RESPONSE OF POTATO TO NITROGEN EFFICIENCY BIO-AVAILABILITY (NEB) IN COMBINATION WITH CHEMICAL FERTILIZER

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CERTIFICATE

This is to certify that the thesis titled, " **RESPONSE OF POTATO TO NITROGEN EFFICIENCY BIO-AVAILABILITY (NEB) IN COMBINATION WITH CHEMICAL FERTILIZER** ***”*** *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* ***MST. MOMTAJ SADIA KAMAL, Reg. No. 15-06924*** *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 by the Author.

Dated:
Place: Dhaka, Bangladesh

(Professor Dr. Tuhin Suvra Roy)
Supervisor

Dedicated to

“My Beloved
Parents and well
wishers”

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RESPONSE OF POTATO TO NITROGEN EFFICIENCY BIO-AVAILABILITY (NEB) IN COMBINATION WITH CHEMICAL FERTILIZER

ABSTRACT

Production of quality potato is 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 NEB (Nitrogen Efficiency Bio-availability), an organic root exudates and chemical fertilizer on growth, yield and quality of potato (cv. Diamant). The experiment consisted of seven different doses of NEB *viz*., T_1= 50% recommended urea + 500 mL NEB ha^{-1}; T_2= 50% recommended urea + 750 mL NEB ha^{-1}; T_3= 50% recommended urea + 1000 mL NEB ha^{-1}; T_4= 50% recommended urea and 25% reduction of P, K, S + 500 mL NEB ha^{-1}; T_5= 50% recommended urea and 25% reduction of P, K, S + 750 mL NEB ha^{-1}; T_6= 50% recommended urea and 25% reduction of P, K, S + 1000 mL NEB ha^{-1} and T_7= 100% recommended fertilizer. The experiment was laid out in a randomized complete block design with four replications. Results demonstrated that NEB in combination with chemical fertilizers had significant effect on most of the growth, yield and quality contributing parameters studied in this experiment. Among the seven treatments, the combination of NEB at the rate of 750 mL ha^{-1} and 50% recommended urea along with other fertilizers at conventional rate showed better performance on yield, marketable yield, specific gravity, dry matter percentage and starch content of tuber compared to those of other treatments. On the other hand; TSS (Total Soluble Solid), non-marketable yield, firmness and reducing sugar showed the best performance when the crop was managed by T_7 (100% recommended fertilizers). The maximum yield of tubers was found from T_2 (36.00 t ha^{-1}) *i.e.*, 45.48% increase yield over 100% recommended chemical fertilizer which was statistically similar to T_1 (34.65 t ha^{-1}) and T_3 (33.52 t ha^{-1}) treatments. Although, the T_1 (50% recommended urea + 500 mL NEB ha^{-1}) treatment showed the statistically similar result in case of tuber yield as T_2 but in case of processing parameters T_2 exhibited the best one for specific gravity (1.108), dry matter (23.27 %) and starch content (23.62 mg g^{-1} FW) of tuber at harvest and at 40 days after storage (DAS) whereas, T_7 performed the worst one. From this study, it may be concluded that NEB had significant positive response for the increasing of potato yield and improving the processing quality of potato also when applied at the rate of 50% Urea and 750 ml of NEB per hectare. Finally, NEB may put remarkable contribution for 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 Storage
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

Potato (*Solanum tuberosum* L.) is the fourth most important food crop in consumption in the world after rice, wheat and maize (Hancock *et al*., 2015). Bangladesh is the 7th potato producing country in the world. In Bangladesh, it ranks third after rice in production (FAOSTAT, 2015). The total area under potato crop, national average yield and total production in Bangladesh are 444534.41 hectares, 19.03 t ha-1 and 86,03000 metric tons, respectively (BBS, 2014). The area and production of potato in Bangladesh has been increasing during the last decades but the quality of the harvested potato is very low compared to the other major potato growing countries. The potato farmers used huge amount of chemical fertilizers, as a result, production cost is increasing and at same time quality is decreasing.

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 potato tuber. So, potato 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 potato 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 potato.
2. To determine the optimum rate of NEB along with other fertilizers for maximizing yield and improving the quality of potato.

CHAPTER II

REVIEW OF LITERATURE

Potato contributing a major part as a staple starchy food crops in many developed country mostly also in Bangladesh. Improvement of growth, yield and quality attributes of potato is much more important for growing hungry people around the world through processing and exporting industry. In Bangladesh the yield of quality potato is much lower than other major potato growing developed countries. But, the yield potential of potato 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 potato with organic root exudates are more or less availed in our country but the optimum cultivation systems with root exudates for better quality potato is not well known to us. Some more related research findings regarding production of potato 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 potato, but the identities of stimulatory compounds were unknown. This study showed that potato 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 potato 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 potato rhizosphere on nitrogen-free malate medium and identified based on their 16S *rRNA* gene sequences and also reported that Rhizosphere engineering with beneficial plant growth promoting bacteria offers great promise for sustainable crop yield such as potato. Potato 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 potato. *Azospirillum* sp. TN10 incited the highest increase in potato 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 potato 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 potato. Hence, it is suggested as a good candidate for the production of potato 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.

Szoboszlay *et al*. (2016) conducted an experiment to investigate how root exudate flavonoids influence the soil bacterial community structure and to identify members of the community that change their relative abundance in response to flavonoid exudation. Using a model system that approximates flavonoid exudation of Medicago sativa roots, we treated a soil with 7, 40-dihydroxyflavone and naringenin in two separate experiments using three different rates: medium (equivalent to the exudation rate of 7, 40-dihydroxyflavone from M. sativa seedlings), high (10× the medium rate), and low (0.1× the medium rate). Controls received no flavonoid. Soil samples were subjected to ATP assays and 16S rRNA gene amplicon sequencing. The flavonoid treatments caused no significant change in the soil ATP content. With the high 7, 40-dihydroxyflavone treatment rate, operational taxonomic units (OTUs) classified as Acidobacteria subdivision 4 increased in relative abundance compared with the control samples.

The OTUs classified as Gaiellales, Nocardioidaceae, and Thermomonosporaceae were more prevalent in the control. The naringenin treatments did not cause significant changes in the soil bacterial community structure. Their results suggested that the root exudate flavonoid 7, 40-dihydroxyflavone can interact with a diverse range of soil bacteria and may have other functions in the rhizosphere in addition to nod gene induction in legume-rhizobia symbiosis.

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 tubers and enhance the potato’s 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 potato tubers. Four table potato cultivars were grown in a feld experiment: very early Volumia and medium early Irga, Satina and Sylvana. Starting from stage 39 on the BBCH scale (crop cover complete), potato 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 potatoes untreated with the bioregulators. The growth regulators, especially Bio-Algeen S90 (6.3-16.3%) and Kelpak SL (14.2-24.7%) raised the tuber yield, but the effect was statistically verifable only in the second year, with less precipitation and lower temperature of the vegetation period. The quality of potato tubers was more strongly dependent on the cultivar-specifc traits than on the applied biostimulators. In the second year, too, potato tubers contained on average 34% more N-total than in the frst year. During storage, the content of N-total in tubers increased by 35-50%. After a five-month storage period, potato tubers 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 potato tuber formation as natural root activity enhancers. Due to its broad impact on many plant developmental processes, a role for auxin in tuber initiation has been suggested but never fully resolved. Here, auxin concentrations were measured throughout the plant prior to and during the process of tuber formation. Auxin levels increase dramatically in the stolon prior to tuberization and remain relatively high during subsequent tuber growth, suggesting a promoting role for auxin in tuber formation. Furthermore, *in vitro* tuberization experiments showed higher levels of tuber formation from axillary buds of explants where the auxin source (stolon tip) had been removed. This phenotype could be rescued by application of auxin on the ablated stolon tips. In addition, a synthetic strigolactone analogue applied on the basal part of the stolon resulted in fewer tubers. The experiments indicate that a system for the production and directional transport of auxin exists in stolons and acts synergistically with strigolactones to control the outgrowth of the axillary stolon buds, similar to the control of above-ground shoot branching.

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 potato root diffusate (PRD) collected by soaking individual potato, Solanum tuberosum, root systems in water for 2 hours was used to assess the relationship between root growth and PRD production. Resistant potato 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 potato 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 vegetative growth, yield and quality attributes of potato.

CHAPTER III

METERAIALS 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-5.60 and organic carbon-0.451%. 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).

3.3 Planting material

“Diamont” was used as planting material under present study which was released and developed by Tuber Crops Research Centre (TCRC), Bangladesh Agricultural research Institute, Gazipur due to its more popularity as table potato in Bangladesh. .

3.4 Treatments

The present experiment was comprised of seven different treatment of NEB in combination with urea and PKS fertilizers as follows:

T_1	50% recommended urea + 500 mL NEB ha^{-1}
T_2	50% recommended urea + 750 mL NEB ha^{-1}
T_3	50% recommended urea + 1000 ml NEB ha^{-1}
T_4	50% recommended urea and 25% reduction of P,K,S + 500mL NEB ha^{-1}
T_5	50% recommended urea and 25% reduction of P,K,S + 750 mL NEB ha^{-1}
T_6	50% recommended urea and 25% reduction of P,K,S + 1000 mL NEB ha^{-1}
T_7	100% recommended chemical fertilizer

3.5 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. The total numbers of unit plots were 28. The size of unit plot was 2.5 m × 4.0 m. The spacing 50 cm × 25 cm was used under present study. The final layout of the experimental plots was shown in Appendix-III.

3.6 Preparation of seed

Uniform size (50-60 g) tubers were used for planting and kept in room temperature to facilitate good sprouting. Finally sprouted full potato tubers were used as planting material in a pit.

3.7 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 four times followed by laddering. Weeds and stubbles were removed from the corners of field using spade. The land was finally prepared on 12 November 2015 three days before planting 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.

