ha^{-1} along with other fertilizers
T_3	50% recommended urea + 1000 ml NEB ha^{-1} along with other fertilizers
T_4	50% recommended urea + 1250 ml NEB ha^{-1} along with other fertilizers
T_5	50% recommended urea and 25% reduction of P,K,S + 750ml NEB ha^{-1}
T_6	50% recommended urea and 25% reduction of P,K,S + 1000 ml NEB ha^{-1}
T_7	50% recommended urea and 25% reduction of P,K,S + 1250 ml NEB ha^{-1}
T_8	100% recommended chemical fertilizer (255-55-140-40-2-6 kg ha^{-1} of N-P-K-S-B-Zn)

NEB increases beneficial microbial populations, microbes consume excess N that would have been lost to leaching, nitrogen is released and available to the plant as the microbes die as s result more nitrogen is available and ore consistent supply of nitrogen available (slow release affect).

3.5 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total numbers of unit plots were 24. The size of unit plot was 2.5 m × 2.0 m. The spacing 75 cm × 25 cm was used under present study. The final layout of the experimental plots was shown in Appendix-III.

3.6 Land preparation

The land of the experimental site was first opened in the first week of November with power tiller and to obtain the desirable tilth the land was ploughed and cross-ploughed three times followed by laddering. Weeds and stubbles were removed from the corners of field using spade. The land was finally prepared on 25 November 2015 three days before sowing the seed. In order to avoid water logging due to rainfall during the study period, drainage channels were made around the land. The soil was treated with Furadan 5G @ 20 kg ha^{-1} when the plot was finally ploughed to protect the young plant from the attack of cut worm.

3.7 Fertilizers

The land was fertilized as per treatments and recommended dose of fertilizers at the rate of 255-55-140-40-2-6 kg ha^{-1} of N-P-K-S-B-Zn, respectively, as Urea, TSP, MoP, gypsum, boric acid and zinc sulphate were applied in the field during final land preparation (Mondal *et al*., 2013). Recommended rate of N was 255 kg ha^{-1}, the required amount of urea was applied as per treatments. Normally urea was applied in three equal split installments with different levels of NEB as liquid solution at 25 DAS, 50 DAS and 75 DAS. MoP was also added with two split doses at FLP and 50 DAS. The treatment from T_1 to T_4 there all recommended fertilizers were applied along with 50% RU with different doses of NEB. But, the treatment from T_5 to T_7 P, K and S were applied as reduced to 25% form recommended rate along with Zn and B fertilizer.

3.8 Sowing of seed

The well sprouted healthy and uniform sized maize cob of "ACI Hybrid DON 111' were sown according to desired. Seed of maize were sown at a depth of 3-4 cm on November 29, 2015 for easy emergence.

3.9 Intercultural operations

3.9.1 Ridging of soil

To reduce the lodging of maize plant the soil near to the base was uplifted as ridge at 30 DAS.

3.9.2 Removal of weed

It was required to keep the crop free from weeds and to keep the soil loose for proper aeration and for proper growth and development of maize plant. First weeding was done two weeks after emergence. Another weeding was done before 2nd top dressing of urea.

3.9.3 Watering and drainage

Three irrigations were provided throughout the growing period in controlled way. The first irrigation was given at 20 DAS. Subsequently, two irrigations were given at 45 and 70 DAS. Top dressing of fertilizers was followed by irrigation for proper utilization of fertilizers.

3.9.4 Control of insects and diseases

All possible phytosanitary measures were adopted to keep plant healthy. Dursban @ 7.5 litre ha^{-1} was drenched on both sides of ridges at 25 DAP to control the cutworm. Dimecron 100 EC @ 2% and Admire 200 SL @ 0.5% were applied to control leaf folder and roller.

3.10 Recording of data

Different types of data were collected on the basis of the aims of the present study. Most of the parameters were taken after harvesting of cob by using electronic balance and rest of the parameters were taken by using plastic scale and measuring tape and means were calculated by using a digital calculator.

3.10.1 Growth traits

i. Plant height (cm) at tassel initiation stage and full tassel emerged stage

Five selected maize plants were considered for taking the plant height. Then the height of stems of five maize plants from each plot was added and then means were taken in centimeter unit.

ii. Days to tassel initiation and full tassel emergence

All the plots were keenly observed daily to see the emergence of tassel from the tip of shoot and full emergence of tassel. The days to first tassel initiation and full tassel emergence was calculated by deducting the days to observing the first days of emergence and full tassel emergence from the days of seed sowing.

iii. Number of leaves plant^{-1} at tassel initiation stage and full tassel emerged stage

Five selected plants of maize were considered for taking the leaf number. Then the total number of leaves of maize plant from each plot was added and then means were taken.

iv. Number of cob initiating node plant^{-1} at tassel initiation stage and full tassel emerged stage

Five selected plants of maize were considered for taking the number of cob initiating nodes. Then the total number of cob initiating nodes of maize plant from each plot was added and then means were taken.

v. SPAD value of leaves at tassel initiation stage and dough stage

The relative content of leaf chlorophyll could be known from the SPAD value. So, SPAD-502 electrical device was used under present study which was manufactured by Minolta Camera Co., Ltd, Osaka, Japan. (1989).

Five selected hills were taken to take the SPAD values and in all time the second leaf just beneath the top leaf was considered to take the SPAD reading considering the 3 leaves from each selected maize plants. Then the mean of five hills was taken.

3.10.2 Yield traits

i. Days to silk initiation

All the plots were keenly observed daily to see the emergence of silk from the tip of shoot. The days to first silk initiation was calculated by deducting the days to observing the first days of emergence from the days of seed sowing.

ii. Number of cobs plant^{-1}

Five selected plants of maize were considered for taking the number of cobs plant^{-1}. Then the total number of cobs of maize plant from each plot was added and then means were taken.

iii. Length of cob

Five selected plants of maize were considered for taking the length of cobs. Then the length of cob of maize cob from each plot was added and then means were taken in centimeter.

iv. Unfilled length of cob

Five selected plants of maize were considered for taking the part of the cob length which was barren. Then the length of unfilled cob of maize cob from each plot was added and then means were taken in centimeter.

v. Bareness percentage

Three cobs where selected from each plot to see the portion of cob length which were barren/unfilled as grain. Bareness percentage was determined according to the following formula:

$$\textbf{Bareness}\ (\%) = \frac{\text{Unfilled cob length (cm)} \times 100}{\text{Whole cob length (cm)}}$$

vi. Diameter of cob

Five selected plants of maize were considered for taking the diameter of cobs. The diameter of apex, medium and lower part of cob was taken. Then the diameter of cob of maize cob from each plot was added and then means were taken in centimeter.

vii. Number of rows cob^{-1}

Five selected plants of maize were considered for taking the number of rows cob^{-1}. Then the total number of rows cob^{-1} of maize plant from each plot was added and then means were taken.

viii. Number of grains row^{-1}

Five selected plants of maize were considered for taking the number of grains row^{-1}. Then the total number of grains row^{-1} of maize plant from each plot was added and then means were taken.

ix. Total number of grains cob^{-1}

Five selected plants of maize were considered for taking the total number of grains cob^{-1}. Then the total number of grains cob^{-1} of maize plant from each plot was added and then means were taken.

x. 100-grains weight

Ten selected ears were weighted from each plot to take the 100-seed weight (g). Then the total 100-weight of grain of maize plant from each plot was added and then means were taken in gram.

xi. Shelling percnetage

Ten selected ears were weighted from each plot. Ears were shelled and weighted the grain. Shelling percentages of normal ears usually about 65 % when fields are ready for physical harvest (20 to 25% grain moisture). Shelling percentage was determined according to the following formula:

$$\textbf{Shelling}\ (\%) = \frac{\text{Grain weight per cob (g)}}{\text{Whole cob weight (g)}} \times 100$$

xii. Grain yield

The entire cob of maize weighted by using an electronic balance from 1 m^2 harvested area of each plot. Then the weight of cob of maize per meter square was converted to per plot and then again converted to ton per hectare.

3.10.3 Quality traits

i. Germination percnetage

Twenty five seeds of maize were places under germination test under three replications at 15 days after harvesting of cobs. From each plot the germination test was carried out and then the means of germination was calculated. The formula of-

$$\textbf{Germination}\ (\%) = \frac{\text{No. of seed germinated}}{\text{No. of ssed placed for germination}} \times 100$$

ii. Grading as large, medium and small 100 seed^{-1}

Hundred seeds were taken to count the number of seeds as per grading as large, medium and small (as > 8.7 mm, 7.5-8.7 mm and < 7.5 mm, respectively) from each plot under three replications and then means were taken.

iii. Popping recovery percentage

Twenty five seeds of maize were places for popping recovery test under three replications at 30 days after harvesting of cobs. The popping was made by using dry and warm sand on gas cylinder strove. From each plot the pop corn recovery test was carried out and then the means of popping recovery was calculated. The formula of-

$$\textbf{Popping recovery}\ (\%) = \frac{\text{No. of seed puffed}}{\text{No. of seeds placed for popping}} \times 100$$

3.11 Correlation coefficient (r)

Correlation coefficient between different growth, yield and yield contributing traits were calculated by using the MS excel spread sheet.

