INFLUENCE OF NITROGEN ON GROWTH YIELD AND QUALITY OF SOME POTATO VARIETIES

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CERTIFICATE

This is to certify that the thesis entitled **"INFLUENCE OF NITROGEN ON GROWTH, YIELD AND QUALITY OF SOME POTATO VARIETIES"** submitted to the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRONOMY**, embodies the result of a piece of *bona fide* research work carried out by **PARSA SANJANA**, Registration No. **09-03317** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Dhaka, Bangladesh

_____

(**Prof. Dr. Tuhin Suvra Roy)**
Supervisor


DEDICATED TO
My Beloved Parents

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The Author

INFLUENCE OF NITROGEN ON GROWTH YIELD AND QUALITY OF SOME POTATO VARIETIES

ABSTRACT

A field experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka, during the period from October 2013 to March 2014, to investigate the Influence of Nitrogen on growth, yield and quality of some potato varieties. The experiment comprised as two factors, Factor A: Nitrogen levels (4); N_0-control (No nitrogen), N_1-100 kg N ha^{-1}, N_2-150 kg N ha^{-1}, N_3-200 kg N ha^{-1} and Factor B: Potato varieties (4); V_1-Diamont, V_2-Asterix, V_3-Lady rosetta, V_4-BARI TPS-1.The experiment was laid in a split-plot design with three replications. The result revealed that nitrogen and potato varieties had significant effects on most of the growth, yield and quality parameter studied in this experiment. The growth parameter such as the highest plant length, maximum number of leaves $plant^{-1}$, maximum of stems $hill^{-1}$, maximum dry matter were recorded from the application of 200 kg N ha^{-1}.Results showed that, tuber yield, flesh dry matter content, specific gravity, total soluble solids and starch content gradually increased with increasing up to 150 kg N ha^{-1} and there after decreased with increasing N level. The highest plant length (81.05cm) and maximum number of leaves $plant^{-1}$ (53.05) were recorded from BARI TPS-1.The different potato varieties, Diamont exhibited better performance in respect of yield. Diamont produced maximum tuber yield (28.45 t ha^{-1}) with the application of 150 kg N ha^{-1}. Among the sixteen treatment combinations, the 150 kg N ha^{-1} along with Lady rosetta produced maximum specific gravity (1.12 g cm^{-3}), highest flesh dry matter (24.52%), maximum starch (18.05%) and optimum total soluble solids (6.00%). This combination also demonstrated better performance for producing quality potato tuber. The information obtained in this study will inform Bangladeshi potato farmers and processors regarding the suitable N level for the production of processing potato tuber.

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LIST OF ACCRONYMS AND ABBREVIATIONS

AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Anon.	Anonymous
As	Arsenic
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BCF	Bio Concentration Factors
cm	Centi-meter
cm"	Square centi-meter
CV	Coefficient of Variance
DAP	Days After Planting
Dev.	Devlopment
DMRT	Duncan's Multiple Range Test
Environ.	Environmental
etd.	And others
Expt.	Experimental
FAO	Food and Agriculture Organization
g	Gram (s)
hill^{1}	Per hill
i.e.	*id est* (L), that is
j.	Journal
kg	Kilogram (s)
mg	Milligram
m^{2}	Meter squares
MS	Master of Science
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
SE	Standard Error
T ha^{-1}	Ton per hectare
TSS	Total Soluble Solids
UNDP	United Nations Development Programme
viz	Namely
WHO	World Health Organization
%	Percentage

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) popularly known as 'The King of vegetables'. It is a tuber crop belongs to the family Solanaceae. It originated in the central area of South America (Keeps, 1979). It is the 4th world crop after wheat, rice and maize. Bangladesh is the 8th potato producing country in the world. In Bangladesh, it ranks 2nd after rice in production (FAO, 2013). It contributes not only energy but also substantial amount of high quality protein and essential vitamins, minerals and trace elements to the diet (Horton, 1987).

In Bangladesh, it ranks second after rice in terms of production. The total area under potato crop, national average yield and total production in Bangladesh are 4,30,446 hectares, 19.071 t ha^{-1} and 82,05,470 metric tons, respectively. The total production is increasing over the time as such consumption also rapidly increasing in Bangladesh (MOA, 2013). It is considered as a vegetable crop and contributes as much 55% of the total vegetable production in Bangladesh (BBS, 2013).The yield is very low in comparison to that of the other leading potato growing countries of the world, 40.16 t ha^{-1} in USA, 42.1t ha^{-1} in Denmark and 40.0 t ha^{-1} in UK (FAO, 2013).

In Bangladesh, potato is grown during the winter season. Nutritionally, the tuber is rich in carbohydrates or starch and is a good source of protein, vitamin C and B, potassium, phosphorus and iron. Potato is one of the most important vegetable crops and having a balanced food containing about 75 to 80% water, 16 to 20 % carbohydrates, 2.5 to 3.2% crude protein, 1.2 to 2.2% true protein, 0.8 to 1.2% mineral water, 0.1 to 0.2% crude fats, 0.6% crude fibre and some vitamins (Schoenemann, 1977). It is a staple diet in European countries and its utilization both in processed and fresh food form increasing considerably in Asian countries (Brown, 2005). Being a carbohydrate rich crop, potato can partially substitute rice, which is our main food item. It is grown in almost all countries of the world. In

main countries including those Europe, America and Canada, potato is a staple food. In the last 2-3 decades, production of potato in Bangladesh has increased with the cultivation of high yielding varieties. In Bangladesh, potato is mainly used as vegetable and available in the market throughout the year with reasonable price as compared to other vegetables. According to Kadly (1972), among crops, the potato ranks first in protein production per gram per day. Biological value, which is an index of the protein of absorbed nitrogen retained in body for growth or maintenance or both, is 73 for potato compared to 54 for maize and 53 for wheat flour.

Potato has acquired great importance in rural economy in Bangladesh. It is not only a cash crop but also an alternative of food crop against rice and wheat. Bangladesh has a great agro-ecological potential of growing potato. The area and production of potato in Bangladesh has been increasing during the last decades but the yield per unit area remains more or less static.The reasons for such a low yield of potato in Bangladesh are imbalanced fertilizer application, use of low quality seed and use of sub-optimal production practices. Available reports indicated that potato production in Bangladesh can be increased by improving cultural practices among which optimization of manure and fertilizer, planting time, spacing and use of optimal sized seed are important which influences the yield of potato (Divis andBarta, 2001).

Potato is considered as a gross feeder and requires adequate supply to different plant nutrients, particularly nitrogen for optimum growth of plants and high yield of tubers. Under Bangladesh conditions, use of both under and over doses of nitrogen has been reported (Hussain, 1998). The use of low nitrogen results in reduction of yield of potato. On the other hand, excess use of nitrogen results in wastage of fertilizer and high cost of production.

Total production is increasing day by day as such consumption also rapidly increasing in Bangladesh (BBS, 2013).A challenge of potato production is effective management of nitrogenous fertilizers (Fageria and Baligar, 2005). Nitrogen is the most essential element in increasing crop yields; thus nowadays,

nitrogenous fertilizers are extensively used worldwide (Fageria and Baligar, 2005).A plant absorbs most nitrogen in nitrate form. Nitrogen is an important and essential structural component of chlorophyll and various proteins (Koochaki, 2006). Application of extraneous nutrients like fertilizers is necessary in potato production because its high rate of dry matter production rapidly discharges soil nutrients (Imas and Bansal, 1999). The research showed that adequate nitrogen application in growing season is required to realize high potato yield and quality .Over dose of nitrogen application or its early or late application adversely affect its produced tubers. N deficiency decreases growth and yield and N excessive application stimulates shoot growth, retards tuber formation and filling period, decreases tuber specific weight and shortens tuber storage time (Rezaee and Sultani, 1996).Under this circumstance, the proposed study was undertaken to examine the effect of nitrogen on growth, yield and quality of potato production in Bangladesh.