3.8 Manure and fertilizers

The crop was fertilized as per treatments and recommended dose of fertilizers at the rate of 160-44-132-15-2-5 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 160 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 30 DAP, 45 DAP and 60 DAP. MoP was also added with two split doses at FLP and 45 DAP.

3.9 Planting of seed tuber

The well sprouted healthy and uniform sized potato tubers of “Diamont’ were planted according to desired. Seed potatoes were planted at a depth of 5-6 cm on November 15, 2015.

3.10 Intercultural Operation

3.10.1 Earthing up

Direct sunlight resulted “Solarization of potato tubers” which is very much harmful and decreased the stolon number and finally reduced the tuber. So, earthing up reduce such problems. Earthing up was done at 35 DAP and second was at 50 DAP with a narrow spade for the development of tubers.

3.10.2 Removal of weed

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

3.10.3 Watering and drainage

Three irrigations were provided throughout the growing period in controlled way. The first irrigation was given at 35 DAP. Subsequently, another two irrigations were given at 50 and 65 DAP. Top dressing of fertilizers was followed by irrigation for proper utilization of fertilizers.

3.10.4 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 30 DAP to control the cutworm. Dimecron 100 EC @ 2% and Admire 200 SL @ 0.5% were applied to control aphid and jassid. At moist condition of weather Ridomil Gold MZ @ 1g $litre^{-1}$ was applied before incidence of late blight of potato at an interval of 7 days.

3.11 Haulm cutting

Haulm cutting was done at February 22, 2016, when 60-70% plants showed senescence. After haulm cutting the tubers were kept under the soil for 7 days for skin hardening and tuber bulking. The tuber was harvested, collected, bagged and tagged separately for further data collection on 2 March, 2016.

3.12 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 tuber 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.

3.12.1 Growth traits

i. Days to first emergence (days)

All the plots were keenly observed daily to see the emergence of tuber from soil. The days to first emergence was calculated by deducting the days to observing the first days of emergence from the days of tuber planting.

ii. Days to 100% emergence (days)

All the plots were keenly observed daily to see the emergence of tuber from soil. The days to 100% emergence was calculated by deducting the days to observing the 100% days of emergence from the days of tuber planting.

iii. Plant height (cm)

Ten randomly selected potato hills were considered for taking the plant height. In all time, two stems of potato were considered for taking height. Then the height of stems of potato plant from each ten hills was added and then means were taken in centimeter unit.

iv. Number of leaves hill^{-1}

Ten randomly selected hills of potato were considered for taking the leaf number. Then the total number of leaves of potato plant from each ten hills was added and then means were taken.

v. Number of stems hill^{-1}

Ten randomly selected hills of potato were considered for taking the leaf number. Then the total number of leaves of potato plant from each ten hills was added and then means were taken.

vi. SPAD value of potato leaf at first stolonization 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). Ten randomly 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 hills. Then the mean of 10 hills was taken.

3.12.2 Yield traits

i. Number of tubers hill^{-1}

Ten hills were randomly selected from each plot. The entire tuber was counted from ten hills and then the mean values of tuber per hill were calculated.

ii. Weight of tubers hill^{-1} (g)

Ten hills were randomly selected from each plot. The entire tuber was weighted from ten hills by using an electronic balance and then the mean values of tuber weight per hill were calculated in gram unit.

iii. Average weight of tuber (g)

Ten hills were randomly selected from each plot. The entire tuber was counted and weighted from ten hills by using an electronic balance.

Then to calculate the average tuber weight, the weight of total tuber hill was divided by the numbers of tuber per hill and then means were taken in gram unit.

iv. Yield (t ha^{-1})

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

v. Marketable yield (t ha^{-1})

The tubers, those are >20 g of their weight were considered for marketable tuber and then the entire tuber weighted by using an electronic balance from 1 m^2 harvested area of each plot. Then the means were taken in ton per hectare unit.

vi. Non-marketable yield (t ha^{-1})

The tubers, those are <20 g of their weight were considered for non-marketable tuber and then the entire tuber weighted by using an electronic balance from 1 m^2 harvested area of each plot. Then the means were taken in ton per hectare unit.

vii. Seed yield (t ha^{-1})

The tubers, those are between 28-55 mm of their size were considered for seed tuber and then the entire tuber weighted by using an electronic balance from 1 m^2 harvested area of each plot. Then the means were taken in ton per hectare unit.

viii. Non-seed yield (t ha^{-1})

The tubers, those are not belonged between 28-55 mm of their size were considered for non-seed tuber and then the entire tuber weighted by using an electronic balance from 1 m^2 harvested area of each plot. Then the means were taken in t h^{-1} unit.

3.12.3 Quality traits

i. Specific gravity

Specific gravity was measured by using the following formula (Gould, 1995). Five tubers were taken from each plot of treatment and then the means were taken.

$$\text{Specicifc gravity} = \frac{\text{Weight of tuber (g) in air}}{\text{Weight of tuber (g) in fresh water at 4 degree centigrade}}$$

ii. Dry matter content (%)

The potato tuber samples were kept in separated envelopes for each plot and five potato tubers were taken to calculate the DMC and were oven dried at 70^0C for 72 hours. Dry weight was determined with a digital balance and means were calculated in percent unit.

$$\text{DMC}= \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

iii. Firmness (N)

To take the firmness reading of tuber, a Texture Analyzer, Sun Rheometer Compac 100 (Sun scientific co. Ltd, Japan) was used and the fresh potato tubers were cut into several slices. The reading seems that, how much pressure is taken by the potato tuber slice to make it chips. Each measurement was conducted on 10 potato slices as described by (Vliet *et al*., 2007). Then the means of each treatment were taken in Neuton (N).

iv. Total soluble solid (TSS, ^{o} brix)

TSS of harvested tubers was determined in a drop of potato juice by using Hand Sugar Refractometer "ERMA" Japan, Range: 0-32% according to (AOAC, 1990) and recorded as ^{o}brix from direct reading of the instrument.

v. Starch (mg g^{-1} FW)

Starch content of tubers was determined by Somogyi-Nelson method (Nelson, 1944). Phosphate buffer solution was prepared through diluted 0.74g $NaH_2PO_4 \cdot 2H_2O$ and 0.09g $Na_2HPO_4 \cdot 12H_2O$ into 100 ml Distilled water. Added 0.1 g Enzyme (Amyloglucosidase) and mixed well. Kept at -20C for the preservation. The residue remained after extraction for sugar was washed for several times with water to ensure that there was no more soluble sugar in the residues. After that using tap water and mark up to 250 ml beaker. Stirred well on a magnetic stirrer. Then 0.5 mL solution was taken from the beaker during stirring into 3 test tubes. Boil the test tubes for 10 min at 100 ˚C. Add 1 ml Amyloglucosidase solution, mix well, and heat at 50-60˚C for 2 hours in hot water. After cooling, add 0.5 ml Copper solution, mix well, heat at 100C for 10 min., cool in tap water, add 0.5 ml Nelson solution, mix well, add 7 ml distilled water, mix well (Final volume = 9.5 ml), and measure the absorbance at 660 nm (Abs). Starch content was calculated using the glucose standard curve.

vi. Reducing sugar (mg g^{-1} FW)

For the analysis of sugar content like reducing sugar glucose potato flesh was extracted. For each extraction, 1 g fresh sample of chopped potato was taken from uniform tuber samples and smashed well in a motor. Sugar was extracted using 5 ml of 80% ethanol heat at 80°c for 30 min using a dry block heat bath and the extracts was centrifuged at 5000 rpm for 10 min and decanted the supernatant. 8 mL 80% EtOH, was added and it was repeated 4 and 5 times in total. All the supernatants were mixed well and the final volume was made up to 25 mL using 80% EtOH. The residue is used for sugar analysis. Reducing sugar was estimated by the photometric adaptation of the Somogyi method (Nelson, 1944) with some modification. Copper solution and Nelson reagent and standard glucose solution (0.5 mL) were used. 3 mL sample solution was put into a small glass container.

Then it was completely dried up on an electric heater, 3 mL distilled water was added and then mixed well. Then 0.5 ml solution was taken from that, two times and was put in different test tubes. In one test tube, 0.5 mL Copper solution was added and was boiled (100° C) for 10 min. After boiling, immediately the test tube was cooled in tap water. 0.5 mL Nelson reagent in the test tube was added, and mixed them well. After 20 min, 8 mL distilled water was added and mixed well (Total volume = 9.5 mL). After that the absorbance at 660 nm (Abs1) was measured and the reducing sugar content was calculated.

3.13 Tuber yield merit (%)

The tuber yield merit means, how much yield was increased for the using of advanced strategies (Treatment of NEB) over the conventional thinking (Control) for the crop production. The tuber yield merit was calculated by as follow as:

Tuber yield merit (%) = (Yield obtained from NEB added treatment–yield obtained from control treatment) × 100/ yield obtained from control treatment

3.14 Correlation coefficient (r)

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

3.15 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 present 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 potato. 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-Xs). The all possible reveals and interpretations were given under the following headings:

4.1 Days to first emergence

In respects of days to first tuber emergence of potato plant a remarkable variation ($p \leq 0.01$) was noted (Table-1 and Appendix IV) against different doses of NEB and chemical fertilizers. There was an increasing trend of days to first tuber emergence found with the decreasing of N accumulation in soil by the treatment. The longest (14.49 days) period was required for the plant produced from T_7 followed by T_6 (12.44 days) and the shortest (7.43 days) was required for the plant produced from T_2. Results are supported by Masome (2014). He explained that, number of days to seed emergence of tomato influenced significantly by urea nitrogen fertilizer with increasing doses. The result of present study showed that, more absorption of nitrogen was exhibited by the treatment of combination of NEB and urea fertilizer resulting a better reduction of days required for first emergence of tuber from field.

4.2 Days to 100% emergence

In respects of days to 100% tuber emergence of potato plant a remarkable variation ($p \leq 0.01$) was noted (Table-1 and Appendix IV) against different doses of NEB and chemical fertilizers.