3.12 Statistical Analysis

Collected data on different parameters were analyzed statistically using the analysis of variance (ANOVA) technique with the help of WASP (Web Agri Stat Package: version-1) computer program and mean were adjusted by using LSD (Least Significant Difference) at 5 % level of probability. Raw data management and graphical representation were done by using Microsoft excel spread sheet.

CHAPTER IV
RESULTS AND DISCUSSION

The study was aimed to observe the response of NEB (nitrogen efficiency bio-availability) organic root exudates on different vegetative growth, yield characteristics, yield and quality of Maize. In this chapter; figures, tables and appendices have been used to present, discuss and compare the findings obtained from the present study. The ANOVA (analysis of variance) of data in aspects of all the visual and measurable characteristics have been presented in Appendix (IV-XIV). The all possible reveals and interpretations were given under the following headings:

4.1 Growth traits

4.1.1 Plant height at tassel initiation stage and full tassel emerged stage

In respects of height of maize at tassel initiation stage a remarkable variation was noted (Table-1 and Appendix IV) against different doses of NEB and chemical fertilizers. The height of Maize mother plant increased with the increasing of partitioning of more N in soil. The tallest (218.4 cm) plant was found from T_3 and the smallest (140.0 cm) was found from T_8 which was statistically similar to T_7, T_6 and T_5. The plant height (cm) at full tassel emerged stage was significant against different doses of NEB and chemical fertilizer (Table-1 and Appendix IV). The tallest (224.01 cm) plant was found from T_3 which was statistically similar to T_4, T_2 and T_1 and the smallest (182.31 cm) was found from T_8. Marschner (1995) reported that, the application of high rates of N to maize's, depending on the variety, generally delays cob initiation of maize and promotes vegetative growth resulted from higher accumulation of nitrogen in plant cell. So, the result of present study is in agreement with cited study. The result also supported by Bean and Patrick, 2010) they reported that, at full tassel stage the plant was at full height.

Table 1. Response of NEB and chemical fertilizers on plant height at tassel initiation stage and full tassel emerged stage of maize

Treatments	Plant height (cm) at tassel initiation stage	Plant height (cm) at full tassel emerged stage
T_1	187.4 b	215.12 ab
T_2	190.0 b	216.01 ab
T_3	218.4 a	224.01 a
T_4	191.2 b	223.01 a
T_5	161.8 c	215.01 ab
T_6	155.8 c	205.03 a-c
T_7	158.1 c	193.01 bc
T_8	140.0 c	182.31 c
CV (%)	7.14	7.09
LSD $_{(0.05)}$	2.19	25.97
Significance level	**	*

Values with common letter (s) within a column do not differ significantly at 5% level of probability

** indicates significant at 1% level of probability

* indicates significant at 5% level of probability

T_1= 50% recommended urea (RU) + 500 ml NEB ha^{-1} along with other fertilizers, T_2= 50% RU + 750 ml NEB ha^{-1} along with other fertilizers, T_3= 50% RU + 1000 ml NEB ha^{-1} along with other fertilizers, T_4= 50% RU + 1250 ml NEB ha^{-1} along with other fertilizers, T_5= 50% RU and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% RU and 25% reduction of P, K, S + 1000 ml NEB ha^{-1}, T_7= 50% RU and 25% reduction of P,K,S + 1250 ml NEB ha^{-1} and T_8= 100% recommended chemical fertilizer

4.1.2 Days to tassel initiation and full tassel emergence

In aspects of days to tassel initiation and full tassel emergence of maize plant a remarkable variation was noted (Table-2 and Appendix V) against different doses of NEB and chemical fertilizers. An increasing trend was found for duration of tassel initiation and full emergence with the increasing doses of NEB doses and reduction of PKS fertilizers. The longest period for tassel initiation was required by the plants produced from T_8 (47.08 days) treatment and the shortest period was required from T_3 (37.00 days). The longest period for full tassel emergence was required by the plants produced from T_8 (78.50 days) treatment and the shortest period was required from T_3 (62.11 days) which was statistically similar to $T_{4,}$ $T_{2,}$ $T_{1,}$ T_5 and T_6 treatment. The result of present study revealed that, more absorption of nitrogen was exhibited by the treatment combination of NEB and urea fertilizer resulting in a better reduction of days required for tassel initiation and 100% emergence of tassel in maize field. Masome and Kazemi (2014) explained that, the number of days to seed emergence of tomato influenced significantly by urea nitrogen fertilizer with increasing doses. The result of present study showed and supported that, more absorption of nitrogen was exhibited by the treatment combination of NEB and urea fertilizer resulting a better reduction of days required for first and full emergence of cob of maize from field.

Table 2. Response of NEB and chemical fertilizers on days to tassel initiation and full tassel emergence of maize

Treatments	Days to tassel initiation	Days to full tassel emergence
T_1	42.17 a-d	67.10 bc
T_2	40.90 b-d	68.71 a-c
T_3	37.00 d	62.11 c
T_4	38.12 cd	62.18 c
T_5	42.97 a-d	70.48 a-c
T_6	44.11 a-c	70.64 a-c
T_7	44.90 ab	72.34 ab
T_8	47.08 a	78.50 a
CV (%)	8.31	8.33
LSD $_{(0.05)}$	6.1342	10.067
Significance level	*	*

Values with common letter (s) within a column do not differ significantly at 5% level of probability

* indicates significant at 5% level of probability

T_1= 50% recommended urea (RU) + 500 ml NEB ha^{-1} along with other fertilizers, T_2= 50% RU + 750 ml NEB ha^{-1} along with other fertilizers, T_3= 50% RU + 1000 ml NEB ha^{-1} along with other fertilizers, T_4= 50% RU + 1250 ml NEB ha^{-1} along with other fertilizers, T_5= 50% RU and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% RU and 25% reduction of P, K, S + 1000 ml NEB ha^{-1}, T_7= 50% RU and 25% reduction of P,K,S + 1250 ml NEB ha^{-1} and T_8= 100% recommended chemical fertilizer.

4.1.3 Number of leaves plant^{-1} at tassel initiation stage and full tassel emerged stage

Number of leaves plant^{-1} of maize plant at tassel initiation stage and full tassel emerged stage were found remarkably varied (Table-3 and Appendix VI) against different doses of NEB and chemical fertilizers. The number of leaves in maize mother plant increased with the increasing of partitioning of more N in soil. Results demonstrated that, at tassel initiation stage the maximum number of leaves was found from T_3 (6.21) which was statistically similar to T_4 (5.91) whereas the minimum number of leaves was found from T_8 (3.91). At full tassel emerged stage, the maximum number of leaves was found from T_4 (15.20) which was statistically similar to T_3 (14.24) whereas the minimum number of leaves was found from T_8 (10.03). The finding also supported by Marschner (1995). Who explained that, application of high rates of N to Maize's, depending on the variety, generally delays cob initiation of maize and promotes vegetative growth resulted from higher accumulation of nitrogen in plant cell which also induces the shoot growth as more leaf buds.

Table 3. Response of NEB and chemical fertilizers on number of leaves plant^{-1} at tassel initiation stage and full tassel emerged stage of maize

Treatments	Number of leaves plant^{-1} at tassel initiation stage	Number of leaves plant^{-1} at full tassel emerged stage
T_1	4.95 bc	12.94 bc
T_2	5.00 b	13.20 bc
T_3	6.21 a	14.24 ab
T_4	5.91 a	15.20 a
T_5	4.62 b-d	12.00 cd
T_6	4.01 de	11.01 de
T_7	4.36 c-e	11.64 c-e
T_8	3.91 e	10.03 e
CV (%)	7.16	8.36
LSD $_{(0.05)}$	0.6120	1.8349
Significance level	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability

** indicates significant at 1% level of probability

T_1= 50% recommended urea (RU) + 500 ml NEB ha^{-1} along with other fertilizers, T_2= 50% RU + 750 ml NEB ha^{-1} along with other fertilizers, T_3= 50% RU + 1000 ml NEB ha^{-1} along with other fertilizers, T_4= 50% RU + 1250 ml NEB ha^{-1} along with other fertilizers, T_5= 50% RU and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% RU and 25% reduction of P, K, S + 1000 ml NEB ha^{-1}, T_7= 50% RU and 25% reduction of P,K,S + 1250 ml NEB ha^{-1} and T_8= 100% recommended chemical fertilizer.

4.1.4 Number of cob initiating nodes plant^{-1} at tassel initiation stage and full tassel emerged stage

Remarkable variation was noted among different doses of NEB and chemical fertilizers regarding number of cob initiating nodes plant^{-1} at tassel initiation stage and full tassel emerged stage (Table-4 and Appendix VII). The maximum (4.01) cob initiating nodes plant^{-1} at tassel initiation stage was exhibited from T_4 which was statistically similar to T_3 (3.84) and the minimum (2.88) were found from T_8. At full tassel emerged stage, the maximum (14.91) cob initiating nodes plant^{-1} at tassel initiation stage was exhibited from T_4 which was statistically similar to T_3 (14.10) and T_2 (13.44) where as the minimum (11.00) was found from T_8. Due to more accumulation of nitrogen fertilizer by the roots of higher concentration of NEB and 50% reduction of urea may increase the percent of efficient nitrogen partitioning generally delays cob of maize initiation and promotes vegetative growth.