It is evident that uses of nitrogen are the very important variables in potato production. The aim of this work was to evaluate the effect of nitrogen levels on the growth, yield and quality which have an effect on potato production in Bangladesh with the following objectives:

1. To find out the suitable dose of nitrogen fertilizer on different varieties of potato production.
2. To study the effect of nitrogen on the yield and quality of potato production.
3. To find out the interaction effect of nitrogen and potato varieties on the yield and quality of potato production.

CHAPTER II

REVIEW OF LITERATURE

Potato is an important food crop in the world and nitrogen is one of the major important macronutrients responsible for controlling growth and yield of potato. A good number of research works have been done on different levels of nitrogen on the growth and yield of potato in various part of the world. Also there are some studies on responses of varieties to different doses of nitrogen. But here is no report of varietals responses of potato to applied nitrogen under Bangladesh conditions for seed and commercial potato production. The literatures related to growth, yield in terms of seed and table potato production have been reviewed in this chapter on the following headings.

2.1 Effect of different levels of nitrogen on the growth, yield and quality of potato

Nitrogen plays a great role on different yield contributing character and yield of potato. Both excess and under–does of nitrogen hamper its yield. So, for higher yield, judicious amount of nitrogen should be applied to the plant.

Dixit (1997) noticed better vegetative growth and higher yield at 150 kg N + 20 t FYM along with 100 kg P_2O_5 + 50 kg K_2O ha^{-1}.

Sujatha and Krishnappa (1996) observed higher tuber yield at 120: 100: 120: kg NPK + 50 t FYM ha^{-1}.

Gagro (1996) carried out an experiment on potatoes cv. Jaerlad Desiree, where they applied 0, 100, 150, or 200 kg N ha^{-1} and observed that number of tubers, tuber size and yield were increased with increasing N rates.

Chowdhary *el al.* (1996) reported that highest tuber yield (12.60 t ha^{-1}) was recorded when the crop was fertilized with 120 kg N ha^{-1}.

Krefft *et al.* (1995) reported that increasing N rates increased plan height but decreased the number of stems m^{-2}. Seed tubers were also increased with increase in N rates up to 150 kg ha^{-1}

Krefft *et al.* (1995) also reported that average plant height was increased from 44.5 to 51.5 cm with an increase of dose from 120 to 180 kg N ha^{-1}. Similar results were found by Singh and Grewal (1984).

Reust (1995) reported that the maximum yield was generally afforded at 120 kg ha^{-1} nitrogen application. Nitrogen application increased the percentage of large tuber.

Hossain *et al.* (1995) worked on nitrogen requirement for raising cut-shoot of potato crop and found that high rate of nitrogen application increased the number of leaves $plant^{-1}$. Leaf length, foliage coverage and delayed tube relation and plant maturity. Tuber yield was increased significantly up to 120 kg N ha^{-1} and decreased of small tuber.

Trehan and Grewal (1995) conducted an experiment on deep alluvial soil at the Central Potato Research Station, Jalandhar with six doses of N (0, 60, 120, 180, 240 and 300 kg ha^{-1}) and five doses each of P_2O_5 and K_20 (0, 50, 100, 150 and 200 kg/ha), and found the highest tuber yield at 240 kg N and 150 kg K_2Oha^{-1} phosphorus gave little response.

Chaurasia and Singh (1995) carried out an experiment in 1986-1988 at Varanasi, Uttar Pradesh, on potatoes cv. Kufri Bahar where 0, 50, 100 or 150 kg N ha^{-1} were given and haulms were cut 80, 90, 100, 110 or 120 days after planting. Tuber yield was increased with rate of N application and with delay in haulm cutting uptake of N, P and K in tubers was increased with N application rate and with the delay in haulm cutting date except uptake or K which was the highest with 100 kg N ha^{-1} Uptake of N, P and K in leaves and stems was increased with range of N application, uptake of N and P in leaves and stems and K in stems were highest when haulms were cut 90 days after planting whereas uptake of K in leaves was the highest when haulms were cut 80 days after planting.

Under Bangladesh condition, Hussain (1995) recommended a dose of 275 kg urea, 185 kg triple super phosphate and 250 kg muriate of potash for seed potato production.

In another experiment Schonaberger and Erichsen (1994) observed that growth and development are related to nutrient uptake. Again, higher N rates promoted general vegetative growth (Borin and Magrini, 1989).

Mohammad *et al.* (1993) reported that tuber diameter and weight per plant were highest at 25 cm spacing and application of 148 kg N ha^{-1}. Tuber number $plant^{-1}$ was increased with increasing spacing and N rates. Similar result was found by Singh *et al.* (1993).

Mollerhagen (1993) observed that the tuber yield was increased with increasing N rates. The dry matter content was decreased with increasing N application. Application of high doses of N resulted in the largest tuber Similar result was found by Proba–Bialezyk (1993) and Juzl (1993). Sharma *et al.* (1995) reported that the optimum sowing date was 25 October and the tuber yield was the highest with 160 kg N/ha.

Zrust and Mica (1992) conducted an experiment on nitrogen requirement using two varieties vix, Karim and Kamyk. The observed that application of nitrogen increases stolon number and extends growth period .They also found that higher nitrogen rates retarded tuber initiation early in the growing season.

Mondal *et al.* (1992) reported that plant height of potato was increased significantly with the application of nitrogen.

In another study Jenkins and Nelson (1992) found that tuber DM percentage was reduced in one experiment with increasing N rate and in the second experiment final DM percentage was the highest following application of 240 kg N ha^{-1}.

Osaki *et al.* (1992) reported that the meant DW of tuber was increased after flowering and was in the order of <300<150 kg N ha^{-1}

Bhowmik and Dandapat (1991) carried out an experiment on potatoes where they applied 90, 120 and 150 kg N ha^{-1} and found that tuber number, volume and yield/plant were increased with increasing nitrogen rates.

Soaud *et al.* (1990) mentioned that nitrogen did not give significantly higher yields, but adversely affected tuber quality and led to increased residual nitrate in the soil profile.

Shvirberga (1990) reported that application of nitrogen at the rate of 175 kg ha^{-1}increased tuber yield, but yield was no further increased with 350 kg ha^{-1}.

Obeirne and Cassidy (1990) stated that tuber dry matter (DM) Content was significantly diminished by the application of more than 150 kg N ha^{-1} The tuber DM was decreased with increasing N application (Juzl, 1991).

Anand and Krishnappa (1990) carried out an experiment in 1984-1985 where they applied 0, 60, 120 or 180 kg N ha^{-1} and 0, 50, 150 kg K/ha and they obtained the highest yield of 26.08 t ha^{-1} with 180 kg N + 150 K ha^{-1}.

Sud *et al.* (1990) carried out an experiment in 1991-1992 at Kufri, Himachal Pradesh, India to investigate the effect of nitrogen and sulphur. Potato cv. Kufri Jyoti was fertilized with 0, 60, 120 or 180 kg N ha^{-1} and 0, 20 or 40 kg S ha^{-1}. Tuber yield was increased by application of S and increased with increasing N rate. Interaction between N and S was not found significant. They noticed that combined application of N and S had a positive effect on tuber quality.

Dorobantu *et al.* (1989) carried out a field experiment where they found that plant height, leaf area and total biomass were maximum with 200 kg N + 60 kg P_2O_2 + 100Kg K_2O + 40 t FYM or 300 kg N + 80kg P_2O_2 + 300kg K_2O.

Anand and Krishnappa (1989) reported that application of 120 and 180 kg Nha^{-1} increased the total dry matter significantly over 60 kg N/ha and the control.

Sahota and Singh (1989) observed that plant height was increased progressively as the levels of nitrogen increased up to 160 kg per ha.

Sharma *et al.* (1988) reported that the higher NPK rates increase yield in some cases. NPK decreased starch and dry matter contents and increased storages loss.

Anand and Krishrappa (1988) reported that increased application of N and K increased the yield of A. B and C grades tuber. Similarly, nitrogen application increased the percentage of large tuber had been reported by Castro (1988).

Sharma and Arora (1987) noticed that increase in the applied nitrogen from 0 to 250 kg N ha^{-1} decreased the small number of tubers and increased medium and large grades.