There was an increasing trend of days to 100% tuber emergence found with the decreasing of N accumulation in soil by the treatment. The longest (16.79 days) period was required for the plant produced from T_7 followed by T_6 (14.19 days) and the shortest (10.29 days) was required for the plant produced from T_2. Results are supported by Masome (2014). He reported that, number of days to final emergence of tomato influenced significantly by urea nitrogen fertilizer with increasing doses.

Table 1. Response of NEB and chemical fertilizers on days to first emergence and days to 100% emergence of potato

Treatment	Days to first emergence	Days to 100% emergence
T_1	8.49 ef	11.49 cd
T_2	7.43 f	10.29 d
T_3	9.09 de	11.59 cd
T_4	10.29 cd	12.39 c
T_5	10.69 c	12.89 bc
T_6	12.44 b	14.19 b
T_7	14.49 a	16.79 a
CV (%)	7.84	7.39
LSD (0.05)	1.454	1.683
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 + 500 ml NEB ha^{-1}, T_2= 50% recommended urea+ 750 ml NEB ha^{-1}, T_3= 50% recommended urea + 1000 ml NEB ha^{-1}, T_4= 50% recommended urea and 25% reduction of P, K, S + 500 ml NEB ha^{-1}, T_5= 50% recommended urea and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% recommended urea and 25% reduction of P,K,S + 1000 ml NEB ha^{-1} and T_7= 100% recommended fertilizer

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 100% emergence of tuber from field.

4.3 Plant height (cm)

In aspects of height of potato plant a remarkable variation ($p \leq 0.01$) was noted (Table-2 and Appendix V) against different doses of NEB and chemical fertilizers. The height of potato mother plant increased with the increasing of partitioning of more N in soil. Results revealed that, the tallest plant was found from T_2 (66.14 cm) which was statistically similar to T_3 (62.11 cm) and T_1 (58.0 cm) whereas the smallest plant from T_7 (52.11 cm). The finding also supported by Marschner (1995). He reported that, application of high rates of N to potatoes, depending on the variety, generally delays tuber initiation and promotes vegetative growth resulted from higher accumulation of nitrogen in plant cell.

4.4 Number of leaves hill^{-1}

Number of leaves hill^{-1} of potato plant was found remarkably varied ($p \leq 0.01$) (Table-2 and Appendix V) against different doses of NEB and chemical fertilizers. The number of leaves in potato mother plant increased with the increasing of partitioning of more N in soil. Results demonstrated that, the maximum number of leaves was found from T_2 (24.64) which was statistically similar to T_1 (23.00) and T_3 (22.60) whereas the minimum number of leaves was found from T_7 (16.97). The finding also supported by Marschner (1995). He explained that, application of high rates of N to potatoes, depending on the variety, generally delays tuber initiation and promotes vegetative growth resulted from higher accumulation of nitrogen in plant cell.

4.5 Number of stems hill^{-1}

Remarkable variation ($p \leq 0.01$) was noted among different doses of NEB and chemical fertilizers regarding number of stems hill^{-1} (Table-2 and Appendix V). The maximum (5.22) number of stems were exhibited from T_2 which was statistically similar to T_1 (5.00) and the minimum (2.85) was found from T_7.

Table 2. Response of NEB and chemical fertilizers on plant height, number of leaves and number of stems at first stolonization period of potato

Treatment	Plant height (cm)	Number of leaves hill^{-1}	Number of stems hill^{-1}
T_1	58.00 a-c	23.00 a	5.00 ab
T_2	66.14 a	24.64 a	5.22 a
T_3	62.11 ab	22.60 ab	4.55 bc
T_4	57.00 bc	21.20 a-c	4.08 c
T_5	55.10 bc	19.10 b-d	3.22 d
T_6	54.99 bc	18.08 cd	3.00 d
T_7	52.11 c	16.97 d	2.85 d
CV (%)	8.33	9.52	8.75
LSD (0.05)	8.587	3.525	0.622
Significance level	*	**	**

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

*,** indicate significant at 5% and 1% level of probability, respectively

T_1= 50% recommended urea + 500 ml NEB ha^{-1}, T_2= 50% recommended urea+ 750 ml NEB ha^{-1}, T_3= 50% recommended urea + 1000 ml NEB ha^{-1}, T_4= 50% recommended urea and 25% reduction of P, K, S + 500 ml NEB ha^{-1}, T_5= 50% recommended urea and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% recommended urea and 25% reduction of P,K,S + 1000 ml NEB ha^{-1} and T_7= 100% recommended fertilizer

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 tuber initiation and promotes vegetative growth.

4.6 SPAD value

Significant variation ($p \leq 0.01$) was noted on SPAD value of potato leaf at stolonization stage (Figure-1and Appendix V) against different doses of NEB and chemical fertilizers. There was an increasing trend of leaf SPAD with the increasing of accumulation of leaf nitrogen. The highest SPAD value was found from T_2 (48.20) which was statistically similar to T_1 (46.00) and T_3 (45.29) treatments whereas the lowest from T_7 (38.50) treatment at stolonization stage.

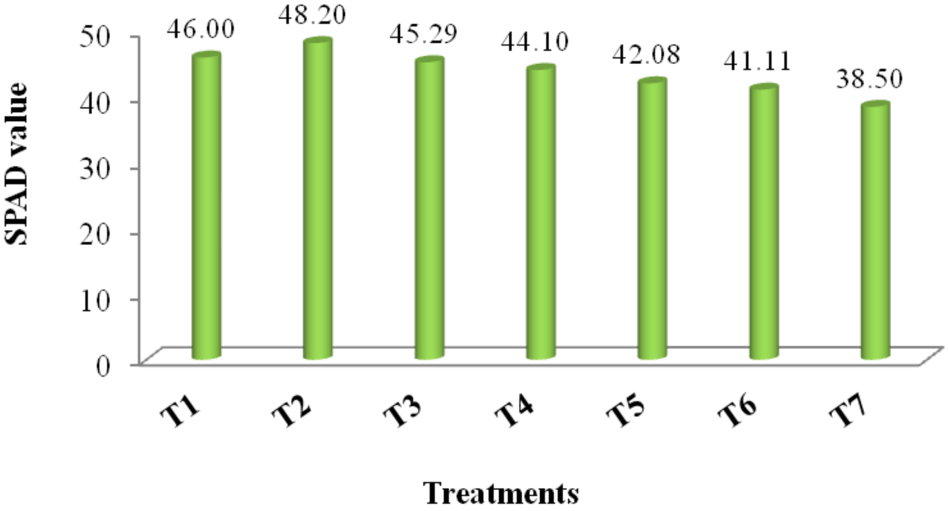

Figure 1. Response of NEB and chemical fertilizers on SPAD value of potato leaf at first stolonization stage [LSD $_{(0.05)}$ = 4.740]

T_1= 50% recommended urea + 500 ml NEB ha^{-1}, T_2= 50% recommended urea+ 750 ml NEB ha^{-1}, T_3= 50% recommended urea + 1000 ml NEB ha^{-1}, T_4= 50% recommended urea and 25% reduction of P, K, S + 500 ml NEB ha^{-1}, T_5= 50% recommended urea and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6=50% recommended urea and 25% reduction of P,K,S + 1000 ml NEB ha^{-1} and T_7= 100% fertilizer

Chlorophyll content is approximately proportional to leaf nitrogen content and at the advent of stolonization of potato tuber, 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 potato plant.

4.7 Number of tubers hill^{-1}

Number of tubers hill^{-1} of potato plant was found remarkably varied ($p \leq 0.01$) (Table-3 and Appendix VI) against different doses of NEB and chemical fertilizers. Results demonstrated that, the maximum number of tubers was found from T_7 (11.22) treatment which was statistically similar to T_6 (10.6) whereas the minimum number of tubers was found from T_2 (7.00) treatment. Results demonstrated that, in the treatment of higher nitrogen accumulation the number of tuber per hill was lower instead of lower nitrogen accumulation by 100% chemical fertilizers.

4.8 Weight of tubers hill^{-1}

Weight of tubers hill^{-1} of potato plant was found remarkably varied ($p \leq 0.01$) (Table-3 and Appendix VI) against different doses of NEB and chemical fertilizers. Results demonstrated that, the highest weight of tubers was found from T_2 (450.01 g) which was statistically similar to T_1 (433.21 g) and T_3 (419.02 g) treatment whereas the lowest weight of tubers was found from T_7 (309.32 g) treatment. More absorption of soil nitrogen by plant may be the main reason for higher weight of tuber per hill.

4.9 Average weight of tuber (g)

Average weight of tubers hill^{-1} of potato plant was found remarkably varied ($p \leq 0.01$) (Table-3 and Appendix VI) against different doses of NEB and chemical fertilizers. Results demonstrated that, the highest average weight of tubers was found from T_2 (64.29 g) whereas the lowest average weight of tubers was found from T_7 (27.58 g).