Table 4. Response of NEB and chemical fertilizers on number of cob initiating nodes plant^{-1} at tassel initiation stage and full tassel emerged stage of maize

Treatments	Number of cob initiating nodes plant^{-1} at tassel initiation stage	Number of cob initiating nodes plant^{-1} at full tassel emerged stage
T_1	3.10 b	13.11 b
T_2	3.18 b	13.44 ab
T_3	3.84 a	14.10 ab
T_4	4.01 a	14.91 a
T_5	3.01 b	13.08 b
T_6	2.99 b	13.00 b
T_7	3.00 b	12.94 b
T_8	2.88 b	11.00 c
CV (%)	5.99	6.65
LSD $_{(0.05)}$	0.3420	1.5375
Significance level	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability

** indicate significant at 1% level of probability

T_1= 50% recommended urea (RU) + 500 ml NEB ha^{-1} along with other fertilizers, T_2= 50% RU + 750 ml NEB ha^{-1} along with other fertilizers, T_3= 50% RU + 1000 ml NEB ha^{-1} along with other fertilizers, T_4= 50% RU + 1250 ml NEB ha^{-1} along with other fertilizers, T_5= 50% RU and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% RU and 25% reduction of P, K, S + 1000 ml NEB ha^{-1}, T_7= 50% RU and 25% reduction of P,K,S + 1250 ml NEB ha^{-1} and T_8= 100% recommended chemical fertilizer.

4.1.5 SPAD value of leaves at tassel initiation stage and dough stage

Significant variation was noted on SPAD value of maize leaf at tassel initiation stage and dough stage (Figure-1 and Appendix VIII) against different doses of NEB and chemical fertilizers. There was an increasing trend of leaf SPAD with the increasing of accumulation of leaf nitrogen up to certain doses and there after decreased. At tassel initiation stage, the highest SPAD value was found from T_4 (40.94) which was statistically similar to T_3 (40.28) treatments whereas the lowest from T_8 (31.27) treatment. At dough stage, the highest SPAD value was found from T_3 (57.20) which was statistically similar to T_4 (57.18) treatments whereas the lowest from T_8 (45.11) treatment.

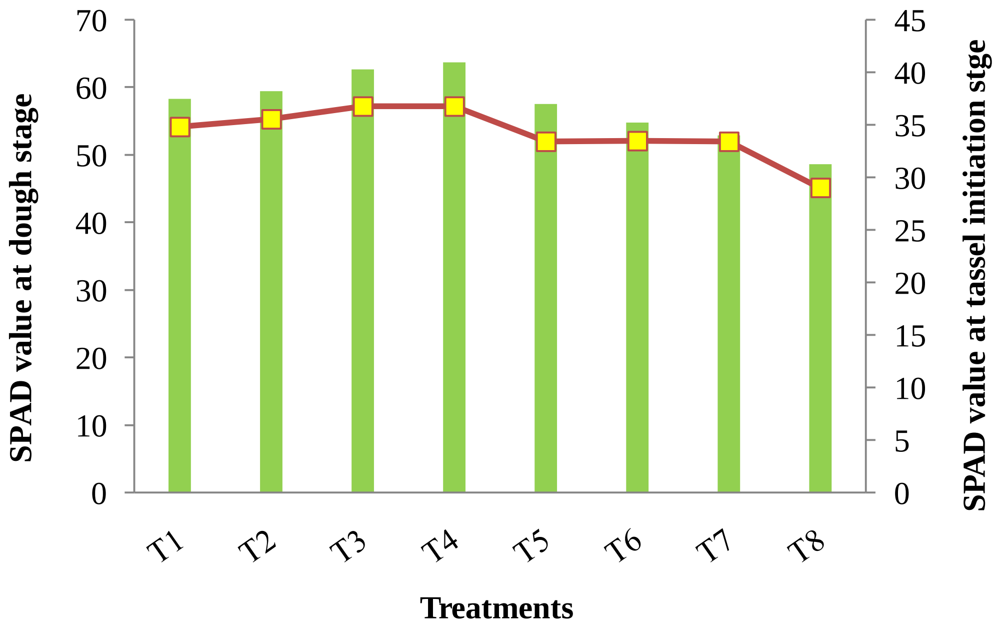

Figure 1. Response of NEB and chemical fertilizers on SPAD value of leaves at tassel initiation stage and dough stage [LSD $_{(0.05)}$ = 4.5691 and 6.6684, respectively]

T_1= 50% recommended urea (RU) + 500 ml NEB ha^{-1} along with other fertilizers, T_2= 50% RU + 750 ml NEB ha^{-1} along with other fertilizers, T_3= 50% RU + 1000 ml NEB ha^{-1} along with other fertilizers, T_4= 50% RU + 1250 ml NEB ha^{-1} along with other fertilizers, T_5= 50% RU and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% RU and 25% reduction of P, K, S + 1000 ml NEB ha^{-1}, T_7= 50% RU and 25% reduction of P,K,S + 1250 ml NEB ha^{-1} and T_8= 100% recommended chemical fertilizer.

Chlorophyll content is approximately proportional to leaf nitrogen content and at the advent of tasseling of maize, the vegetative growth was stopped to patron the sink to reproductive part as a whole. As a result, the SPAD value was varied among the treatment at this stage of maize plant. This behavior is consistent with the data obtained by Gregersen *et al.* (2013) who reported that the highest content of chlorophyll was found in the cob leaf when it was in the dough stage.

4.2 Yield traits

4.2.1 Days to silk initiation

In aspects of days to silk initiation of maize plant a remarkable variation was noted (Table-5 and Appendix V) against different doses of NEB and chemical fertilizers. An increasing trend was found for duration of silk initiation with the increasing doses of NEB doses and reduction of PKS fertilizers. The longest period for silk initiation was required by the plants produced from T_8 (85.00 days) treatment and the shortest period was required from T_3 (72.017days) which was statistically similar to T_4. The result of present study revealed that, more absorption of nitrogen may be exhibited by the treatment combination of NEB and urea fertilizer resulting in a better reduction of days required for silk initiation in maize field.

4.2.2 Number of cobs plant^{-1}

Number of cobs plant^{-1} of maize was found remarkably varied (Table-5 and Appendix IX) against different doses of NEB and chemical fertilizers. Results demonstrated that, the highest weight of cob of maize was found from T_4 (3.08) which was statistically similar to T_3 (3.00) treatment whereas the lowest number of cob of maize was found from T_8 (1.51) treatment. More absorption of soil nitrogen by plant may be the main reason for higher number of cob of maize per plant.

4.2.3 Length of cob

Length of cob of maize was found remarkably varied (Table-5 and Appendix IX) against different doses of NEB and chemical fertilizers. Results demonstrated that, the longest cob of maize was found from T_4 (22.71 cm) which was statistically similar to T_3 (22.01 cm) treatment whereas the shortest cob of maize was found from T_8 (15.10 cm).

Table 5. Response of NEB and chemical fertilizers on days to silk initiation, number of cobs plant^{-1} and length of cob of maize

Treatments	Days to silk initiation	Number of cobs plant^{-1}	Length of cob (cm)
T_1	74.23 b	2.28 bc	19.30 bc
T_2	75.71 b	2.51 b	20.10 a-c
T_3	72.01 b	3.00 a	22.01 ab
T_4	72.00 b	3.08 a	22.71 a
T_5	77.10 ab	1.99 cd	19.88 a-c
T_6	77.55 ab	1.94 cd	18.16 c
T_7	79.28 ab	1.85 de	17.85 cd
T_8	85.00 a	1.51 e	15.10 d
CV (%)	5.93	9.75	8.57
LSD $_{(0.05)}$	7.9550	0.3889	2.9113
Significance level	**	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability

** indicate significant at 1% level of probability

T_1= 50% recommended urea (RU) + 500 ml NEB ha^{-1} along with other fertilizers, T_2= 50% RU + 750 ml NEB ha^{-1} along with other fertilizers, T_3= 50% RU + 1000 ml NEB ha^{-1} along with other fertilizers, T_4= 50% RU + 1250 ml NEB ha^{-1} along with other fertilizers, T_5= 50% RU and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% RU and 25% reduction of P, K, S + 1000 ml NEB ha^{-1}, T_7= 50% RU and 25% reduction of P,K,S + 1250 ml NEB ha^{-1} and T_8= 100% recommended chemical fertilizer.

4.2.4 Unfilled length of cob

Unfilled length of cob of maize that means which barren was found remarkably varied (Table-6 and Appendix X) against different doses of NEB and chemical fertilizers. Results demonstrated that, the largest part of barren cob length was found from T_8 (6.80 cm) whereas the smallest part of cob length of maize was found from T_3 (3.33 cm).