Singh and Sharma (1987) in separate experiment noticed up to 120 kgN ha^{-1}

A field trial conducted by Anand and Krishnappa (1980) in red sandy loan soil of Bangalore to assess the effect of four levels of nitrogen (o, 60, 120, and 180 kg ha^{-1}) found that the number of shoot per hill was not increased significantly due to the application of different levels of N and as well as their interaction.

Anand and Krishnappa (1980) worked on dry matter accumulation and nutrient uptake by potato cv. Kufri Badshah where 0-180 kg Nha^{-1} and 0-150 kg K ha^{-1} were applied. They reported that application of N and K increased DM accumulation in roots, tubers and total plant.

In a field trail under Bangladesh conditions Islam and Siddique (1978) observed than application of different doses of nitrogen from 0 to 224.55 kg per hectare had no significant effect on emergence. Similar result was found (up to 120 kg ha^{-1}) by Grewal *et al.* (1979).

Sahota and Grewal (1979) reported that different doses of nitrogen significantly affected the number of tubers per plant when the dose of nitrogen was increased from 80 to 120 kg ha^{-1}, there was no increase in the number of tubers per plant.

Sharma and Grewal (1978) reported that higher dose of urea affected or delayed the germination due to accumulation of free ammonia and nitrites in the soils. They stated that over doses of urea killed the seed tuber sprouts and checked the root growth.

Gupta and Ghosh (1973) reported that the rates of stem elongation and leaf production and the number of axillaries branches were increased with an increase in the levels of nitrogen. The leaf surface was increased till the tuber initiation stage but decreased during the tuber development stage. The increase in the total leaf surface was because of the production of more branches and leaves and expansion of the leaves under high nitrogen fertilizer. Increasing N fertilizers application increased plant growth rates and N uptake and absorption. Leaf number on main stem and total number of nodes on branches were also increased withthe increasing level of N fertilizer as reported by Osaki *et al.* (1992).

In a separate investigation Swaminathan (1972) found that the efficiency of urea was lower in light texture alluvia soils as compared to black cotton soils. Low efficiency of urea had been attributed to its adverse effect on the germination of tubers.

2.2 Effect of varietieson growth, yield and quality of potato

Ganga and Kulakarni (2014) conducted an experiment where ten potato cultivars were used and their chemical analysis was done. The dry matter content ranged from 15.30 (J/99-242) to Kufri Khayti (20.93%). Starch was minimum in J/99-242 (52.55%) and maximum in Kufri Khayti (85.67%). The dry matter was positively correlated with flavour and taste of baked potatoes which could be due to high amount of starch that forms stable complex with flavour compounds during cooking.

Kassim *et al.* (2014) found that reducing physiological functions of above ground part of potato plant (leaf area and total chlorophyll content), the number and the weight of tuber decreased, so the productivity of the plant decreased.

Abebe (2013) carried out an experiment at three distinct locations in the Amhara region of Ethiopia for evaluation of the specific gravity of 25 potato varieties. The pooled specific gravity values ranged from 1.058 to 1.102. The specific gravity of tubers of the improved varieties Belete was the highest while that of Menagesha was the lowest. Furthermore, the specific gravity values for varieties grown at Debretabor were higher than those for the corresponding varieties grown at Adet and Merawi. He mentioned that specific gravity is the measure of choice for estimating dry matter and ultimately for determining the processing quality of potato varieties.

Behjati *et al.* (2013) conducted a field experiment to evaluate the yield and yield components on promising potato clones. Clone No. 397031-1, had the highest yield and Lady Rosetta varieties had the lowest yield compared with other varieties. The lowest and highest average number of main stems per plant, related to Lady Rosetta and clone No. 397067-2. Lady Rosetta varieties had the highest number of tube per plant and clone No. 397067-2 had the lowest number of tubers per plant. The lowest and highest average tuber weight per plant related to clone No. 397067-2 and Lady Rosetta varieties respectively.

Hossain (2011) conducted three experiments with BARI released twelve potato varieties to determine the yield potentiality, natural storage behaviour and degeneration rate for three consecutive years. He found that the highest emergence was observed in Granola at 34 DAP. At 50 DAP plant height (cm) of Diamont was (43.50), BARI TPS-I (47.70), Felsina (52.00), Asterix (52.97), Granola (38.30), Cardinal (46.33). Foliage coverage (%) of Diamont was (83.33), BARI TPS -I (85.56), Felsina (82.22), Asterix (89.44), Granola (85.56), Cardinal (81.67). No. of stems $hill^{-1}$ of Diamont was (4.06), BARI TPS -I (3.21), Felsina (3.14), Asterix (4.03), Granola (3.30), Cardinal (3.89). Tuber yield $hill^{-1}$ (g) of Diamont was (244.2), BARI TPS-I (227.9), Felsina (300.1), Asterix (276.9), Granola (277.0),

Cardinal (316.9). Under the grade 28-40mm, the highest number (48.63%) of seed tubers was produced by Granola which was statistically identical with Asterix (46.43%). Under the same grade (28-40 mm), the highest weight (43.46%) of seed tubers was produced by Patrones followed by Asterix (37.16%), Granola (36.64%) and Multa (35.39%) among which there was no significant variation.

Karim *et al.* (2011) conducted an experiment with ten exotic potato varieties (var. All Blue, All Red, Cardinal, Diamont, Daisy, Granola, Green Mountain, Japanese Red, Pontiac and Summerset) to determine their yield potentiality. The highest total tuber weight per plant (344.60g) recorded in var. Diamont and total tuber weight plant^{-1} was the lowest (65.05 g) recorded in var. All red, all blue varieties showed the most potential yield in this experiment.

Evaluation of potato cultivars for processing into crisps was carried out by Along*et al.* (2010) in Kenya. The specific gravity of the cultivars varied from 1.074 to 1.098 and dry matter contents from 19.50 to 24.20%.

Evaluation of potato cultivars for processing into potato crisps was carried out by Along*et al.* (2010) in Kenya. Most cultivars with exception of six them including RoslinTana, Desire, RoslinEbura, Nyayo, Tigonilong and Kihora had acceptable physical characteristics suitable for processing. Tuber diameter varied significantly ($p<0.5$) among the cultivars ranging from 43 mm in Tigoni long to 56 mm in Kenya Sifa and Clone 392617.54. The specific gravity of the cultivars varied from 1.074 to 1.098 and dry matter contents from 19.50 to 24.20%.

Abong *et al.* (2009) experiment on Kenyan cultivars to observe the influence of potato cultivars and stage of maturity on chips and French fries. Dry matter content ranged from 19.50 to 24.07% and 20.56 to 24.66% in clone 393385.39 and varieties Dutch Robyin for tubers harvested 90 and 120 days after planting respectively.

Anonymous (2009a) conducted an experiment with three potato varieties to observe their performance on yield under different soil moisture levels. The highest plant height (50.75 cm) was found in Cardinal which was similar to

Diamant (48.88 cm). The lowest plant height was observed in Granola (38.50 cm). The highest foliage coverage (93.25%) was observed in Diamant followed by Cardinal (92.75%) and the lowest in Granola (90.33%). The highest no. of stems hill^{-1} (6.25) was observed in Cardinal which was similar to Diamant (5.42) and the lowest in Granola (4.75). The highest no. of tubers hill^{-1} (13.83) was observed in Granola which was similar to Cardinal (13.33) and the lowest in Diamant (11.92).

Anonymous (2009b) conducted an experiment with twenty five varieties were evaluated at six locations. They found that, plant height (cm) in case of Diamant (47.87), Sagitta (56.20), Quincy (95.40); No. of stem hill^{-1} in Diamant (3.66), Sagitta (2.53), Quincy (2.26); Foliage coverage at 60 DAP (%) in Diamant (73.33), Sagitta (93.67), Quincy (92.00); No of tuber hill^{-1} in Diamant (6.72), Sagitta (3.94), Quincy (9.95); Weight of tuber hill^{-1} (kg) in Diamant (0.30), Sagitta (0.34), Quincy (0.35); Dry matter (%) in case of Diamant (19.54), Sagitta (20.10), Quincy (18.70).