Table 3. Response of NEB and chemical fertilizers on number and weight of tuber hill^{-1} and average weight of potato tuber

Treatment	Number of tubers hill^{-1}	Weight of tuber hill^{-1} (g)	Average weight of tuber (g)
T_1	7.65 cd	433.21 ab	56.64 b
T_2	7.00 d	450.01 a	64.29 a
T_3	8.10 cd	419.02 ab	51.74 c
T_4	9.10 bc	401.12 a-c	44.09 d
T_5	9.65 b	392.11 bc	40.65 e
T_6	10.6 ab	365.11 c	34.39 f
T_7	11.22 a	309.32 d	27.58 g
CV (%)	9.54	7.43	2.15
LSD (0.05)	1.536	52.317	1.746
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 + 500 ml NEB ha^{-1}, T_2= 50% recommended urea+ 750 ml NEB ha^{-1}, T_3= 50% recommended urea + 1000 ml NEB ha^{-1}, T_4= 50% recommended urea and 25% reduction of P, K, S + 500 ml NEB ha^{-1}, T_5= 50% recommended urea and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6=50% recommended urea and 25% reduction of P,K,S + 1000 ml NEB ha^{-1} and T_7= 100% recommended fertilizer

4.10 Yield (t ha^{-1})

Yield of potato (t ha^{-1}) was found remarkably varied ($p \leq 0.01$) (Table-4 and Appendix VI) against different doses of NEB and chemical fertilizers. Results demonstrated that, the highest yield of tubers was found from T_2 (36.00 t ha^{-1}) which was statistically similar to T_1 (34.65 t ha^{-1}), T_3 (33.52 t ha^{-1}) and T_4 (32.08 t ha^{-1}) treatment whereas the lowest yield of tubers was found from T_7 (24.74 t ha^{-1}) treatment. The higher weight of tuber per hill and higher average weight of tuber might be the main reason for higher tuber yield per hectare.

4.11 Marketable yield (t ha^{-1})

Marketable yield of potato (t ha^{-1}) was found remarkably varied ($p \leq 0.01$) (Table-4 and Appendix VII) against different doses of NEB and chemical fertilizers. Results demonstrated that, the highest marketable yield of tubers was found from T_2 (32.32 t ha^{-1}) treatment which was statistically similar to T_1 (29.85 t ha^{-1}) whereas the lowest marketable yield of tubers was found from T_7 (14.48 t ha^{-1}) treatment. The higher weight of tuber hill^{-1} and higher average weight of tuber may be the main reason for higher tuber marketable yield ton per hectare.

4.12 Non-marketable yield (t ha^{-1})

Non-marketable yield of potato (t ha^{-1}) was found remarkably varied ($p \leq 0.01$) (Table-4 and Appendix VII) against different doses of NEB and chemical fertilizers. Results demonstrated that, the highest non-marketable yield of tubers was found from T_7 (10.26 t ha^{-1}) treatment whereas the lowest non-marketable yield of tubers was found from T_2 (3.68 t ha^{-1}) treatment.

Table 4. Response of NEB and chemical fertilizers on yield grading of potato

Treatment	Yield (t ha^{-1})	Marketable yield (t ha^{-1})	Non-marketable yield (t ha^{-1})
T_1	34.65 ab	29.85 ab	4.80 d
T_2	36.00 a	32.32 a	3.68 e
T_3	33.52 ab	26.52 bc	7.00 c
T_4	32.08 a-c	23.61 cd	8.48 b
T_5	31.36 bc	22.61 d	8.75 b
T_6	29.20 c	20.13 d	9.08 b
T_7	24.74 d	14.48 e	10.26 a
CV (%)	7.43	8.54	6.26
LSD (0.05)	4.185	3.679	0.829
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 + 500 ml NEB ha^{-1}, T_2= 50% recommended urea+750 ml NEB ha^{-1}, T_3= 50% recommended urea + 1000 ml NEB ha^{-1}, T_4= 50% recommended urea and 25% reduction of P, K, S + 500 ml NEB ha^{-1}, T_5= 50% recommended urea and 25% reduction of P, K, S+750 ml NEB ha^{-1}, T_6= 50% recommended urea and 25% reduction of P,K,S + 1000 ml NEB ha^{-1} and T_7= 100% recommended fertilizer

4.13 Seed yield (t ha^{-1})

Seed yield of potato (t ha^{-1}) was found significantly varied ($p \leq 0.01$) (Figure-2 and Appendix VII) against different doses of NEB and chemical fertilizers. Results revealed that, the highest seed yield of tubers was found from T_2 (24.82 t ha^{-1}) which was statistically similar to T_1 (21.08 t ha^{-1}) and T_3 (18.97 t ha^{-1}) treatment whereas the lowest seed yield of tubers was found from T_7 (9.20 t ha^{-1}) treatment.

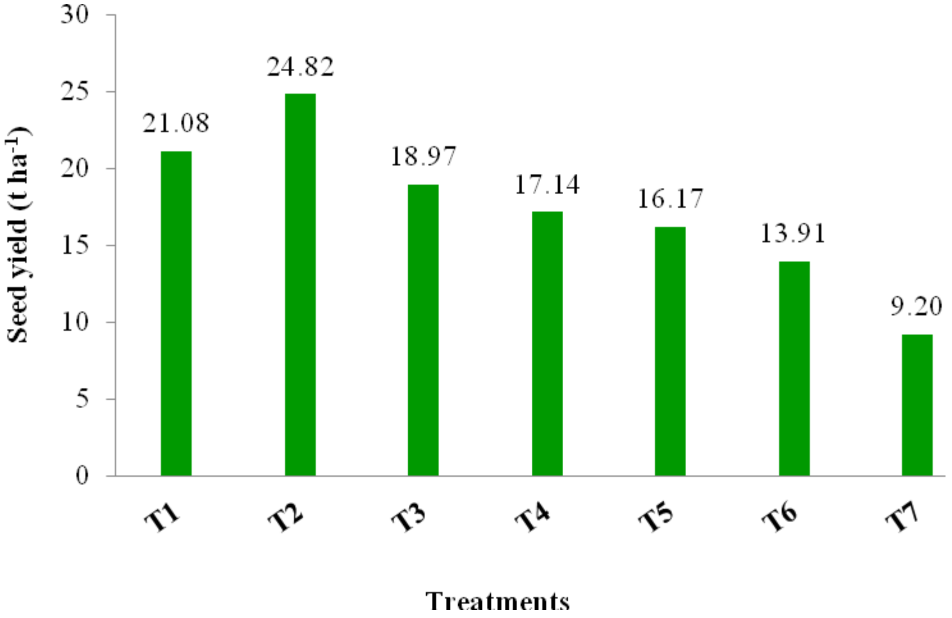

Figure 2. Response of NEB and chemical fertilizers on seed yield of potato (t ha^{-1}) [LSD $_{(0.05)}$ = 2.441]

T_1= 50% recommended urea + 500 ml NEB ha^{-1}, T_2= 50% recommended urea+ 750 ml NEB ha^{-1}, T_3= 50% recommended urea + 1000 ml NEB ha^{-1}, T_4= 50% recommended urea and 25% reduction of P, K, S + 500 ml NEB ha^{-1}, T_5= 50% recommended urea and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6=50% recommended urea and 25% reduction of P,K,S + 1000 ml NEB ha^{-1} and T_7= 100% fertilizer

4.14 Non-seed yield (t ha^{-1})

Non-seed yield of potato (t ha^{-1}) was not-found remarkably varied (p=NS) against different doses of NEB and chemical fertilizers (Figure-3 and Appendix VII). But, numerically the highest non-seed yield of tubers was found from T_7 (15.53 t ha^{-1}) which was closely followed by T_6 (15.29 t ha^{-1}) and T_5 (15.19 t ha^{-1}) treatment whereas the lowest non-seed yield of tubers was found from T_1 (13.50 t ha^{-1}) which was closely similar to T_2 (14.50 t ha^{-1}) treatment.

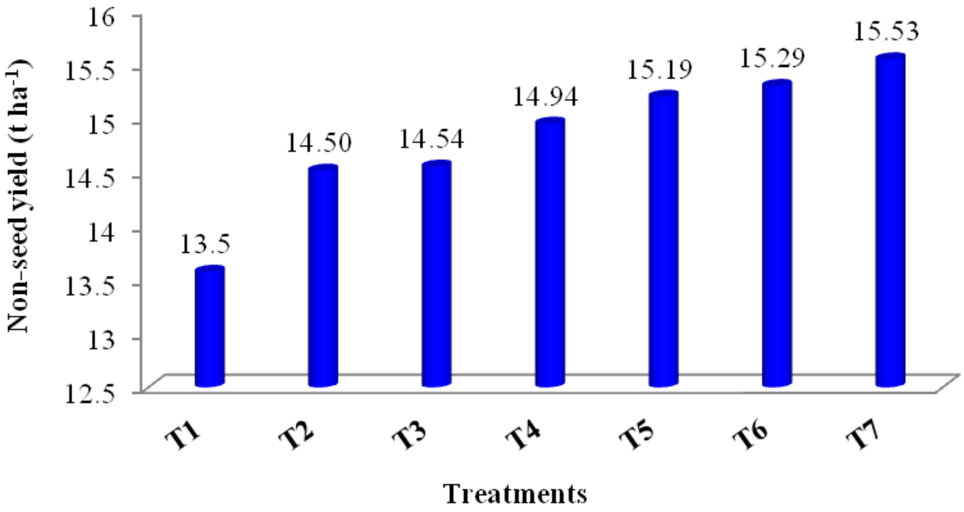

Figure 3. Response of NEB and chemical fertilizers on non-seed yield of potato (t ha^{-1}) [LSD $_{(0.05)}$ = NS]

T_1= 50% recommended urea + 500 ml NEB ha^{-1}, T_2= 50% recommended urea+ 750 ml NEB ha^{-1}, T_3= 50% recommended urea + 1000 ml NEB ha^{-1}, T_4= 50% recommended urea and 25% reduction of P, K, S + 500 ml NEB ha^{-1}, T_5= 50% recommended urea and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% recommended urea and 25% reduction of P,K,S + 1000 ml NEB ha^{-1} and T_7= 100% fertilizer

4.15 Specific gravity at harvest

Specific gravity of potato tuber at harvest was found remarkably varied ($p \leq 0.01$) against different doses of NEB and chemical fertilizers (Table-5 and Appendix VIII). Result demonstrated that, the highest specific gravity of tubers was found from T_2 (1.108) which was statistically similar to T_3 (1.091), T_5 (1.080) and T_6 (1.068) treatment whereas the lowest specific gravity of tubers was found from T_7 (0.879) treatment.