4.2.5 Bareness percentage

Bareness percentage of cob of maize that means which barren in respect of length was found remarkably varied (Table-6 and Appendix X) against different doses of NEB and chemical fertilizers. Results demonstrated that, the highest bareness percentage was found from T_8 (45.08 %) whereas the lowest bareness percentage of maize was found from T_3 (15.16 %). The increased cob grain free length might be due to increased nitrogen accumulation in plant enhanced more grains in cob which reduced the length of free cob grain space (Majid *et al.*, 2017) which support the present findings.

4.2.6 Diameter of cob

Diameter of cob of maize was found remarkably varied (Table-6 and Appendix X) against different doses of NEB and chemical fertilizers. Results demonstrated that, the widest cob of maize was found from T_4 (16.857 cm) which was statistically similar to T_3 (16.24 cm) treatment whereas the narrowest cob of maize was found from T_8 (11.59 cm).

Table 6. Response of NEB and chemical fertilizers on cob length unfilled, bareness and diameter of cob of maize

Treatments	Unfilled length of cob (cm)	Bareness (%)	Diameter of cob (cm)
T_1	4.91 cd	25.48 e	14.20 b
T_2	4.34 de	21.63 f	14.55 b
T_3	3.33 f	15.16 h	16.24 a
T_4	3.84 ef	16.94 g	16.85 a
T_5	5.20 c	26.19 d	14.00 b
T_6	5.34 bc	29.44 c	13.51 bc
T_7	5.88 b	32.98 b	12.20 cd
T_8	6.80 a	45.08 a	11.59 d
CV (%)	7.37	1.39	6.09
LSD $_{(0.05)}$	0.6406	0.6469	1.5084
Significance level	**	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability

** indicates significant at 1% level of probability

T_1= 50% recommended urea (RU) + 500 ml NEB ha^{-1} along with other fertilizers, T_2= 50% RU + 750 ml NEB ha^{-1} along with other fertilizers, T_3= 50% RU + 1000 ml NEB ha^{-1} along with other fertilizers, T_4= 50% RU + 1250 ml NEB ha^{-1} along with other fertilizers, T_5= 50% RU and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% RU and 25% reduction of P, K, S + 1000 ml NEB ha^{-1}, T_7= 50% RU and 25% reduction of P,K,S + 1250 ml NEB ha^{-1} and T_8= 100% recommended chemical fertilizer.

4.2.7 Number of rows cob^{-1}

Number of rows cob^{-1} was found significantly varied (Table-7 and Appendix XI) against different doses of NEB and chemical fertilizers. Results revealed that, the maximum number of rows cob^{-1} was found from T_3 (17.31) which was statistically similar to T_4 (16.40) and T_2 (16.00) treatment.

The minimum number of rows cob^{-1} of maize was found from T_8 (12.91) treatment that is similar to T_6 and T_7. The increased diameter may be reason for the higher number of rows cob^{-1}.

4.2.8 Number of grains row^{-1}

Number of grains row^{-1} was not varied (Table-7 and Appendix XI) against different doses of NEB and chemical fertilizers.

4.2.9 Total number of grains cob^{-1}

Total number of grains cob^{-1} was found significantly varied (Table-7 and Appendix XI) against different doses of NEB and chemical fertilizers. Results revealed that, the maximum total number of grains cob^{-1} was found from T_3 (586.12) which was statistically similar to T_4 (551.25) treatment whereas the minimum total number of grains cob^{-1} of maize was found from T_8 (432.12) treatment.

Table 7. Response of NEB and chemical fertilizers on number of rows cob^{-1}, number of grains row^{-1} and total number of grains cob^{-1} of maize

Treatments	Number of rows cob^{-1}	Number of grains row^{-1}	Total number of grains cob^{-1}
T_1	15.20 bc	32.87	500.01 bc
T_2	16.00 ab	31.98	512.02 bc
T_3	17.31 a	33.84	586.12 a
T_4	16.40 ab	33.58	551.25 ab
T_5	14.95 bc	32.84	491.32 b-d
T_6	14.01 cd	34.31	481.19 cd
T_7	14.55 b-d	32.77	477.25 cd
T_8	12.91 d	33.44	432.12 d
CV (%)	7.26	6.29	7.12
LSD $_{(0.05)}$	1.927	------	62.870
Significance level	**	NS	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability

** indicates significant at 1% level of probability, NS=Non-significant

T_1= 50% recommended urea (RU) + 500 ml NEB ha^{-1} along with other fertilizers, T_2= 50% RU + 750 ml NEB ha^{-1} along with other fertilizers, T_3= 50% RU + 1000 ml NEB ha^{-1} along with other fertilizers, T_4= 50% RU + 1250 ml NEB ha^{-1} along with other fertilizers, T_5= 50% RU and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% RU and 25% reduction of P, K, S + 1000 ml NEB ha^{-1}, T_7= 50% RU and 25% reduction of P,K,S + 1250 ml NEB ha^{-1} and T_8= 100% recommended chemical fertilizer.

4.2.10 100-grains weight

A remarkable variation was found among different doses of NEB and chemical fertilizers in case of 100-grains weight (g) of maize (Table-8 and Appendix XII). The highest 100-grains weight was found from T_3 (36.50 g) which was statistically similar to T_4 (36.34 g) treatment whereas the minimum 100-grains weight of maize was found from T_8 (29.81 g) treatment.

The higher accumualtion on nitrogen from artificial root edudates resulting the higher partitiong of protein may increased the 100-grain weight (g) of maize (Majid *et al*., 2017).

4.2.11 Shelling percentage

Shelling percentage of cob of maize that means which how much of grain was shelled out was found remarkably varied (Table-8 and Appendix XII) against different doses of NEB and chemical fertilizers. Results demonstrated that, the highest shelling percentage was found from T_4 (72.01 %) which was statistically similar to T_3 (71.34 %) whereas the lowest shelling percentage of maize was found from T_8 (43.11 %).

4.2.12 Grain yield

Significant variation was found among different doses of NEB and chemical fertilizers in case of grain yield of maize (Table-8 and Appendix XII). The highest grain yield was found from T_4 (13.51 t ha^{-1}) which was statistically similar to T_3 (12.61 t ha^{-1}) treatment whereas the lowest grain yield of maize was found from T_8 (4.10 t ha^{-1}) treatment. The positive increase in yield components demonstrates that N increased assimilates supply for component development and yield set (Akmal *et al*., 2010) which supported the present findings.

Table 8. Response of NEB and chemical fertilizers on 100-grain weight, shelling percentage and grain yield of maize

Treatments	100-grain weight (g)	Shelling percentage	Grain yield (t ha^{-1})
T_1	32.28 ab	65.18 b	8.12 bc
T_2	33.00 ab	65.40 b	9.01 b
T_3	36.50 a	71.34 ab	12.61 a
T_4	36.34 a	72.01 a	13.51 a
T_5	32.00 ab	57.10 c	7.09 cd
T_6	31.12 b	55.40 c	6.99 d
T_7	30.04 b	54.11 c	6.24 d
T_8	29.81 b	43.11 d	4.10 e
CV (%)	8.27	6.00	7.55
$LSD_{(0.05)}$	4.7251	6.3511	1.1187
Significance level	*	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability

** indicates significant at 1% level of probability * indicates significant at 5% level of probability

T_1= 50% recommended urea (RU) + 500 ml NEB ha^{-1} along with other fertilizers, T_2= 50% RU + 750 ml NEB ha^{-1} along with other fertilizers, T_3= 50% RU + 1000 ml NEB ha^{-1} along with other fertilizers, T_4= 50% RU + 1250 ml NEB ha^{-1} along with other fertilizers, T_5= 50% RU and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% RU and 25% reduction of P, K, S + 1000 ml NEB ha^{-1}, T_7= 50% RU and 25% reduction of P,K,S + 1250 ml NEB ha^{-1} and T_8= 100% recommended chemical fertilizer.

4.3 Quality traits

4.3.1 Germination percentage

Germination percentage of grains of maize was found remarkably varied (Table-9 and Appendix XIII) against different doses of NEB and chemical fertilizers. Results demonstrated that, the highest germination (%) was found from T_4 (88.11 %) which was statistically similar to T_3 (85.22 %), T_2 (82.87 %) and T_1 (81.00 %) whereas the lowest germination percentage of maize was found from T_8 (72.91 %) which was statistically similar to T_5 (75.23 %), T_6 (77.05 %) and T_7 (76.23 %).

4.3.2 Popping recovery

Popping recovery (%) of grains of maize was found remarkably varied (Table-9 and Appendix XIII) against different doses of NEB and chemical fertilizers. Results demonstrated that, the highest popping recovery (%) was found from T_4 (35.00 %) whereas the lowest popping recovery (%) of maize was found from T_8 (11.10 %).