Anonymous (2009c) conducted an experiment with twelve varieties were evaluated at six locations in their third generation. They found that, plant height (cm) in case of Diamant (50.93), Granola (69.10), Sagitta (41.33), Quincy (65.87); No. of stem hill^{-1} in Diamant (5.66), Granola (3.20), Sagitta (3.46), Quincy (4.86); Foliage coverage at 60 DAP (%) in Diamant (92.00), Granola (91.00), Sagitta (89.33), Quincy (96.00); No. of tuber hill^{-1} in Diamant (7.24), Granola (6.82), Sagitta (5.23), Quincy (5.76); Weight of tuber hill^{-1} (kg) in Diamant (0.38), Granola (0.26), Sagitta (0.33), Quincy (0.35); Dry matter (%) in case of Diamant (20.80), Granola (20.45), Sagitta (19.80), Quincy (18.40).

Anonymous (2009d) conducted an experiment with twenty eight varieties were evaluated at five locations. They found that, plant height at 60 DAP (cm) in case of Diamant (54.13), Sagitta (47.27), Quincy (80.93); No. of stem hill^{-1} in Diamant (4.66), Sagitta (5.40), Quincy (5.80); Foliage coverage at 60 DAP (%) in Diamant (93.67), Sagitta (90.67), Quincy (97.00); No. of tubers hill^{-1} in Diamant (8.11), Sagitta (5.41), Quincy (6.95); Weight of tubers hill^{-1} (kg) in Diamant (0.28),

Sagitta (0.37), Quincy (0.45); Dry matter (%) in case of Diamant (19.91), Sagitta (20.60), Quincy (18.34).

Anonymous (2009e) conducted an experiment with four exotic potato varieties along with check Diamant, Cardinal and Granola were evaluated at six locations in Regional Yield Trial. They found that plant height (cm) in case of Diamant (51.20), Cardinal (48.27), Meridian (48.33) and Laura (41.00); No. of stem hill^{-1} in Diamant (5.93), Cardinal (6.20), Meridian (5.67) and Laura (4.73); Foliage coverage (%) in Diamant (88.33), Cardinal (90.33), Meridian (95.67) and Laura (86.67); No. of tuber hill^{-1} in Diamant (9.48), Cardinal (9.81), Meridian (9.63) and Laura (7.50); Weight of tuber hill^{-1} (kg)in case of Diamant (0.313), Cardinal (0.377), Meridian (0.490) and Laura (0.430); Dry matter (%) in case of Diamant (22.69), Cardinal (21.03), Meridian (19.49) and Laura (20.22).

Anonymous (2009f) conducted an experiment with seven potato varieties were evaluated at MLT site. They found that plant height (cm) in case of Diamant (43.00), Lady Rosetta (37.00), and Courage (44.47); No of stem plant^{-1} in Diamant (3.57), Lady Rosetta (2.80), and Courage (3.67); No of tuber plant^{-1} in Diamant (8.07), Lady Rosetta (5.67), and Courage (6.70).

Anonymous (2009g) conducted adaptive trails with new potato varieties at eleven districts. The mean yield of varieties over locations arranged in order of descending as BARI TPS-I (23.87 t ha^{-1}), Granola (23.68 t ha^{-1}), Diamant (23.63 t ha^{-1}), Asterix (20.83 t ha^{-1}) and Raja (18.28 t ha^{-1}).

Gluer (2009) observed that first, second, third class tuber yields and total tuber yield, tuber number per plant, mean tuber weight and leaf chl were significantly influenced by potato cultivar.There were significant correlations between chl and yield and yield related characters. Total yield significantly correlated with leaf chl. Correlations between first class yield and total yield as well as total yield and tuber number per plant were highly significant.

Mahmud *et al.* (2009) assessed the yield of seed size tubers in five standard potato cultivars (Cardinal, Multa, Ailsa, Heera, and Dheera) in relation to dates of

dehaulming (65, 70, and 80 days after planting) in a Seed Potato Production Farm, Debijong, Panchagarh. The maximum seed tuber yield was recorded from Cardinal at 80 DAP followed by Heera and Cardinal at 70 DAP, Dheera and Ailsa at 75 DAP.

Changes in reducing sugars content and chip color of tubers during storages at different temperature was observed by Singh and Ezekiel (2008) in Jalandhar. Dry matter content varied with the cultivar and growing location. Processing cultivars kurif Chipsona-1 and kurif Chipsona-2 had higher dry matter content (24.4 and 25.8% respectively) as compared to other cultivars. Least dry matter content was observed in kufri Pukhraj (15.6%).

Haque (2007) conducted a field experiment with 12 exotic potato germplasm to determine their suitability as a varieties in Bangladesh. He found that all the varieties gave more than 90% emergence at 20-35 DAP. He also observed that Plant height (cm) of Quincy was (87.8), Sagitta (65.8), Diamant (62.6); No. of stems $hill^{-1}$ was counted in Diamant (7.2), Quincy (4.5), Sagitta (4.4); Plant diameter (cm) of Sagitta was (4.0), Quincy (3.7), Diamant (2.6) at 60 DAP; Foliage coverage (%) of Sagitta was (100.0), Diamant (98.3), Quincy (96.6); No. of tubers $plant^{-1}$ of Diamant was (13.06), Sagitta (8.34), Quincy (6.71); Wt. of tubers $plant^{-1}$ (kg) of Quincy was (0.64), Sagitta (0.63), Diamant (0.49); Dry matter (%) of Sagitta was (20.8), Diamant (20.1), Quincy (18.5).

Physic-chemical properties of dry matter and starch from potatoes grown in Canada were estimated by Liu *et al.* (2007). Percent total starch, dietary fiber, protein, free sugar and apparent amylase content of AC Stampede Russet, Russet Burbank and Karnico potato dry matter ranged between 70.5 to 72.4%, 5, to 5.6%, 7.1 to 9.7%, 3.3to 6% and 29.7 to 33.3% respectively.

Das (2006) carried out an experiment to study the physio-morphological characteristics and yield potentialities of potato varieties. He found that Foliage coverage (%) of Diamant was (93.3), Asterix (71.7), Granola (66.7), Quincy (90.0), Courage (63.3), Felsina (83.3), Lady Rosetta (83.3), Laura (78.3); No. of

tubers hill^{-1} of Diamant (11.7), Asterix (8.00), Granola (11.3), Quincy (9.33), Courage (7.33), Felsina (8.00), Lady Rosetta (10.3), Laura (8.33); Tuber weight hill^{-1} (g) of Diamant (380), Asterix (285), Granola (275), Quincy (300), Courage (320), Felsina (333), Lady Rosetta (348), Laura (258); Dry matter (%) of Diamant (25), Asterix (17.5), Granola (23), Quincy (31), Courage (34.5), Felsina (22.5), Lady Rosetta (22.0), Laura (27.0); Regarding size grade distribution of tubers the varieties Courage, Espirit, Granola, Lady rosetta, Laura were found superior.

Yaghbani *et al.* (2006) investigated composition and characterization of starch extracted from various potato cultivars in Golestan province of Iran. The diameter of potato starch granular were shown to range from 34.2 to 42.1µm with a mean of 38.7+3.3µm, indicating that the granular size had no significant differences among potato varieties. The yield of potato starch varied from 9 to 12.6% on fresh weight basis. The highest and lowest yield of starch was observed in concord and Draga respectively. The starch yield was directly correlated to the dry matter content of the tubers, which ranged between 17.2 and 22%. Among the six potato cultivars, the average value of the amylase content was lowest in santé (24.4%) and highest in Graga (27.1%).

Anonymous (2005) evaluated twenty one varieties along with two standard checks Diamant and Granola at seven locations. The yields of the varieties varied from location to location as well as within location. Of all the stations, except Pahartoli, none crossed the check varieties Diamant but comparatively higher yields were produced by the varieties Espirit, Courage, Innovator, Quincy, Matador, Markies, Laura and Lady Rosetta.