4.16 Specific gravity at 40 DAS

Specific gravity of potato tuber at 40 DAS was found remarkably varied ($p \leq 0.01$) against different doses of NEB and chemical fertilizers (Table-5 and Appendix VIII). Result demonstrated that, the highest specific gravity of tubers was found from T_2 (1.058) which was statistically similar to T_3 (1.041), T_5 (1.030) and T_6

(1.018) treatment whereas the lowest specific gravity of tubers was found from T_7 (0.877) treatment. With the increasing of storing period and also with the increasing of losses of tuber weight may be the main reason for lower specific gravity at 40 DAS than that of at harvest, due; at harvest the weight of tuber was higher with its fleshy slices.

Table 5. Response of NEB and chemical fertilizers on specific gravity of potato

Treatment	Specific gravity at harvest	Specific gravity at 40 DAS
T_1	1.049 bc	0.999 ab
T_2	1.108 a	1.058 a
T_3	1.091 ab	1.041 ab
T_4	1.026 c	0.976 b
T_5	1.080 a-c	1.030 ab
T_6	1.068 a-c	1.018 ab
T_7	0.879 d	0.877 c
CV (%)	3.17	4.60
LSD (0.05)	0.058	0.081
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 + 500 ml NEB ha^{-1}, T_2= 50% recommended urea +750 ml NEB ha^{-1}, T_3= 50% recommended urea + 1000 ml NEB ha^{-1}, T_4= 50% recommended urea and 25% reduction of P, K, S + 500 ml NEB ha^{-1}, T_5= 50% recommended urea and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% recommended urea and 25% reduction of P,K,S + 1000 ml NEB ha^{-1} and T_7= 100% recommended fertilizer

4.17 Dry matter (%) at harvest

Dry matter content of potato tuber at harvest was found remarkably varied ($p \leq 0.01$) against different doses of NEB and chemical fertilizers (Table-6 and Appendix VIII). Result demonstrated that, the highest dry matter content of tubers was found from T_2 (23.27 %) followed by T_1 (21.20 %) treatment whereas the lowest dry matter content of tubers was found from T_7 (16.55 %) treatment.

4.18 Dry matter (%) at 40 DAS

Dry matter content of potato tuber at 40 DAS was found remarkably varied ($p \leq 0.01$) against different doses of NEB and chemical fertilizers (Table-6 and Appendix VIII). Result demonstrated that, the highest dry matter content of tubers was found from T_2 (20.94 %) which was statistically similar to T_1 (19.68 %) and T_3 (18.55 %) treatment whereas the lowest dry matter content of tubers was found from T_7 (13.22 %) treatment. With the increasing of storing period and also with the increasing of losses of tuber weight may be the main reason for lower dry matter content at 40 DAS than that of at harvest, due; at harvest the weight of tuber was higher with its fleshy slices. The stored food materials are also used by the dormant embryo to sprout resulting the lower dry matter content at 40 DAS.

Table 6. Response of NEB and chemical fertilizers on dry matter content of potato

Treatment	Dry matter (%) at harvest	Dry matter (%) at 40 DAS
T_1	21.20 b	19.68 ab
T_2	23.27 a	20.94 a
T_3	20.08 b	18.55 ab
T_4	18.00 c	16.95 bc
T_5	17.84 c	15.11 cd
T_6	17.50 c	14.78 cd
T_7	16.55 c	13.22 d
CV (%)	5.99	9.57
LSD (0.05)	2.047	2.900
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 + 500 ml NEB ha^{-1}, T_2= 50% recommended urea+ 750 ml NEB ha^{-1}, T_3= 50% recommended urea + 1000 ml NEB ha^{-1}, T_4= 50% recommended urea and 25% reduction of P, K, S + 500 ml NEB ha^{-1}, T_5= 50% recommended urea and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% recommended urea and 25% reduction of P,K,S + 1000 ml NEB ha^{-1} and T_7= 100% recommended fertilizer

4.19 Firmness (N) at harvest

Firmness of potato tuber at harvest was found remarkably varied ($p \leq 0.01$) against different doses of NEB and chemical fertilizers (Table-7 and Appendix IX). Result demonstrated that, the highest firmness of tubers was exhibited from T_7 (43.07 N) which was statistically similar to T_6 (40.11 N), T_5 (39.18 N) and T_4 (38.51 N) treatment whereas the lowest firmness of tubers was exhibited from T_2 (32.22 N) treatment.

4.20 Firmness (N) at 40 DAS

Firmness of potato tuber at 40 DAS was found remarkably varied ($p \leq 0.01$) against different doses of NEB and chemical fertilizers (Table-7 and Appendix IX). Result demonstrated that, the highest firmness of tubers was exhibited from T_7 (40.34 N) whereas the lowest firmness of tubers was exhibited from T_2 (25.25 N). Joshi *et al*. (2015) reported that, firmer the tuber resulted from lowers the uptake of nitrogen from the soil.

Table 7. Response of NEB and chemical fertilizers on firmness of potato

Treatment	Firmness (N) at harvest	Firmness (N) at 40 DAS
T_1	34.41 cd	27.23 de
T_2	32.22 d	25.25 e
T_3	37.08 b-d	30.10 cd
T_4	38.51 a-c	32.12 bc
T_5	39.18 a-c	34.00 bc
T_6	40.11 ab	35.84 b
T_7	43.07 a	40.34 a
CV (%)	8.29	6.89
LSD (0.05)	5.573	3.937
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 + 500 ml NEB ha^{-1}, T_2= 50% recommended urea + 750 ml NEB ha^{-1}, T_3= 50% recommended urea + 1000 ml NEB ha^{-1}, T_4= 50% recommended urea and 25% reduction of P, K, S + 500 ml NEB ha^{-1}, T_5= 50% recommended urea and 25% reduction of P, K, S+750 ml NEB ha^{-1}, T_6= 50% recommended urea and 25% reduction of P,K,S + 1000 ml NEB ha^{-1} and T_7= 100% recommended fertilizer

With the increasing of storing period and also with the increasing of shrinkages of tuber may be the main reason for lower firmness at 40 DAS than that of at harvest, due; at harvest the weight of tuber was higher with its fleshy slices. The internal water is also used by the dormant embryo to sprout resulting the more shrinkages of tuber at 40 DAS.

4.21 TSS (° brix) at harvest

Total Soluble Solid (TSS) of potato tuber at harvest was found remarkably varied ($p \leq 0.01$) against different doses of NEB and chemical fertilizers (Table-8 and Appendix IX). Result demonstrated that, the highest total soluble solid of tubers was exhibited from T_7 (7.09 ° brix) which was statistically similar to T_6 (6.59 ° brix) treatment whereas the lowest total soluble solid of tubers was exhibited from T_2 (5.09 ° brix) treatment.

4.22 TSS (° brix) at 40 DAS

Total Soluble Solid (TSS) of potato tuber at 40 DAS was found remarkably varied ($p \leq 0.05$) against different doses of NEB and chemical fertilizers (Table-8 and Appendix IX). Result demonstrated that, the highest total soluble solid of tubers was exhibited from T_7 (7.49 ° brix) which was statistically similar to T_6 (7.39 ° brix), T_5 (7.09 ° brix) and T_4 (6.89 ° brix) treatment whereas the lowest total soluble solid of tubers was exhibited from T_2 (5.69 ° brix) treatment. Joshi *et al.* (2015) reported that, more nitrogen uptake by the tuber lowering the rate of TSS in tuber. With the increasing of storing period and also with the decreasing of water of tuber may be the main reason for lower total soluble solid at 40 DAS than that of at harvest, due; at harvest the weight of tuber was higher with its fleshy slices. The internal water is also used by the dormant embryo to sprout resulting the more shrinkages of tuber at 40 DAS. As a result, only the solid tuber was stayed at storage.

Table 8. Response of NEB and chemical fertilizers on TSS (Total Soluble Solid) of potato

Treatment	TSS at harvest (°brix)	TSS at 40 DAS (°brix)
T_1	5.49 de	6.29 bc
T_2	5.09 e	5.69 c
T_3	5.69 c-e	6.49 a-c
T_4	6.09 b-d	6.89 ab
T_5	6.29 bc	7.09 ab
T_6	6.59 ab	7.39 ab
T_7	7.09 a	7.49 a
CV (%)	6.11	9.49
LSD (0.05)	0.657	1.142
Significance level	**	*

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

*,** indicate significant at 5% and 1% level of probability, respectively

T_1= 50% recommended urea + 500 ml NEB ha^{-1}, T_2= 50% recommended urea + 750 ml NEB ha^{-1}, T_3= 50% recommended urea + 1000 ml NEB ha^{-1}, T_4= 50% recommended urea and 25% reduction of P, K, S + 500 ml NEB ha^{-1}, T_5= 50% recommended urea and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6=50% recommended urea and 25% reduction of P,K,S + 1000 ml NEB ha^{-1} and T_7= 100% recommended fertilizer

4.23 Starch (mg g^{-1} FW) at harvest

Starch content of potato tuber at harvest was found remarkably varied ($p \leq 0.01$) against different doses of NEB and chemical fertilizers (Table-9 and Appendix X). Result demonstrated that, the highest starch content of tubers was determined from T_2 (23.62 mg g^{-1} FW) which was statistically similar to T_1 (22.11 mg g^{-1} FW) treatment whereas the lowest starch content of tubers was determined from T_7 (14.00 mg g^{-1} FW) treatment.

4.24 Starch (mg g^{-1} FW) at 40 DAS

Starch content of potato tuber at 40 DAS was found remarkably varied ($p \leq 0.01$) against different doses of NEB and chemical fertilizers (Table-9 and Appendix X). Result demonstrated that, the highest starch content of tubers was determined from T_2 (18.11 mg g^{-1} FW) which was statistically similar to T_1 (17.94 mg g^{-1} FW) treatment whereas the lowest starch content of tubers was determined from T_7 (12.10 mg g^{-1} FW) treatment. With the increasing of period of storing, the stored food materials were started to breakdown to sprout in a new plant due to that of inter respiration of tuber. So, the starch content of potato was decreased upon storing.