Table 9. Response of NEB and chemical fertilizers on germination percentage and popping recovery percentage of maize

Treatment	Germination percentage	Popping recovery percentage
T_1	81.00 a-d	18.53 c
T_2	82.87 a-c	20.09 c
T_3	85.22 ab	35.00 a
T_4	88.11 a	28.14 b
T_5	75.23 cd	15.24 d
T_6	77.05 b-d	14.10 d
T_7	76.23 b-d	13.04 de
T_8	72.91 d	11.10 e
CV (%)	7.02	7.64
LSD (0.05)	9.8079	2.5960
Significance level	*	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability

** indicates significant at 1% level of probability *indicates significant at 5% level of probability

T_1= 50% recommended urea (RU) + 500 ml NEB ha^{-1} along with other fertilizers, T_2= 50% RU + 750 ml NEB ha^{-1} along with other fertilizers, T_3= 50% RU + 1000 ml NEB ha^{-1} along with other fertilizers, T_4= 50% RU + 1250 ml NEB ha^{-1} along with other fertilizers, T_5= 50% RU and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% RU and 25% reduction of P, K, S + 1000 ml NEB ha^{-1}, T_7= 50% RU and 25% reduction of P,K,S + 1250 ml NEB ha^{-1} and T_8= 100% recommended chemical fertilizer.

4.3.3 Grading of 100 $seed^{-1}$ as large, medium and small

Grading of maize grain was significantly varied with different doses of NEB and chemical fertilizers (Table-10 and Appendix XIV). In case of larger grain fraction, the maximum lager grain was found from T_4 (69.99) whereas minimum larger grain of maize was found from T_8 (26.99).

In aspects of medium grain fraction, the maximum medium grain was found from T_4 (44.99) which was statistically similar to T_8 (44.99) which was statistically similar to T_7 (41.99) whereas minimum medium grain of maize was found from T_4 (24.99). In respects of small grain fraction, the maximum smaller grain was found from T_8 (27.99) which was statistically similar to T_7 (24.99) and T_5 (25.99) whereas minimum smaller grain of maize was found from T_4 (4.99) that is similar to T_3 (7.99).

Table 10. Response of NEB and chemical fertilizers on grading as large, medium and small 100 seed^{-1} of maize

Treatment	Grading 100 seed^{-1}		
	Large (>8.7 mm)	Medium (7.5-8.7mm)	Small (<7.5 mm)
T_1	54.99 b	31.99 cd	12.99 c
T_2	58.99 b	28.99 de	11.99 c
T_3	64.99 a	26.99 ef	7.99 d
T_4	69.99 a	24.99 f	4.99 d
T_5	38.99 c	34.99 bc	25.99 a
T_6	41.99 c	37.99 b	19.99 b
T_7	32.99 d	41.99 a	24.99 a
T_8	26.99 e	44.99 a	27.99 a
CV (%)	6.20	6.04	10.45
LSD (0.05)	5.2900	3.6115	3.1321
Significance level	**	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability

** indicates significant at 1% level of probability

T_1= 50% recommended urea (RU) + 500 ml NEB ha^{-1} along with other fertilizers, T_2= 50% RU + 750 ml NEB ha^{-1} along with other fertilizers, T_3= 50% RU + 1000 ml NEB ha^{-1} along with other fertilizers, T_4= 50% RU + 1250 ml NEB ha^{-1} along with other fertilizers, T_5= 50% RU and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% RU and 25% reduction of P, K, S + 1000 ml NEB ha^{-1}, T_7= 50% RU and 25% reduction of P,K,S + 1250 ml NEB ha^{-1} and T_8= 100% recommended chemical fertilizer.

4.4 Correlation coefficient (r)

The application of NEB and chemical fertilizers in comparison with control has significantly influenced the different traits of maize and so, the correlation co-efficient (r) was calculated among some growth, yield and quality traits. A strong linear relation (r=0.90**) was exhibited between number of cob initiating nodes plant^{-1} at full tassel emerged stage and number of cobs plant^{-1} of maize (Figure-2). A strong linear relation (r=0.99**) was also exhibited between number of cobs plant^{-1} and grain yield (t ha^{-1}) of maize (Figure-3). In figure-4, a linear strong relation (r=0.98**) was found between cob length unfilled (cm) and bareness (%) of maize. In figure-5, there was present a strong relation (r=0.90**) between diameter of cob (cm) and number of rows cob^{-1} of maize. A linear relation (r=0.89*) was present between number of grains row^{-1} and total number of grains cob^{-1} of maize (Figure-6). A strong linear relation (r=0.96**) was present between total number of grains cob^{-1} and grain yield (t ha^{-1}) of maize (Figure-7). A strong linear relation (r=0.96**) was present between 100-grain weight (g) and grain yield (t ha^{-1}) of maize (Figure-8). About 85 to 100% of maize yield was dependent on different yield contributing traits and all of these characters had significant contribution on cob of maize yield and yield could be increased by improving these yield attributes.

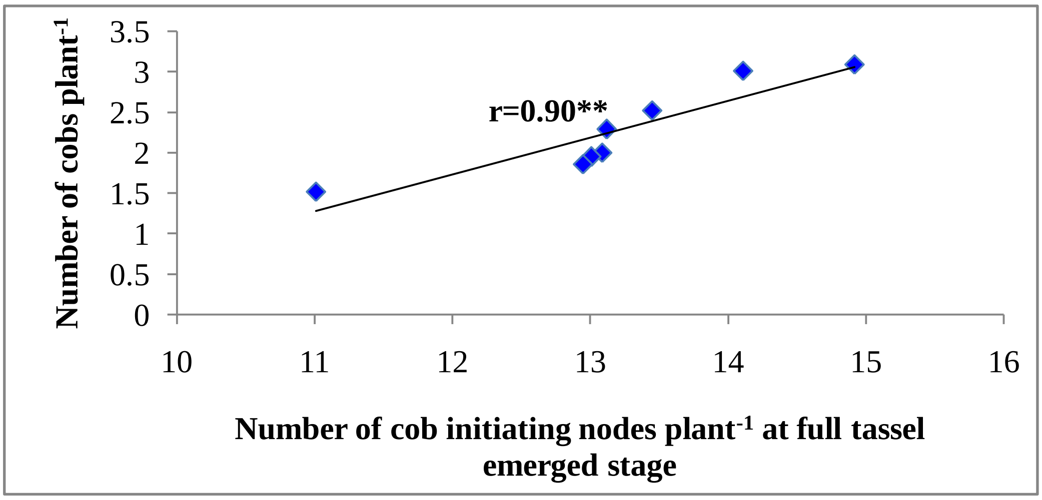

Figure 2. Relationship between number of cob initiating nodes plant^{-1} at full tassel emerged stage and number of cobs plant^{-1} of maize

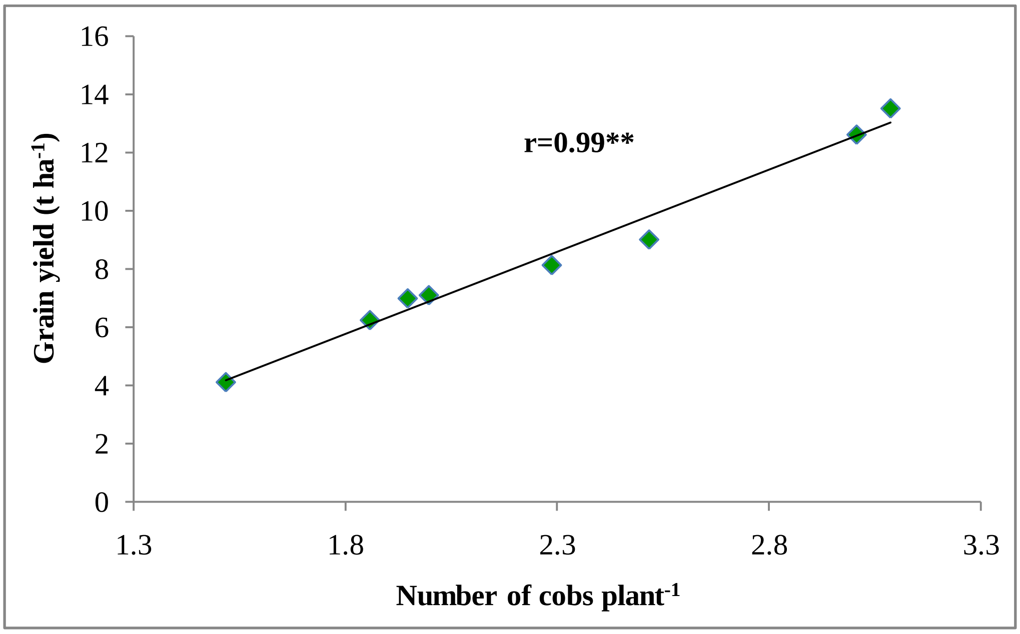

Figure 3. Relationship between number of cobs plant^{-1} and grain yield of maize