Kumar *et al.* (2005) determined under water weight, specific gravity, dry matter and starch content of potatoes grown at Modipuram, Uttar Pradesh. He found that there was a positive correlation between under water weight and specific gravity (r=0.99), under water weight and dry matter (r=0.92).

Study on distribution of dry matter and sugars of potato cultivars namely: Kufri Chipsona-1,Kufri Chipsona-2, kufrijyoti, Kufri Lauvkar and Atlantic were

undertaken by Kumar and Ezckiel (2004) in Himachal Pradesh. The highest values of dry matter were obtained in stem end cortical tissue of kufri Chipsona-2 (27.5%) and lowest in pith region of Kufri Lauvkar (14.8%). The dry matter distribution pattern was more or less similar when compared within the individual varieties.

Mondol (2004) conducted an experiment to evaluate the performance of seven exotic (Dutch) varieties of potato. He found that plant height (cm) of Diamant was (18.07), Granola (13.47); No. of main stem hill^{-1} of Diamant (4.36), Granola (4.90); No. of tubers hill^{-1} of Diamant (12.00), Granola (10.93); Weight of tubers plant^{-1} (kg) of Diamant (0.57), Granola (0.39); Dry matter (%) of Diamant (17), Granola (16.30).

Alam *et al.* (2003) conducted a field experiment with fourteen exotic varieties of potato under Bangladesh condition. The highest emergence (91%) was observed from Cardinal which was statistically identical with most of the varieties except the varieties Granola (63%). The highest number of stem per hill was recorded in Ailsa (4.59) followed by Cardinal (4.50). Significantly maximum number of leaves hill^{-1} was produced from the plants of the varieties Ailsa (53.80), which was followed by Cardinal (49.75). The yields ranged of exotic varieties were 19.44 to 46.67 t ha^{-1}. Varieties Ailsa produced the maximum yield (46.67 t ha^{-1}) which was followed by Cardinal (42.21 t ha^{-1}).

A study as carried out the effect of chemical composition of potato on crips by Kita (2002) in Poland. The contents of dry matter, starch and protein nitrogen ranged from 19.92 to 23.28%, 15.2 to 18.4% and 0.136 to 0.0180% respectively.

Hossain (2000) conducted an experiment to study the effects of different levels of nitrogen on the yield of seed tubers in four potato varieties. He found that the tallest plants were produced by the seedling tubers of BARI TPS-1 (74.51 cm) and the shortest plants came from the varieties Diamant (58.63 cm); Foliage coverage (%) of Diamant at 75 DAP was (79.00), BARI TPS-1 (89.00); No. of stems hill^{-1} of Diamant was (3.50), BARI TPS-1 (2.71); No. of tubers hill^{-1} of Diamant was

(7.85), BARI TPS-1 (9.55); Weight of tubers hill^{-1} of Diamant was (416.67), BARI TPS-1 (491.33); Dry matter of tuber (%) of Diamant was (19.71), BARI TPS-1 (18.18).

Rabbani and Rahman (1995) studied the performance of 16 Dutch potato varieties in their third generation. They reported that the height of the plants significantly varied among the varieties. The highest foliage coverage at maximum vegetative growth stage was found in the varieties Cardinal (93.3%) followed by Diamant. The highest yield of tubers per hectare was obtained from Cardinal (35.19 t ha^{-1}) followed by Romano (30.09 t ha^{-1}) and the lowest from Stroma (11.11 t ha^{-1}).

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, intercultural operations, data collection and statistical analysis. The details of experiments and methods are described below:

3.1 Experimental period

The experiment was conducted during the period from October 20, 2013 to March 30, 2014 in Rabi season.

3.2 Site description

3.2.1 Geographical location

The present piece of research work was conducted in the experimental plot of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^0 74^/$N latitude and $90^0 35^/$E longitude with an elevation of 8.2 m from sea levels.

3.2.2 Agro-Ecological Region

The experimental site belongs to the agro-ecological zone of "Modhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.2.3 Soil

Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood levels. The selected plot was medium high land. The details were presented in Appendix II.

3.2.4 Climate of the experimental site

Experimental site was located in the sub-tropical monsoon climatic zone, set a parted by winter during the months from November, 10 to February, 15 (Rabi season). Plenty of sunshine and moderately low temperature prevails during experimental period, which is suitable for potato growing in Bangladesh. The weather data during the study period at the experimental site are shown in Appendix III.

3.3 Details of the Experiment

3.3.1 Experimental treatments

The experiment consisted of two factors such as nitrogen fertilizer and potato varieties. The treatments were as follows:

Factor A: Nitrogen fertilizer (4 levels)

N_0 - Control (No nitrogen)

N_1 - 100 kg N ha^{-1}

N_2 - 150 kg N ha^{-1}

N_3 - 200 kg N ha^{-1}

Factor B: Potato (4 varieties)

V_1 - Diamont

V_2 - Asterix

V_3–Lady rosetta

V_4–BARI TPS-I

Sixteen treatment combinations were as:

N_0V_1 = 0 kg Nha^{-1} with Diamont
N_0V_2 = 0 kg Nha^{-1} with Asterix
N_0V_3 = 0 kg Nha^{-1} with Lady rosetta
N_0V_4 = 0 kg Nha^{-1} with BARI TPS-I
N_1V_1 = 100 kg N $ha^{-1}$with Diamont
N_1V_2 = 100 kg N $ha^{-1}$with Asterix
N_1V_3 = 100 kg N $ha^{-1}$with Lady rosetta
N_1V_4 = 100 kg N $ha^{-1}$with BARI TPS-I
N_2V_1 = 150 kg N $ha^{-1}$with Diamont
N_2V_2 = 150 kg N $ha^{-1}$with Asterix
N_2V_3 = 150 kg N $ha^{-1}$with Lady rosetta
N_2V_4 = 150 kg N $ha^{-1}$with BARI TPS-I
N_3V_1 = 200 kg N $ha^{-1}$with Diamont
N_3V_2 = 200 kg N $ha^{-1}$with Asterix
N_3V_3 = 200 kg N $ha^{-1}$with Lady rosetta
N_3V_4 = 200 kg N $ha^{-1}$with BARI TPS-I

3.3.2 Experimental design

The experiment was laid out in a split-plot design with three replications thus comprised 48 plots.Nitrogen was assigned to main plots and varieties to sub-plots. The layout of the experiment was prepared for distributing the combination of nitrogen and varieties. The size of each unit sub plot 2.5 m × 2.0 m. The spacing between blocks and plots were 1.0 m and 0.5 m, respectively.The layout are shown in Appendix IV.

3.4 Planting material

The planting materials comprised the first generation tubers ofDiamont, Asterix, Lady rosetta and BARI TPS-I.

3.5 Crop management

3.5.1 Collection of seed

All varieties of seed potato (certified seed) was collected from, Tuber Crops Research Centre (TCRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.5.2 Preparation of seed

Collected seed tubers were kept in room temperature to facilitate sprouting. Finally sprouted potato tubers were used as a planting material.

3.5.3 Land preparation

The land of the experimental site was first opened in the last week of October with power tiller. Later on, the land was ploughed and cross-ploughed four times followed by laddering to obtain the desirable tilth. The corners of the land were spaded and weeds and stubbles were removed from the field. The land was finally prepared on 10 November 2013 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 @10 kg ha^{-1} when the plot was finally ploughed to protect the young plant from the attack of cut worm.

3.5.4 Fertilizer application

The crop was fertilized as per recommendation of TCRC (2004).The experimental plot was fertilized with following dose of muriat of potassium, triple super phosphate (TSP), gypsum, zinc sulphate and boric acid.

Fertilizers	Dose ($kg\ ha^{-1}$)	Dose ($g\ plot^{-1}$)
Cowdung	10,000	2000
MOP	300	70.00
TSP	220	52.00
Gypsum	120	27.10
Zinc Sulphate	14	3.20
Boric Acid	6	1.40

Source: Mondal *et al.*, 2011.