Table 9. Response of NEB and chemical fertilizers on starch content of potato tuber

Treatment	Starch at harvest ($mg\ g^{-1}$ FW)	Starch at 40 DAS ($mg\ g^{-1}$ FW)
T_1	22.11 ab	17.94 ab
T_2	23.62 a	18.11 a
T_3	20.10 bc	16.00 bc
T_4	17.55 cd	14.24 cd
T_5	17.10 c-e	13.50 de
T_6	16.00 de	14.94 cd
T_7	14.00 e	12.10 e
CV (%)	9.93	7.72
LSD (0.05)	3.293	2.095
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 + 500 ml NEB ha^{-1}, T_2= 50% recommended urea+750 ml NEB ha^{-1}, T_3= 50% recommended urea + 1000 ml NEB ha^{-1}, T_4= 50% recommended urea and 25% reduction of P, K, S + 500 ml NEB ha^{-1}, T_5= 50% recommended urea and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% recommended urea and 25% reduction of P,K,S + 1000 ml NEB ha^{-1} and T_7= 100% recommended fertilizer

4.25 Reducing sugar ($mg\ g^{-1}$ FW) at harvest

Reducing sugar content of potato tuber at harvest was found remarkably varied ($p \leq 0.01$) against different doses of NEB and chemical fertilizers (Table-10 and Appendix X).

Result demonstrated that, the highest reducing sugar content of tubers was determined from T_7 (0.471 mg g^{-1} FW) which was statistically similar to T_6 (0.440 mg g^{-1} FW) and T_5 (0.420 mg g^{-1} FW) treatment whereas the lowest reducing sugar content of tubers was determined from T_2 (0.331 mg g^{-1} FW) treatment.

4.26 Reducing sugar (mg g^{-1} FW) at 40 DAS

Reducing sugar content of potato tuber at 40 DAS was found remarkably varied ($p \leq 0.01$) against different doses of NEB and chemical fertilizers (Table-10 and Appendix X). Result demonstrated that, the highest reducing sugar content of tubers was exhibited from T_7 (0.995 mg g^{-1} FW) which was statistically similar to T_6 (0.968 mg g^{-1} FW) and T_5 (0.908 mg g^{-1} FW) treatment whereas the lowest reducing sugar content of tubers was exhibited from T_2 (0.748 mg g^{-1} FW) treatment. With the increasing of period of storing, the stored food materials were started to breakdown to sprout in a new plant due to that of inter respiration of tuber. So, the starch content of potato was decreased upon storing and the starch was breakdown to produce more reducing sugar as glucose resulting the more sweetening of potato tuber after one month of storage.

Table 10. Response of NEB and chemical fertilizers on reducing sugar content of potato tuber

Treatment	Reducing sugar at harvest (mg g^{-1} FW)	Reducing sugar at 40 DAS (mg g^{-1} FW)
T_1	0.360 cd	0.767 c
T_2	0.331 d	0.748 c
T_3	0.394 bc	0.794 bc
T_4	0.411 bc	0.827 bc
T_5	0.420 ab	0.908 ab
T_6	0.440 ab	0.968 a
T_7	0.471 a	0.995 a
CV (%)	7.11	7.52
LSD (0.05)	0.051	0.114
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 + 500 ml NEB ha^{-1}, T_2= 50% recommended urea+750 ml NEB ha^{-1}, T_3= 50% recommended urea + 1000 ml NEB ha^{-1}, T_4= 50% recommended urea and 25% reduction of P, K, S + 500 ml NEB ha^{-1}, T_5= 50% recommended urea and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6=50% recommended urea and 25% reduction of P,K,S + 1000 ml NEB ha^{-1} and T_7= 100% recommended fertilizer

4.27 Tuber yield merit (%)

There was an increasing trend found among the treatment in case of tuber yield improvement under present study (Table-11). The treatment, T_2 *i.e.*, the application of 50% Urea and 750 ml of NEB along with other recommended fertilizers exhibited the significantly best performance on the increasing of tuber yield (45.48 %) over 100% recommended chemical fertilizers.

Table 11. Tuber yield merit (%) over 100% chemical fertilizers

Treatment	**Tuber yield merit (%)**
T_1	40.05
T_2	**45.48**
T_3	35.46
T_4	29.67
T_5	26.76
T_6	18.04
T_7	--------

T_1= 50% recommended urea + 500 ml NEB ha^{-1}, T_2= 50% recommended urea +750 ml NEB ha^{-1}, T_3= 50% recommended urea + 1000 ml NEB ha^{-1}, T_4= 50% recommended urea and 25% reduction of P, K, S + 500 ml NEB ha^{-1}, T_5= 50% recommended urea and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6=50% recommended urea and 25% reduction of P,K,S + 1000 ml NEB ha^{-1} and T_7= 100% recommended fertilizer

4.28 Correlation coefficient (r)

The application of NEB and chemical fertilizers in comparison with control has significantly influenced the different traits of potato tuber and so, the correlation co-efficient (r) was calculated among some yield and quality traits. A negative linear relation ($r=-0.99$) was exhibited between number of tuber hill^{-1} and average tuber weight potato (Figure-4). A negative linear relation ($r=-0.95$) was also exhibited between number of tuber hill^{-1} and tuber yield (t ha^{-1}) of potato (Figure-5). In figure-6, a linear relation ($r=1$) was found between weight of tuber hill^{-1} and tuber yield (t ha^{-1}) of potato. In figure-7, there was present a strong relation ($r=0.88$) between dry matter content at harvest and tuber yield (t ha^{-1}) of potato. A negative linear relation ($r=-0.97$) was present between total soluble solid at harvest and tuber yield (t ha^{-1}) of potato (Figure-8).

About 88 to 100% of tuber yield of potato was dependent on different yield contributing traits and all of these characters had significant contribution on tuber yield and yield could be increased by improving these yield attributes.

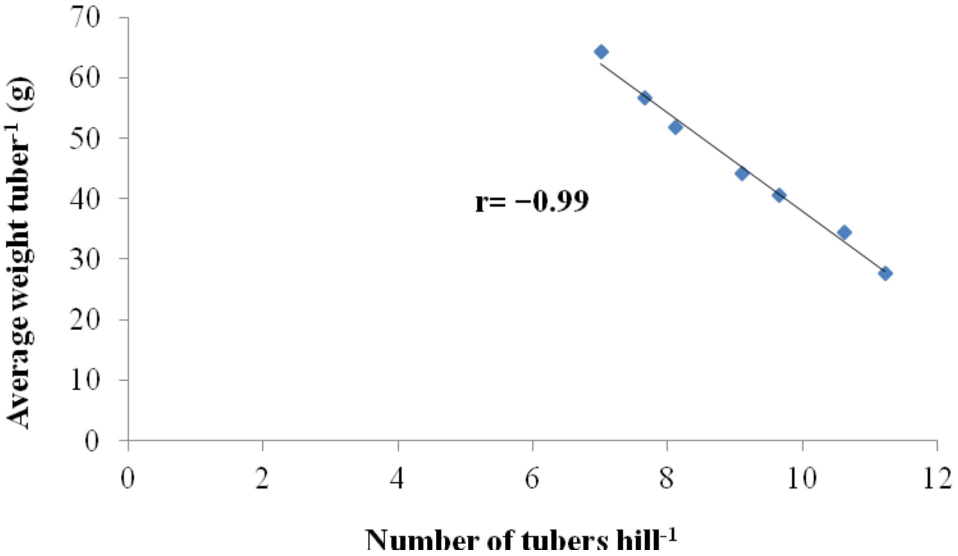

Figure 4. Relationship between number of tubers hill^{-1} and average weight tuber^{-1} of potato

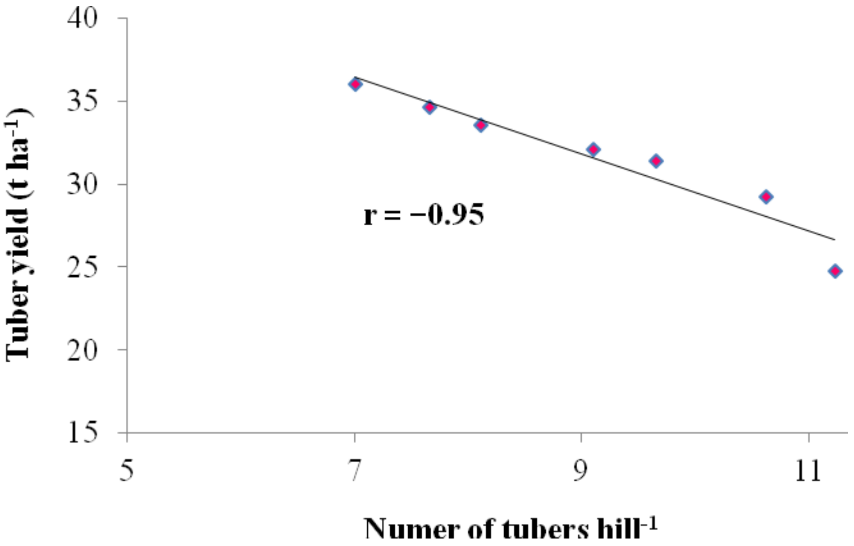

Figure 5. Relationship between number of tubers hill^{-1} and tuber yield (t ha^{-1}) of potato