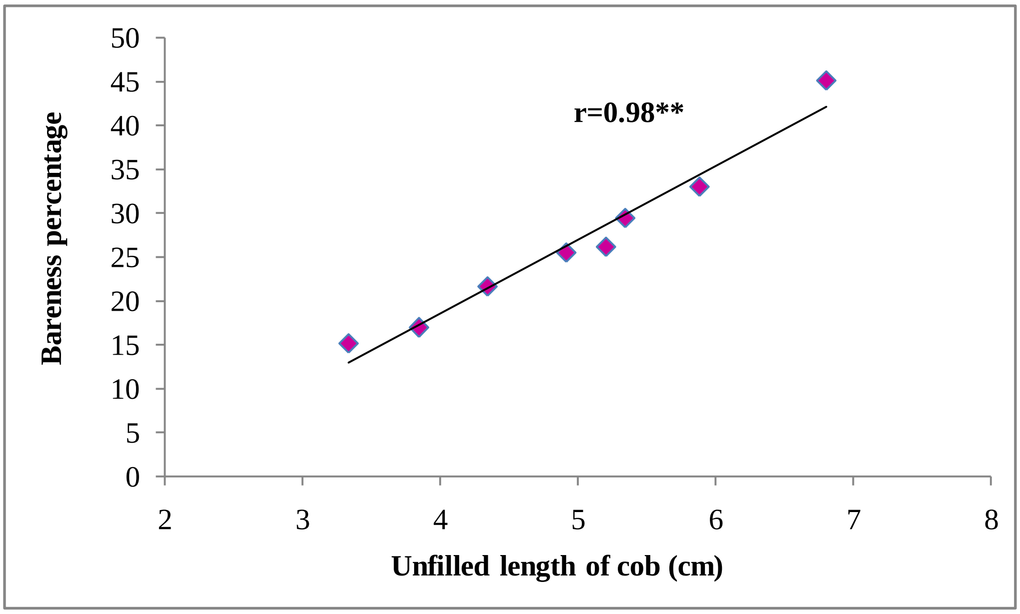

Figure 4. Relationship between cob length unfilled and bareness percentage of maize

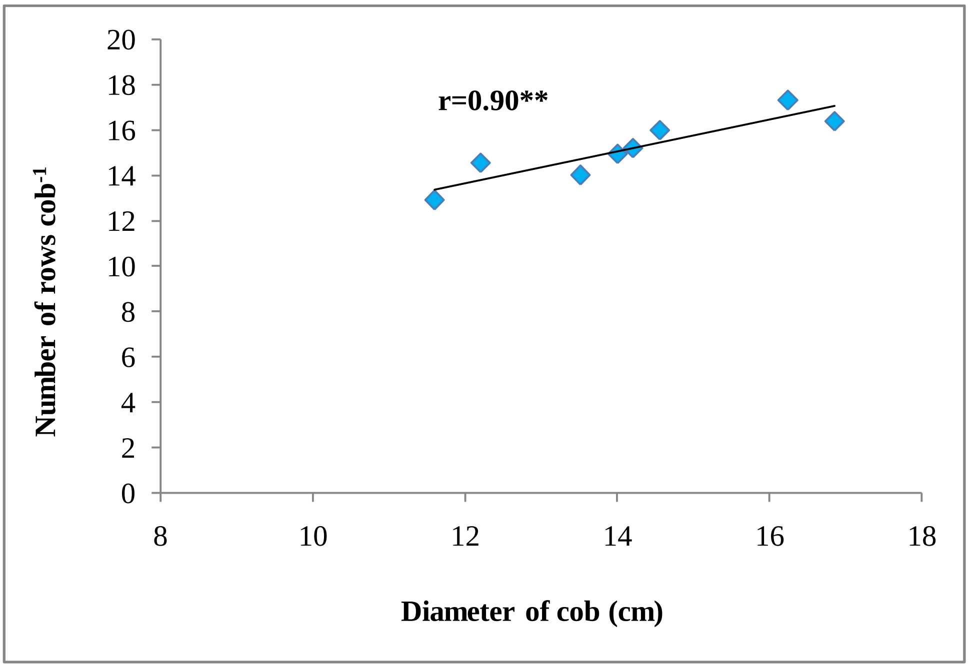

Figure 5. Relationship between diameter of cob and number of rows cob^{-1} of maize

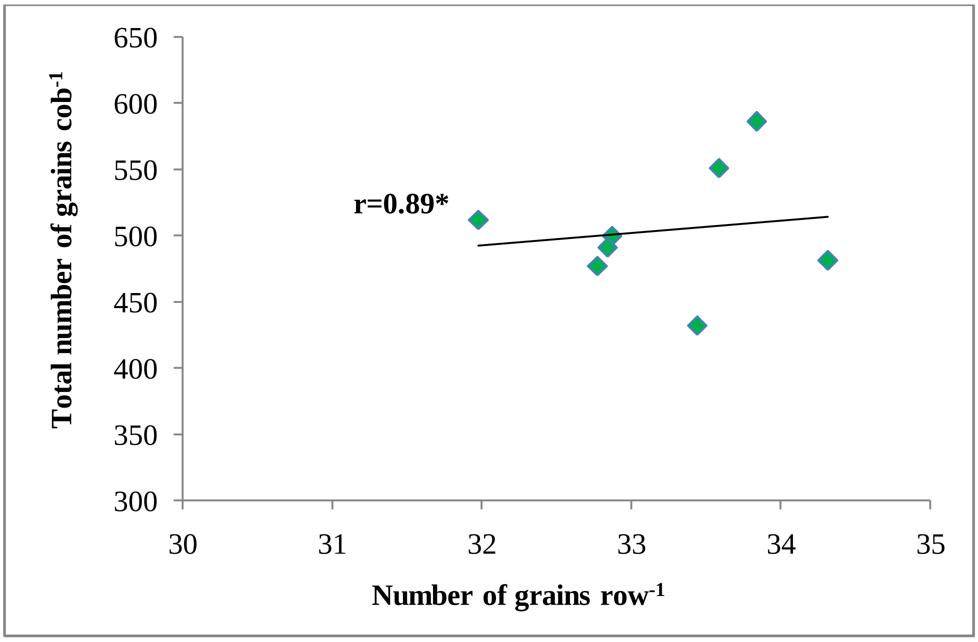

Figure 6. Relationship between number of grains row^{-1} and total number of grains cob^{-1} of maize

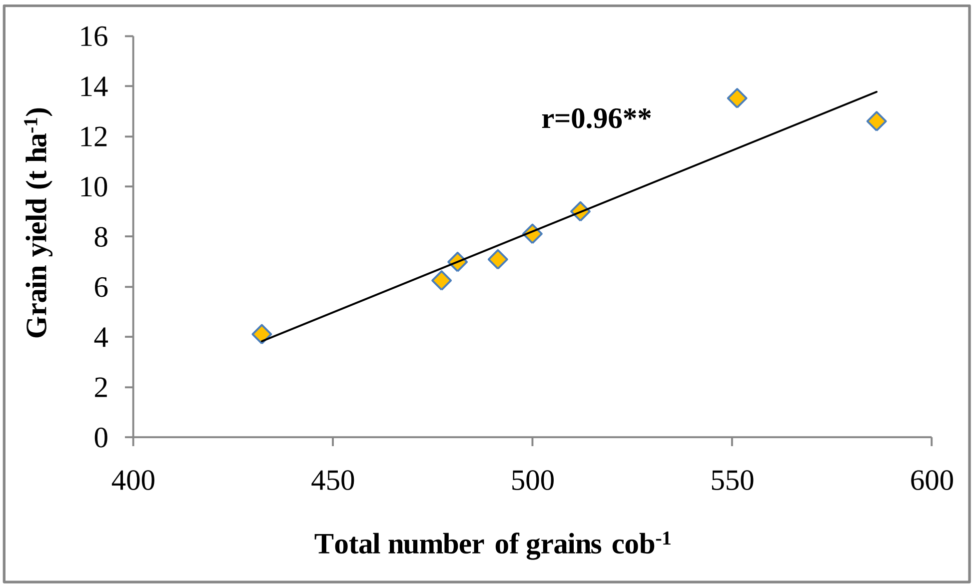

Figure 7. Relationship between total number of grains cob^{-1} and grain yield of maize