Cowdung was applied 10 days before final land preparation. Total amount of triple superphosphate, gypsum, zinc sulphate, boric acid was applied at basal doses during final land preparation. Different dose of ureawere applied as per treatment. One third of urea was applied at final land preparation and one third was applied at 30 DAP. Finally rest amount was applied at 45 DAP.

3.5.5 Planting of seed tuber

The well sprouted healthy and uniform sized potato tubers were planted and 28 potatoes was used for one plot. Seed potatoes were planted in such a way that potato does not go much under soil or does not remain in shallow. On an average, potatoes were planted at 4-5 cm depth in plot on November 12, 2013.

3.5.6 Intercultural operations

3.5.6.1 Weeding

Weeding was necessary to keep the plant free from weeds. The newly emerged weeds were uprooted carefully after complete emergence of sprouts and afterwards when necessary.

3.5.6.2 Watering

Frequency of watering was done upon moisture status of soil retained as requirement of plants. Excess water was not given, because it always harmful for potato plant.

3.5.6.3 Earthing up

Earthing up process was done by pouring the soil in the plot at two times, during crop growing period. First pouring was done at 35 DAP and second was at 50 DAP.

3.5.6.4 Plant protection measures

Dithane M-45 was applied at 30 DAP as a preventive measure for controlling fungal infection. Ridomil (0.25%) was sprayed at 45 DAP to protect the crop from the attack of late blight.

3.5.6.5 Haulm cutting

Haulm cutting was done at February 12, 2014 at 90 DAP, when 40-50% plants showed senescence and the tops started drying. After haulm cutting the tubers were kept under the soil for 10 days for skin hardening. The cut haulm was collected, bagged and tagged separately for further data collection.

3.5.6.6 Harvesting of potatoes

Harvesting of potato was done at February 22, 2014 at 10 days after haulm cutting. The potatoes of each plot were separately harvested, bagged and tagged and

brought to the laboratory. The yield of potato plant^{-1} was determined in gram. Harvesting was done manually by hand.

3.5.7 Recording of data

Experimental data were recorded from 20 days after planting(DAP) and continued until harvest. Dry weights of different plant parts were collected after harvesting. The following data were collected during the experimentation.

A. Crop growth characters
   - i. Days to 1st emergence and days to final emergence
   - ii. Plant length at 20, 40, 60 and 80 DAP
   - iii. Number of leaves plant^{-1} at 20, 40, 60 and 80 DAP
   - iv. Number of stems hill^{-1} at 20, 40, 60 and 80 DAP
   - v. Stem dry matter plant^{-1} (%) at 20, 40, 60, 80 DAP and at harvest

B. Yield and yield components
   - vi. Number of tubers hill^{-1}
   - vii. Average weight of tuber (g)
   - viii. Yield of tuber (t ha^{-1})

C. Quality characters
   - ix. Tuber flesh dry matter content (%)
   - x. Specific gravity
   - xi. Total soluble solids (% Brix)
   - xii. Firmness
   - xiii. Starch
   - xiv. Skin color (L*, a*, b*, hue angle and chroma)
   - xv. Flesh color (L*, a*, b*, hue angle and chroma)

3.5.8 Experimental measurements

A brief outline of the data recording procedure followed during the study is given below:

A. Crop growth characters

i. Days to 1st emergence and days to final emergence

After planting the potato tuber keenly observed the emergence twice in a day (morning and afternoon) until final emergence.

ii. Plant length (cm)

Plant length refers to the length of the plant from ground levels to the tip of the tallest stem. It was measured at an interval of 20 days starting from 20 DAP till 80 DAP. The height of each plant of each plot was measured in cm with the help of a meter scale and mean was calculated.

iii. Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted at an interval of 20 days starting from 20 DAP till 80 DAP. Leaves number plant^{-1} were recorded by counting all leaves from each plant of each plot and mean was calculated.

iv. Number of stems hill^{-1}

Number of stems hill^{-1} was counted at an interval of 20 days starting from 20 DAP till 80 DAP. Stem numbers hill^{-1} was recorded by counting all stem from each plot.

v. Stem dry matter (%)

First the fresh weight of haulm was taken. Then the samples of stem were dried in oven at 72^0C for 72 hours. From which the dry matter percentage of above ground harvestwas calculated with the following formula (Elfnesh *et al.,* 2011)-

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

B. Yield and yield components

vi. Number of tubers hill^{-1}

Number of tubers hill^{-1} was counted at harvest. Tuber numbers hill^{-1}was recorded by counting all tubers from each plant.

vii. Average weight of tuber (g)

Average weight of tuber was measured by using the following formula-

$$\text{Average weight of tuber} = \frac{\text{Yield of tuber/plant}}{\text{Number of tubers/hill}}$$

viii. Yield of tuber (t ha^{-1})

Tubers of each plot were collected separately from which yield of tuber hill^{-1} was recorded in kilogram and converted to ton ha^{-1}.

C. Quality characters

ix. Tuber flesh dry matter content (%)

The samples of tuber were collected from each treatment. After peel off the tubers the samples were dried in oven at 72^{0}C for 72 hours. From which the weights of tuber flesh dry matter content % were recorded.

x. Specific Gravity (gcm^{-3})

It was measured by using the following formula (Gould, 1995)-

$$\text{Specific gravity} = \frac{\text{Weight of tuber in air}}{\text{Weight of tuber in fresh water at } 4^0\text{ C}}$$

xi. Total soluble solids (TSS)

TSS of harvested tubers was determined in a drop of potato juice by using Hand Sugar Refractor meter "ERMA" Japan, Range: 0-32% according to (AOAC, 1990) and expressed as BRIX value.

xii. Color measurements

Color was measured with a color spectrophotometer NF 333 (Nippon Denshoku, Japan) using the CIE Lab L*, a* and b* color scale. The 'L*' value is the lightness parameter indicating degree of lightness of the simple; if varies from 0 = black (dark) to 100 = white (light). The 'a*' which is the chromatic redness parameters whose value means trending to red color when positive (+) and green color when negative (-). The 'b*' is yellowness chromatic parameters corresponding to yellow color when it is positive (+) and blue color when it is negative (-). Each sample consisted of 10 slices, each of which was measured thrice. Hue angle = arctg$\frac{a*}{b*}$ and chroma = $\sqrt{a^{*2} + b^{*2}}$ were calculated. Higher numbers of chromaticity indicate a more vivid color, whereas lower numbers correspond to dull colors. Color management was done just after cutting tubers.

xiii. Firmness

Fries texture measurements were performed at room temperature by a puncture test performed in a Texture Analyzer (Sun scientific co. Ltd, Japan) equipped with a wedge probe imitating front teeth. Maximum Force (MF) was defined as the force at which the wedge penetrates the outer layer of the surface of the fried potato fries and crisps slices (Segnini *et al.*, 1999). Higher firmness and lower crispness are suitable for chips/frence fry product. For this result, determination of firmness and crispness are essential for processing quality potato.

xiv Determination of starch content

Starch content of tubers was determined by Somogyi-Nelson method (Nelson, 1944). Preparation of phosphate buffer. Dilute 0.74 $NaH_2PO_4 \cdot 2H_2O$ and 0.09g $NaH_2PO_4 \cdot 12H_2O$ into 100 ml Distilled water. Add 0.1 g Enzyme (Amylo glucosidase) and mix well. Keep at - 20°C for the preservation. Measure 250 ml tap water using a measuring cylinder and put it into a 250 ml beaker. Take 0.5 ml solution from the beaker into 3 test tubes. Boil the test tubes for 10 min at 100°C. Add 1 ml Amylo glucosidase 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 100℃ for 10 minutes, 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). Calculate starch content using the glucose standard curve.

Calculation of starch content

Starch = Abs × 0.9

3.6 Statistical Analysis

The data obtained for different characters were statistically analyzed following the analysis of variance techniques by using MSTAT-C computer package programme. The significant differences among the treatment means were compared by Least Significant Different (LSD) at 5% levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the response of nitrogen on the growth, yield and quality of potato. The results obtained from the study have been presented, discussed and compared in this chapter through table(s), figures and appendices. The analysis of variance of data in respect of all the parameters has been shown in Appendix V-XIII. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following headings.