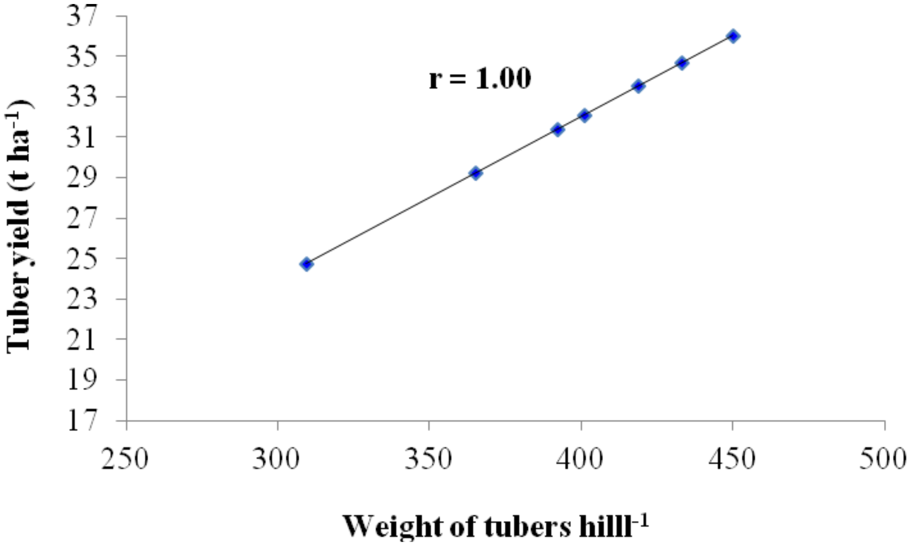

Figure 6. Relationship between weight of tubers hill^{-1} and tuber yield (t ha^{-1}) of potato

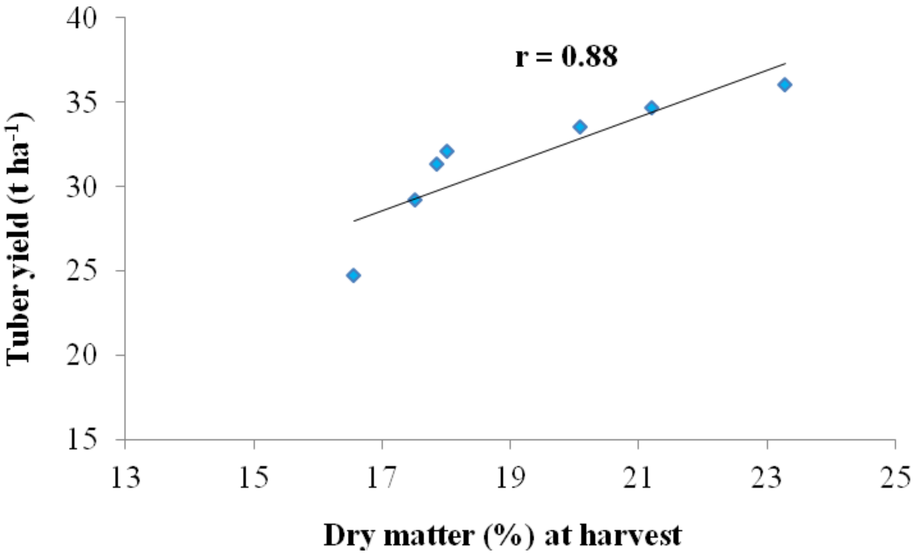

Figure 7. Relationship between dry matter content at harvest and tuber yield (t ha^{-1}) of potato

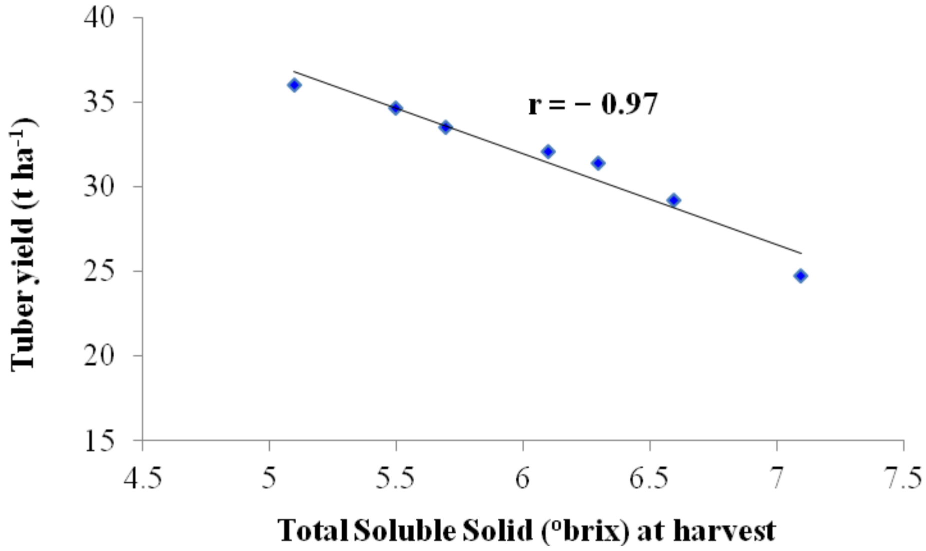

Figure 8. Relationship between total soluble solid at harvest and tuber yield (t ha^{-1}) of potato

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 potato tuber. "Diamant" was used as planting material under present study. The experiment consisted of seven different combinations with inorganic fertilizers namely, T_1= 50% recommended urea + 500 ml NEB ha^{-1}, T_2= 50% recommended urea + 750 ml NEB ha^{-1}, T_3= 50% recommended urea + 1000 ml NEB ha^{-1}, T_4= 50% recommended urea and 25% reduction of P, K, S + 500 ml NEB ha^{-1}, T_5= 50% recommended urea and 25% reduction of P, K, S + 750 ml NEB ha^{-1}, T_6= 50% recommended urea and 25% reduction of P, K, S + 1000 ml NEB ha^{-1} and T_7= 100% recommended fertilizer. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. The total numbers of unit plots were 28. The size of unit plot was 2.5 m × 4.0 m. The spacing 50 cm × 25 cm was used under present study. Uniform size (50-60 g) tubers were used for planting. Seed potatoes were planted at a depth of 5-6 cm on November 15, 2015. Different intercultural operations were done as per when needed. Data on different growth, yield and quality attributes were taken such as, days to first emergence, days to 100% emergence, plant height (cm), number of leaves hill^{-1}, number of stems hill^{-1}, SPAD value of potato leaf at first stolonization stage, number of tubers hill^{-1}, weight of tuber hill^{-1} (g), average weight of tuber (g), yield (t ha^{-1}), marketable yield (t ha^{-1}), non-marketable yield (t ha^{-1}), seed yield (t ha^{-1}), non-seed yield (t ha^{-1}), specific gravity, dry matter content (%), firmness (N), total soluble solid (TSS, ^{o} brix), starch (mg g^{-1} FW), reducing sugar (mg g^{-1} FW), tuber yield merit (%) 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 contributing parameters studied in this experiment. Among the seven treatments, the combination of NEB at the rate of 750 mL ha^{-1} and 50% recommended urea along with other fertilizers at conventional rate showed better performance on yield, marketable yield, specific gravity, dry matter percentage and starch content of tuber compared to those of other treatments. On the other hand; TSS (Total Soluble Solid), non-marketable yield, firmness and reducing sugar showed the best performance when the crop was managed by T_7 (100% recommended fertilizers). The maximum yield of tubers was found from T_2 (36.00 t ha^{-1}) *i.e.*, 45.48% increase yield over 100% recommended chemical fertilizer which was statistically similar to T_1 (34.65 t ha^{-1}) and T_3 (33.52 t ha^{-1}). Although, the T_1 (50% recommended urea + 500 mL NEB ha^{-1}) treatment showed the statistically similar result with T_2 in case of tuber yield but in case of processing parameters T_2 exhibited the best one for specific gravity (1.108), dry matter (23.27 %) and starch content (23.62 mg g^{-1} FW) of tuber at harvest and at 40 days after storage (DAS) whereas, T_7 performed the worst one.

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 potato. With considering the yield and quality attributes of potato, the application of 50% Urea and 750 ml of NEB per hectare exhibited significantly the best one in case of higher yield, marketable yield, seed yield, specific gravity, dry matter and starch content of tuber. The NEB also showed better and positive response of growth traits of potato plant compared to 100% application of chemical fertilizers in the field.

Recommendations

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

3. If, potato 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 potato yield and quality in combination with reduced inorganic fertilizers.