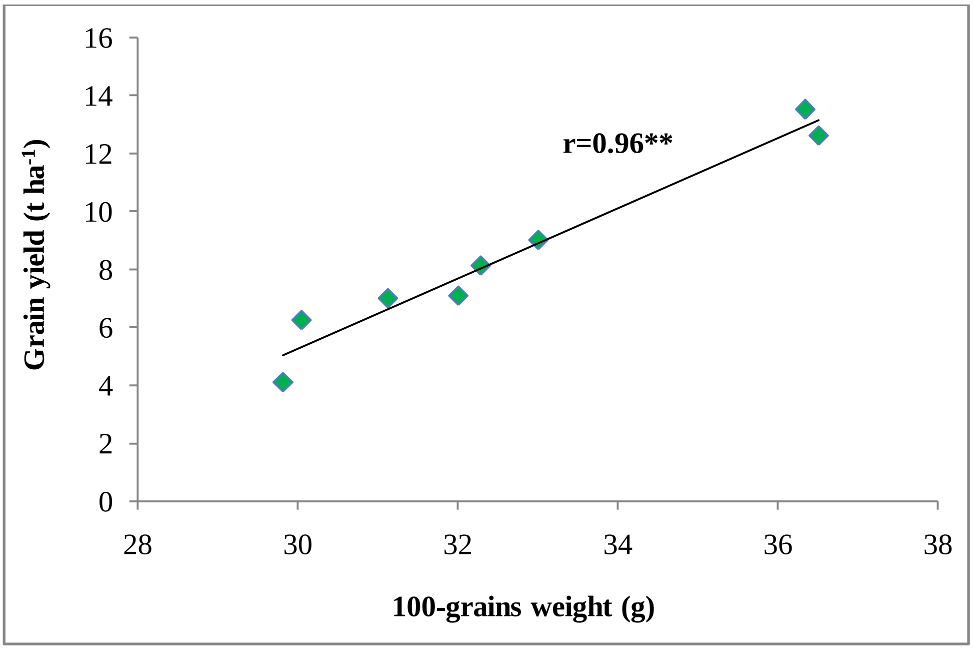

Figure 8. Relationship between 100-grains weight and grain yield of maize

CHAPTER V

SUMARRY AND CONCLUSION

The study was conducted in the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, during November, 2015 to April, 2016 to evaluate the response of NEB along with chemical fertilizers on the growth, yield and quality of maize. “ACI Hybrid DON 111” was used as planting material under study. The experiment consisted of eight different combinations of NEB with inorganic fertilizers namely, T_1= 50% recommended urea (RU) + 500 ml NEB ha^{-1} along with other fertilizers, T_2= 50% RU + 750 ml NEB ha^{-1} along with other fertilizers, T_3= 50% RU + 1000 ml NEB ha^{-1} along with other fertilizers, T_4= 50% RU + 1250 ml NEB ha^{-1} along with other fertilizers, T_5= 50% RU and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% RU and 25% reduction of P, K, S + 1000 ml NEB ha^{-1}, T_7= 50% RU and 25% reduction of P,K,S + 1250 ml NEB ha^{-1} and T_8= 100% recommended chemical fertilizer. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total numbers of unit plots were 28. The size of unit plot was 2.5 m × 2.0 m. The spacing 75 cm × 25 cm was used under present study. More or less the uniform sized seeds of maizes were used for sowing materials and seeds were sown at a depth of 3-4 cm on November 29, 2015. Different intercultural operations were done as and when needed. Data on different growth, yield and quality attributes were taken such as, plant height (cm) at tassel initiation stage and full tassel emerged stage, days to tassel initiation and full tassel emergence, number of leaves $plant^{-1}$ at tassel initiation stage and full tassel emerged stage, number of cob initiating node $plant^{-1}$ at tassel initiation stage and full tassel emerged stage, SPAD value of leaves at tassel initiation stage and dough stage, days to silk initiation, number of cobs $plant^{-1}$, length of cob, cob length unfilled, bareness percentage, diameter of cob, number of rows cob^{-1}, number of grains row^{-1}, total number of grains cob^{-1}, 100-grains weight, shelling percentage and grain yield.

The germination (%), grain grading as large, medium and small 100 $seed^{-1}$, popping recovery (%) as quality traits and correlation coefficient (r) was calculated. Results demonstrated that NEB in combination with chemical fertilizers had significant effect on most of the growth, yield and quality parameters of maize studied in this experiment. Among the eight treatments, the combination of NEB at the rate of 1250 ml ha^{-1} and 50% recommended urea along with other fertilizers at conventional rate showed better performance on number of cobs $plant^{-1}$, bareness (%), number of rows cob^{-1}, number of grains row^{-1}, shelling (%), grain yield, germination (%), seed grading and also on pop corn recovery (%) of maize which statistically similar to the combination of NEB at the rate of 1000 ml ha^{-1} and 50% recommended urea along with other fertilizers at conventional rate. On the other hand; days to tassel initiation and full tassel emergence, days to silk initiation showed the highest performance when the crop was managed by T_8 (100% recommended chemical fertilizers). The maximum yield of maize was found from T_4 (13.51 t ha^{-1}) which was statistically similar to T_3 (12.61 t ha^{-1}) where as the application of 100% recommended chemical fertilizers exhibited the wrost one (4.10 t ha^{-1}) for grain yield of maize.

Conclusion

On the basis of present study it may be concluded that, the application of NEB as NRE has the capacity to improve the performances of maize. With considering the yield and quality attributes of maize, the application of 50% Urea and 1000 ml of NEB per hectare exhibited significantly the best one in case of 100-grain weight, grain yield, germination and pop corn recovery percent of maize. The NEB also showed better and positive response of growth traits of maize plant compared to 100% application of chemical fertilizers in the field.

Recommendations

1. Usually the maize growers use recommended rate of fertilizers on their crop field so, the exogenous application of root exudates might be improved the yield and quality of maize as found from present study.

3. If, maize growers apply root exudates on their field it may reduce the rate of fertilizer especially nitrogen (urea) per hectare and may reduce the cost of production per hectare by reducing the bulkiness of fertilizer carrying and maintenance cost too.

4. So, it may be suggested that the application of 100 % inorganic fertilizers can be replaced by NEB as NRE for enhancing maize yield and quality in combination with reduced inorganic fertilizers especially urea.

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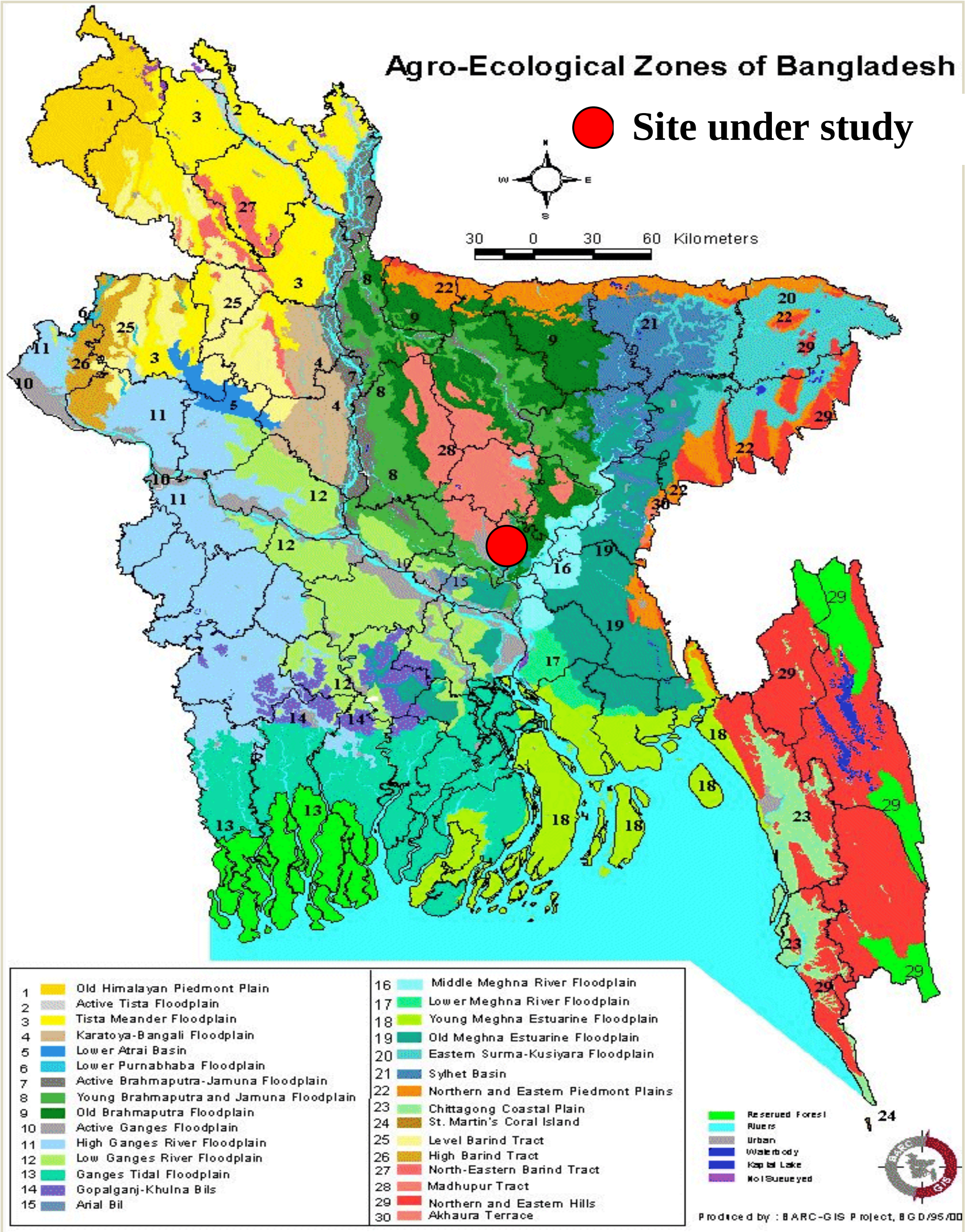
APPENDICES