4.1 Crop growth characters

4.1.1 Days to 1st emergence (Visual observation)

4.1.1.1 Effect of nitrogen

Days to 1st emergence was significantly influenced by the application of different nitrogen levels, results revealed that, the duration of emergence decreased gradually with increasing up to N_3 level (Appendix V and Figure1). The control treatment (N_0) took the maximum days (11.33days) for 1stemergence whereas, the minimum days (9.43 days) was taken by N_3 (200 kg N ha^{-1}). This result showed that 200 kg N ha^{-1} was the early emergence nitrogen levels whereas;control treatment was the late one. Emergence depends on soil moisture, soil temperature, seed temperature, disease and physiological age of seed. Fertilizer affects the plant when plant had root. Roots are being developed 10-15 days after emergence. This trend was supported by the trends of Eugenia (2008).

4.1.1.2 Effect of varieties

Significant variation of days to emergence was found due to different varieties (Appendix V and Figure 2). The minimum days to 1st emergence (9.65 days) was required in V_1 (Diamont) treatment and the maximum (11.25 days) was recorded

in $V_{\$}$ (BARI TPS-I). Yamaguchi *et al.* (1964); Manrique and Meyer (1984); Jalil (1995) and Collins (1977) also show similar trends of results in their studies.

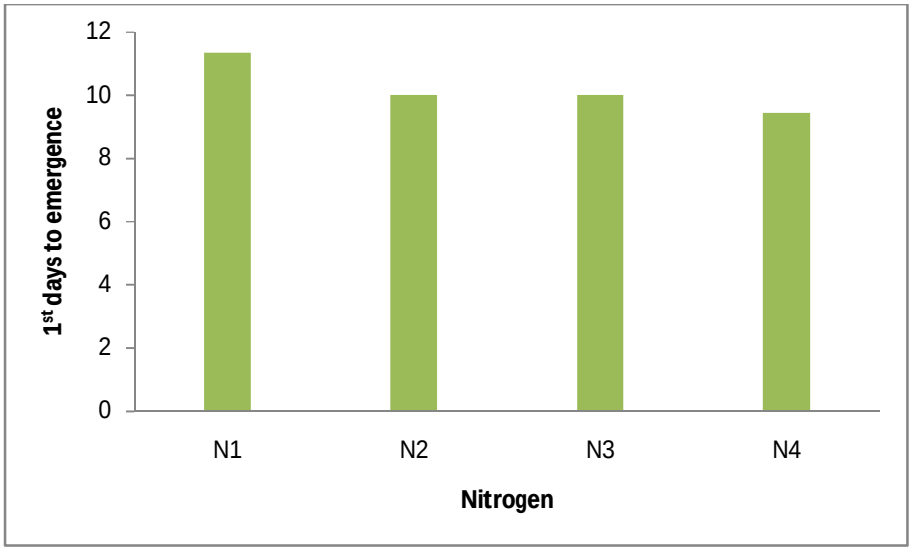

Figure 1. Effect of nitrogen on 1st days to emergence of potato (LSD value = 0.41)

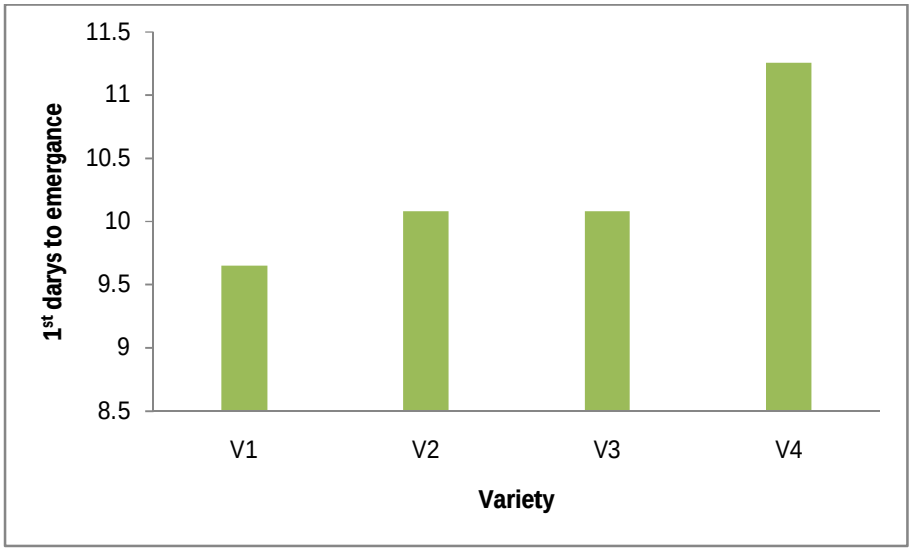

Figure 2. Effect of varieties on 1st days to emergence of potato (LSD value = 0.38)

4.1.1.3 Interaction effect of nitrogen and varieties

Interaction effect of nitrogen levels and varieties significantly influenced by days to 1st emergence of potato (Appendix V and Table 1). The minimum duration for

1st emergence (9 days) was recorded from the combination of '200 kg N ha-1withDiamont' treatment whereas, the maximum duration (15 days) was recorded from the combination of '0 kg N ha^{-1} with BARI TPS-I' treatment.

4.1.2 Days to final emergence (Visual observation)

4.1.2.1 Effect of nitrogen

Days to final emergence was significantly influenced by the application of different nitrogen levels, results revealed that, then duration of emergence decreased gradually with increasing the rate of nitrogen (Appendix V and Figure 3). The minimum days to final emergence (16.10 days) was required in N_3 (200 kg N ha^{-1}) treatment and the maximum (19.43 days) was recorded in N_0 (control treatment). This result showed that 250 kg N $ha^{-1}$was the early emergence nitrogen levels whereas; control treatment was the late one.

4.1.2.2 Effect of varieties

Days to final emergence was significantly influenced by the different varieties (Appendix V and Figure 4). Results revealed that V_4 (BARI TPS-I) took the maximum days (17.83days) for final emergence whereas, the minimum days (16.43days) was taken by V_1 (Diamont) treatment.

4.1.2.3 Interaction effect of nitrogen and varieties

Interaction effect of nitrogen levels and varieties significantly influenced the days taken to final emergence of potato (Appendix V and Table 1). The minimum duration for final emergence (15 days) was recorded from the combination of '200 kg N ha^{-1} with Diamont' treatment (N_3V_1). The maximum duration (22 days) was recorded from the combination of '0 kg N ha^{-1} with BARI TPS-I' (N_0V_4) treatment.

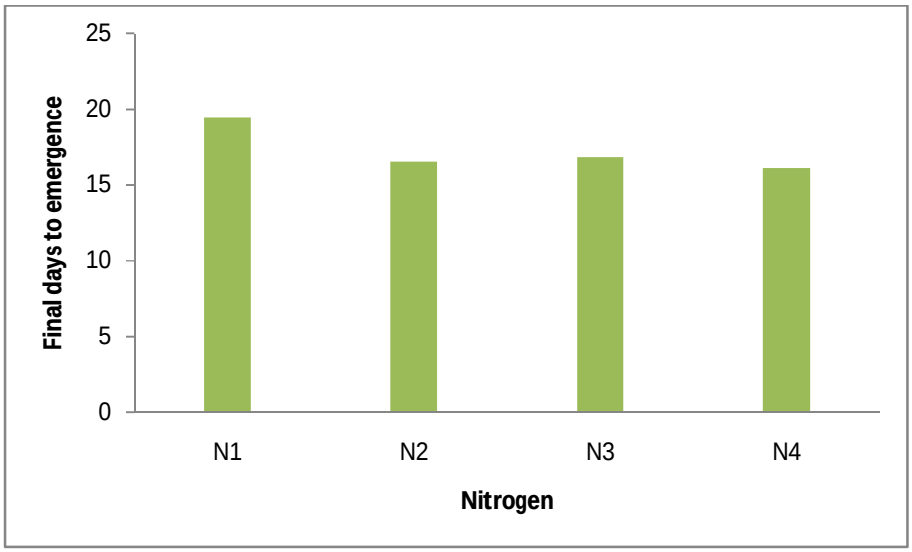

Figure 3. Effect of nitrogen on final days to emergence of potato (LSD value = 0.30)