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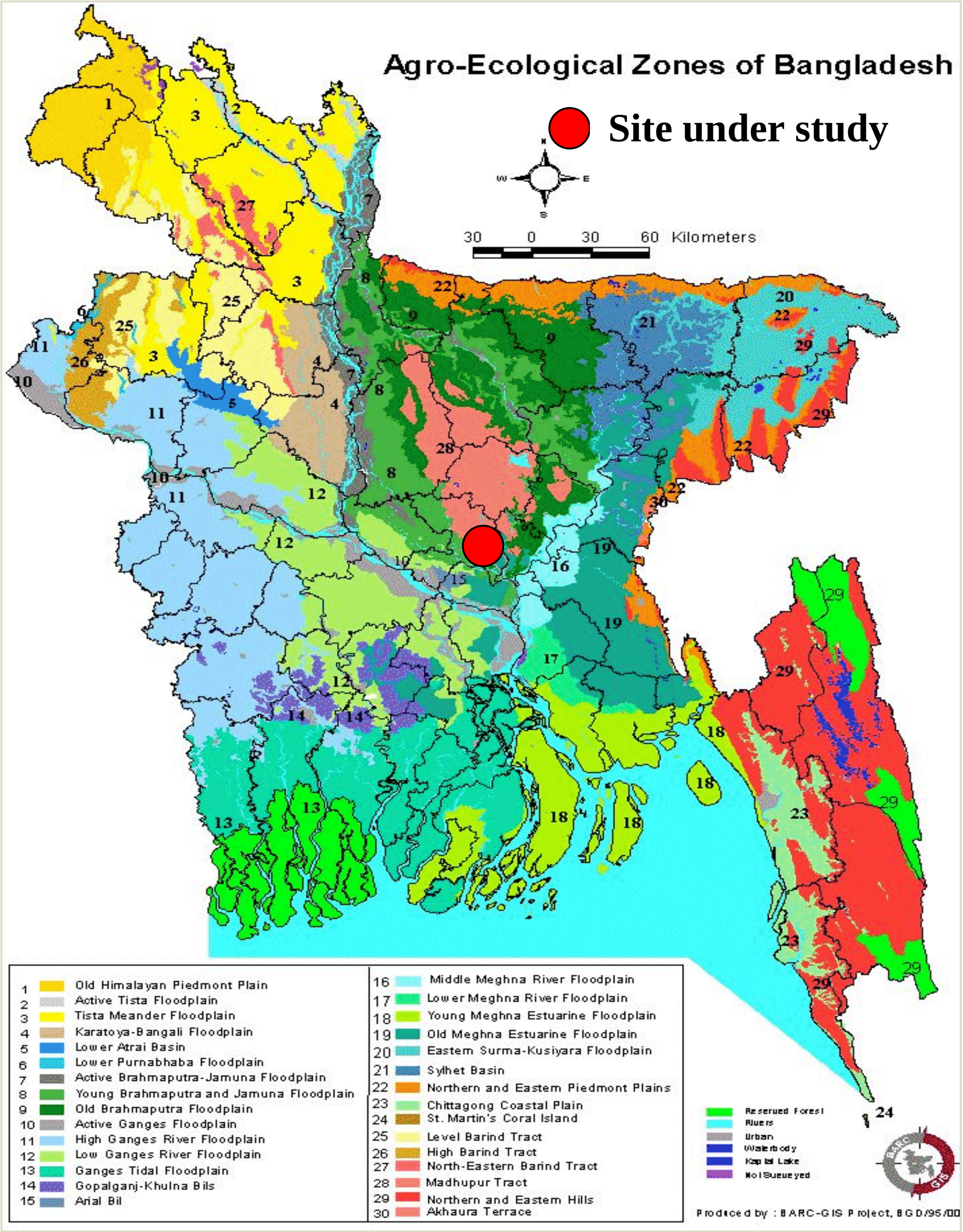
APPENDICES

Appendix I. Map showing the site used for present study

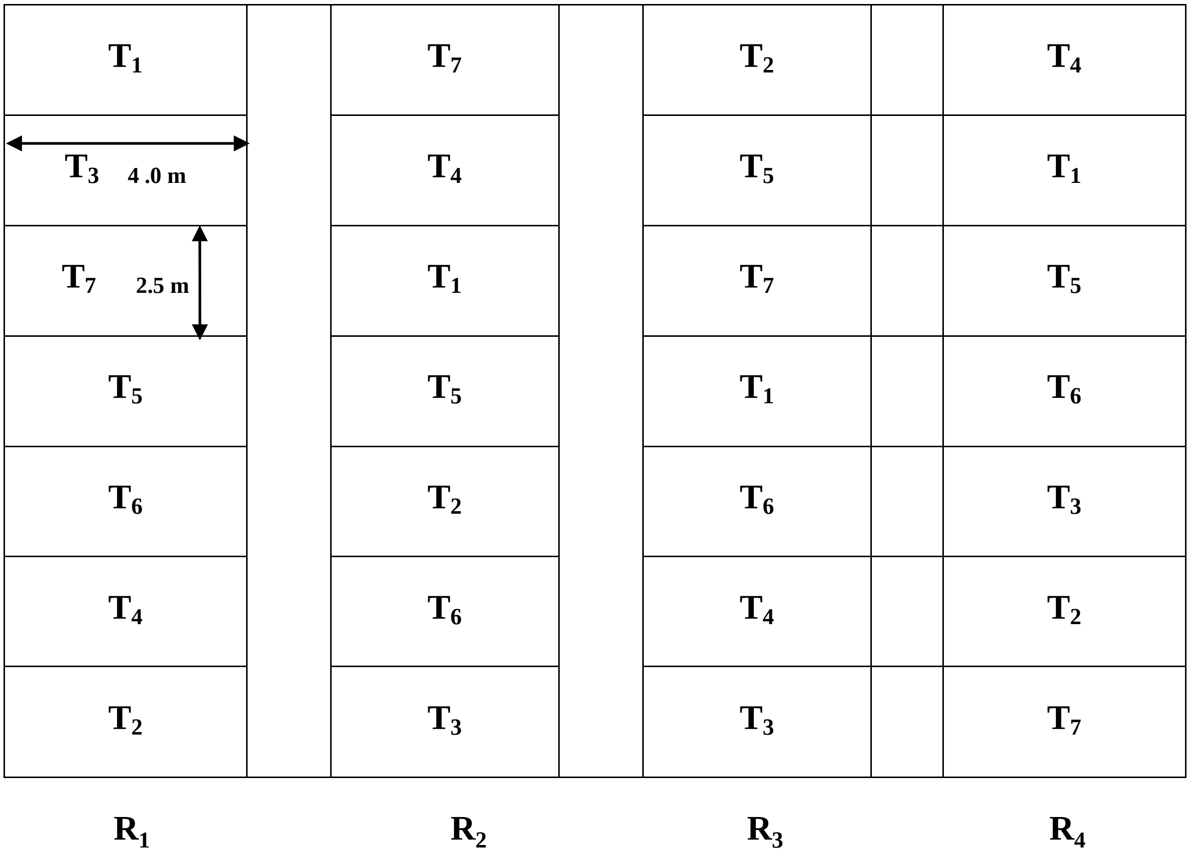


Appendix II. Monthly meteorological information during the period from November, 2015 to April, 2016

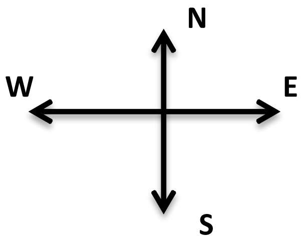
Year	**Month**	**Air temperature (^oC)**		**Relative Humidity (%)**	**Total rainfall (mm)**
		Maximum	**Minimum**		
2015-2016	November	28.89	11.88	56.58	51
	December	25.13	8.98	69.85	1.21
	January	23.97	9.28	71.09	Trace
	February	25.12	13.89	76.99	Trace
	April	30.85	16.96	65.98	63

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

Appendix III. Layout of experimental plot



T_1	T_7	T_2	T_4
T_3	T_4	T_5	T_1
T_7	T_1	T_7	T_5
T_5	T_5	T_1	T_6
T_6	T_2	T_6	T_3
T_4	T_6	T_4	T_2
T_2	T_3	T_3	T_7
R_1	R_2	R_3	R_4



Legends : Unit plot size : 2.5 m × 4.0 m

Appendix IV. Mean sum square values for days to emergence of potato tuber

Source of variation	df	Days to first emergence	Days to 100 % emergence
Replication	3	0.1670	0.1682
Treatment	6	17.6044**	13.7543**
Error	18	0.6685	0.8960

**, indicates significant at 1% level of probability

Appendix V. Mean sum square values for height, leaves, stems number and chlorophyll of potato at first stolonization stage

Source of variation	df	Plant height	Number of leaves per hill	Number of stems per hill	SPAD value
Replication	3	2.0792	0.3499	0.00935	0.6883
Treatment	6	68.1353*	23.9714**	2.86364**	32.2728**
Error	18	23.3025	191.644	0.12225	7.0995

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

Appendix VI. Mean sum square values for number and weight of tuber hill^{-1}, average weight of tuber and tuber yield

Source of variation	df	Number of tubers hill^{-1}	Weight of tuber hill^{-1}	Average weight of tuber	Yield
Replication	3	0.11195	77.26	0.097	0.4944
Treatment	6	7.30064**	6669.96**	493.073**	42.6877**
Error	18	0.74608	864.86	0.964	5.5351

**, indicates significant at 1% level of probability

Appendix VII. Mean sum square values for yield grading of potato tuber

Source of variation	df	Marketable yield	Non-marketable yield	Seed yield	Non-seed yield
Replication	3	0.260	0.0417	0.0671	9.3392
Treatment	6	108.578**	17.3755**	76.0136**	1.3128^{NS}
Error	18	4.278	0.2172	1.8836	10.8835

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

Appendix VIII. Mean sum square values for specific gravity and dry matter content of potato tuber at harvest and 40 DAS

Source of variation	df	Specific gravity at harvest	Specific gravity at 40 DAS	Dry matter at harvest	Dry matter at 40 DAS
Replication	3	0.00238	0.00626	0.1249	0.2144
Treatment	6	0.01791**	0.01103**	17.2706**	23.9462**
Error	18	0.00109	0.00212	1.3240	2.6584

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

Appendix IX. Mean sum square values for firmness and total soluble solid of potato tuber at harvest and 40 DAS

Source of variation	df	Firmness at harvest	Firmness at 40 DAS	TSS at harvest	TSS at 40 DAS
Replication	3	1.5794	0.7534	0.02123	0.05949
Treatment	6	39.3322**	80.0652**	1.39857**	1.24714*
Error	18	9.8164	4.8998	0.13673	0.41239

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

Appendix X. Mean sum square values for starch and reducing sugar content of potato tuber at harvest and 40 DAS

Source of variation	df	Starch at harvest	Starch at 40 DAS	Reducing sugar at harvest	Reducing sugar at 40 DAS
Replication	3	0.3067	0.1069	0.03866	0.00055
Treatment	6	35.5159**	15.0392**	0.02327**	0.02940**
Error	18	3.4270	1.3880	0.03173	0.00417

**, indicates significant at 1% level of probability

Plate 1: Overall view of experimental plot

Plate 2: Harvesting and bagging scenario

Plate 3: Storing of potato tuber

Plate 4: Compartmentalization of reducing sugar content in test tube

a. Sedimentation of starch **b.** Washing of starch

Plate 5 (a & b): Potato starch determination

Plate 6: Spectrophotometer

Plate 7: Hand Sugar Refractometer "ERMA" Japan

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