Appendix I. Map showing the site used for present study

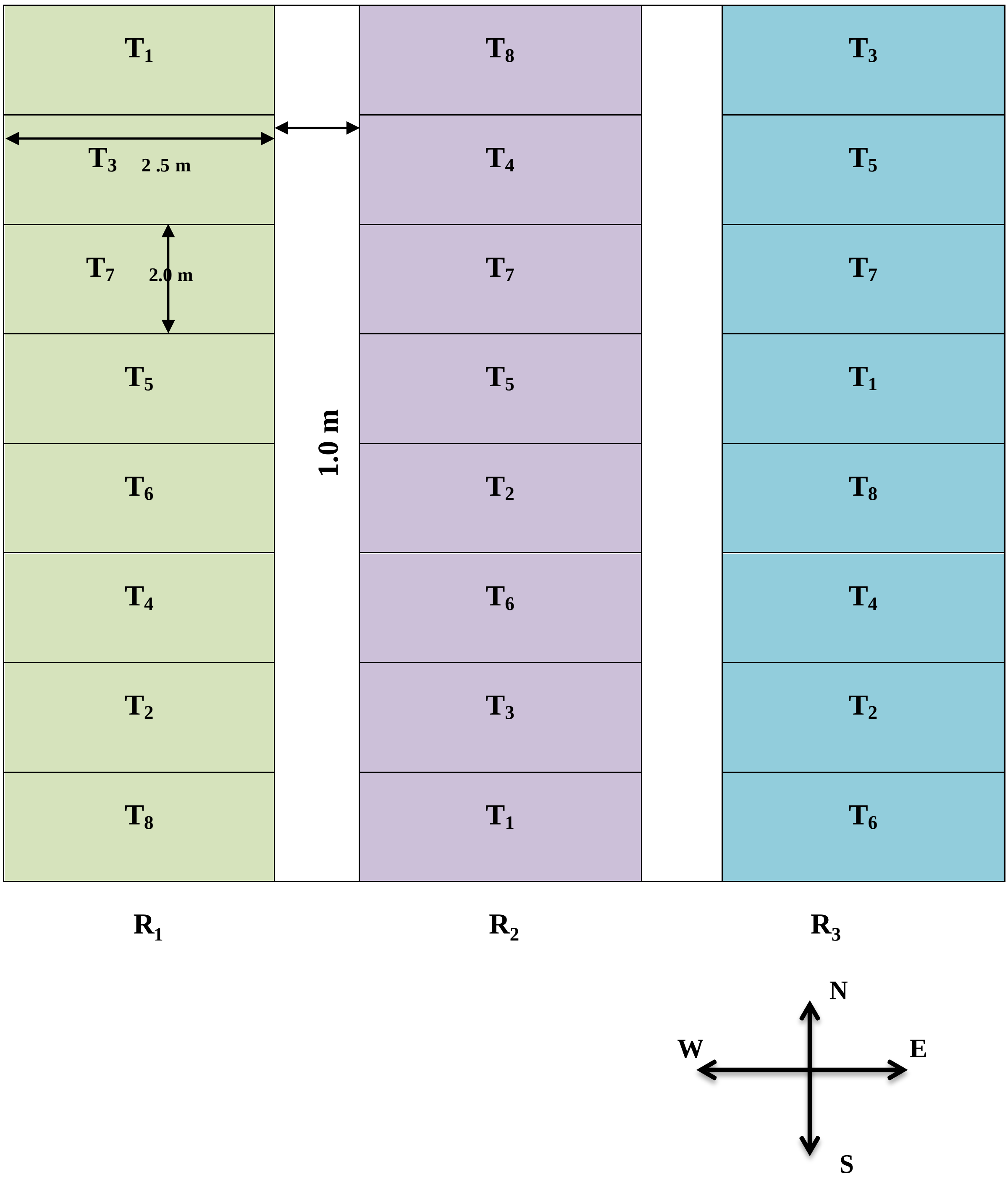


Appendix II. Monthly meteorological information during the period from November, 2015 to April, 2016

Year	Month	Air temperature (^oC)		Relative Humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2015-2016	November	28.89	11.88	56.58	51
	December	25.13	8.98	69.85	1.21
	January	23.97	9.28	71.09	Trace
	February	25.12	13.89	76.99	Trace
	March	29.21	14.09	75.89	1.01
	April	30.85	16.96	65.98	63

Source: Metrological Centre (Climate Division), Agargaon, Dhaka.

Appendix III. Layout of experimental plot



Legends : Unit plot size : 2.5 m × 2.0 m

Appendix IV. Mean sum square values for plant height of maize

Source of variation	df	at tassel initiation stage	at full tassel emerged stage
Replication	2	0.0137	0.238
Treatment	7	19.6172**	654.774*
Error	14	1.5677	220.071

**, indicates significant at 1% level of probability, *, indicates significant at 5% level of probability

Appendix V. Mean sum square values for days to tassel initiation and emergence of maize

Source of variation	df	Days to tassel initiation	Days to full tassel emergence
Replication	2	0.0073	0.0666
Treatment	7	34.5889*	87.4130*
Error	14	12.2699	33.0445

*, indicates significant at 5 % level of probability

Appendix VI. Mean sum square values for number of leaves plant^{-1} of maize

Source of variation	df	at tassel initiation stage	at full tassel emerged stage
Replication	2	0.00087	0.00187
Treatment	7	2.09327**	8.70144**
Error	14	0.12211	1.09791

**, indicates significant at 1% level of probability

Appendix VII. Mean sum square values for number of cob initiating node plant^{-1} of maize

Source of variation	df	at tassel initiation stage	at full tassel emerged stage
Replication	2	0.00008	0.00038
Treatment	7	0.54758**	3.75504**
Error	14	0.03814	0.77081

**, indicates significant at 1% level of probability

Appendix VIII. Mean sum square values for SPAD value of leaves of maize

Source of variation	df	at tassel initiation stage	at dough stage
Replication	2	0.0061	0.0172
Treatment	7	31.2057**	45.7345*
Error	14	6.8074	14.4998

**, indicates significant at 1% level of probability, *, indicates significant at 5 % level of probability

Appendix IX. Mean sum square values for days to silk initiation, number of cobs plant^{-1} and length of cob of maize

Source of variation	df	Days to silk initiation	Number of cobs plant^{-1}	Length of cob
Replication	2	0.0211	0.00007	0.0073
Treatment	7	54.6562*	0.93771**	17.5404**
Error	14	20.6352	0.04931	2.7637

**, indicates significant at 1% level of probability, *, indicates significant at 5 % level of probability

Appendix X. Mean sum square values for cob length unfilled, bareness percentage and diameter of cob of maize

Source of variation	df	Cob length unfilled	Bareness	Diameter of cob
Replication	2	0.00052	0.005	0.00007
Treatment	7	3.74229**	274.638**	9.68929**
Error	14	0.13382	0.136	0.74191

**, indicates significant at 1% level of probability

Appendix XI. Mean sum square values for number of rows cob^{-1}, number of grains row^{-1} and total number of grains cob^{-1} of maize

Source of variation	df	Number of rows cob^{-1}	Number of grains row^{-1}	Total number of grains cob^{-1}
Replication	2	0.00458	0.00050	3.35
Treatment	7	5.85779**	1.61523^{NS}	6694.20**
Error	14	1.21201	4.35782	1288.86

**, indicates significant at 1% level of probability, NS= Non-significant

Appendix XII. Mean sum square values for 100-grains weight, shelling percentage and grain yield of maize

Source of variation	df	100-grains weight	Shelling percentage	Grain yield
Replication	2	0.0231	0.051	0.0002
Treatment	7	19.8378*	290.013**	30.4289**
Error	14	7.2803	13.153	0.4081

**, indicates significant at 1% level of probability, *, indicates significant at 5% level of probability

Appendix XIII. Mean sum square values for germination percentage and popping recovery percentage of maize

Source of variation	df	Germination percentage	Popping recovery percentage
Replication	2	0.0056	0.039
Treatment	7	84.8382*	203.878**
Error	14	31.3670	2.197

**, indicates significant at 1% level of probability, *, indicates significant at 5% level of probability

Appendix XIV. Mean sum square values for grain grading of maize

Source of variation	df	Large (>8.7 mm)	Medium (7.5-8.7 mm)	Small (<7.5 mm)
Replication	2	0.014	0.037	0.048
Treatment	7	737.786**	154.661**	231.804**
Error	14	9.125	4.25300	3.199

**, indicates significant at 1% level of probability

Appendix XV. Soil data for treatments

Treatments	TOTAL N Before planting *	TOTAL N After harvest	Phosphorous (P) Before planting *	Phosphorous (P) After harvest	Potassium (K) soil Before planting *	Potassium (K) soil After harvest
T_1	0.074	0.074	7.71	20.15	0.15	0.30
T_2	0.074	0.070	7.72	20.69	0.12	0.27
T_3	0.071	0.068	7.70	20.95	0.15	0.27
T_4	0.075	0.071	7.69	21.22	0.14	0.28
T_5	0.073	0.074	7.68	17.35	0.16	0.30
T_6	0.071	0.071	7.71	12.41	0.13	0.41
T_7	0.073	0.067	7.73	5.38	0.12	0.60
T_8	0.072	0.069	7.71	5.14	0.15	0.10

Plate 1. Overview of experimental plot

Plate 2. Side dressing of experimental plots

Plate 3. Shelling of maize cob

Plate 4. Maize cob of T_3 treatment

Plate 5. Maize cob of T_4 treatment

Plate 6. Barred maize cob from T_8 treatment