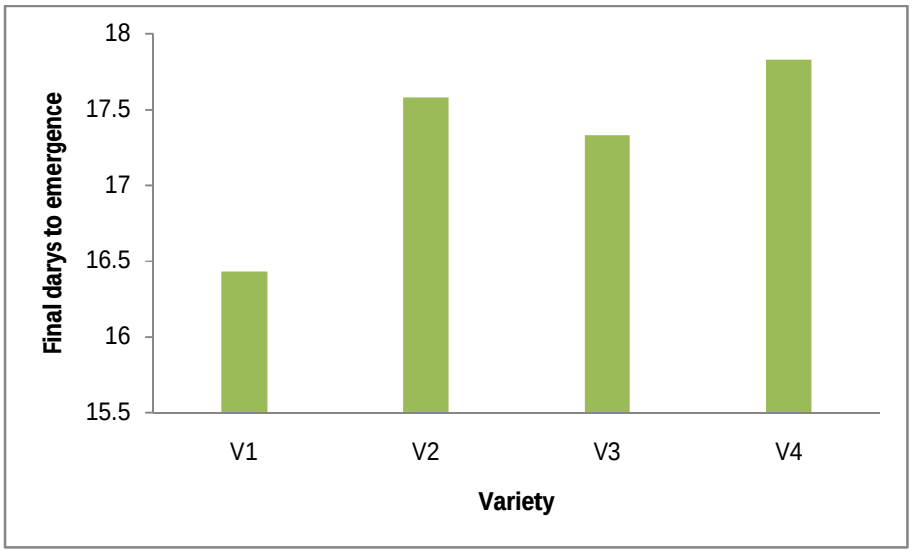

Figure 4. Effect of varieties on final days to emergence of potato (LSD value = 0.21)

Table 1. Interaction effect of nitrogen levels and varieties on 1st days to emergence and final days to emergence of potato

Treatments	1st days to emergence	Final days to emergence
N_0V_1	10.00 bc	17.70 c
N_0V_2	10.33 b	19.00 b
N_0V_3	10.00 bc	19.00 b
N_0V_4	15.00 a	22.00 a
N_1V_1	9.67 c	15.70 h
N_1V_2	9.67 c	15.70 h
N_1V_3	10.33 b	17.30 d
N_1V_4	10.33 b	17.30 d
N_2V_1	10.00 bc	16.30 g
N_2V_2	10.00 bc	17.30 d
N_2V_3	10.00 bc	16.70 f
N_2V_4	10.00 bc	17.00 e
N_3V_1	9.00 d	15.00 i
N_3V_2	10.33 b	17.30 d
N_3V_3	10.00 bc	16.30 g
N_3V_4	10.00 bc	17.00 e
$LSD_{(0.05)}$	0.44	0.24
CV (%)	3.61	1.55

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: N_0 – 0 kg ha^{-1}, N_1 –100 kg ha^{-1}, N_2 – 150 kg ha^{-1}, N_3 – 200 kg ha^{-1} and V_1 – Diamont, V_2 – Asterix, V_3 – Lady rosetta, V_4 – BARI TPS-I

4.1.3 Plant length

4.1.3.1 Effect of nitrogen

The plant length of potato was measured at 20, 40, 60 and 80 DAP. It was evident from Figure 5 and Appendix VI that the length of plant was significantly influenced by nitrogen at all the sampling dates. Figure 5 showed that plant length increased with advancing growing period irrespective of nitrogen, the potato plant length increased rapidly at the early stages of growth and rate of progression in length was slow at the later stages except control treatment. At 20 DAP, 200 kg N ha^{-1} treatment showed the longest plant (8.08 cm) whereas, the shortest plant (6.25 cm) was found from control treatment. At 40 DAP, 200 kg N ha^{-1} gave the highest plant length (35.25 cm) whereas, the lowest was recorded from control treatment (28.45 cm). At 60 and 80 DAP, 200 kg N ha^{-1} gave the highest plant length (67.40 and 76.06 cm, respectively) whereas, the lowest length was recorded from control

treatment (57.21 and 59.91 cm, respectively). Plant height of a crop depends on the plant vigor, cultural practices, growing environment and agronomic management. In the present experiment since potato was grown in the same environment and were given same cultural practices except nitrogen fertilization. So, the variation of plant height might be due to the effect different level of nitrogen fertilization.

4.1.3.2 Effect of varieties

Significant variation of plant length was found due to different varieties in all the studied durations (Appendix VI and Figure 6). At 20 DAP, the tallest plant (8.13 cm) was obtained from the'Diamont' varieties whereas, the shortest plant (6.30 cm) was obtained from the 'BARI TPS-I'varieties. At 40, 60 and 80 DAP, the tallest plant (34.85, 75.97 and 81.080 cm, respectively) was obtained from the 'BARI TPS-I' varieties whereas, the shortest plant (27.27, 48.13 and 53.16 cm, respectively) was obtained from the 'Lady rosetta' varieties.

4.1.3.3 Interaction effects of nitrogen and varieties

Significant Interaction effects of nitrogen and varieties on plant length was observed at 20, 40, 60 and 80 DAP (Appendix VI and Table 2). Plant length increased with advancing growing period irrespective of nitrogen and varieties. At 20 DAP, the tallest plant (8.90 cm) was obtained from the combination of '200 kg N ha^{-1} with Diamont' treatment (N_3V_1) and the shortest plant (6.10 cm) was obtained from the combination of '0 kg N ha^{-1} with Lady rosseta' (N_0V_3) treatment which was statistically identical with N_1V_4 (6.10 cm) and similar with N_0V_2 (6.20 cm). At 40, 60 and80 DAP, the highest plant length (39.90, 81.90 and 90.60 cm, respectively) was observed from the '200 kg N ha^{-1} with BARI TPS-I' treatment whereas, the shortest plant (24.20, 43.90 and 46.60 cm) was obtained from the combination of '0 kg N ha^{-1} with Lady rosseta' (N_0V_3) treatment.

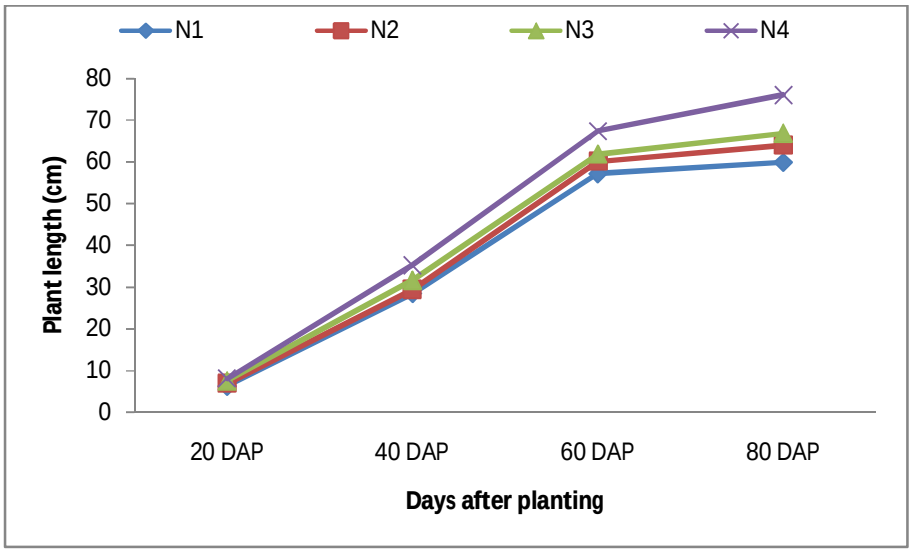

Figure 5. Effect of nitrogen on plant length (cm) of potato (LSD value = 0.32, 0.18, 0.65 and 0.46 at 20, 40, 60 and 80 DAP, respectively)

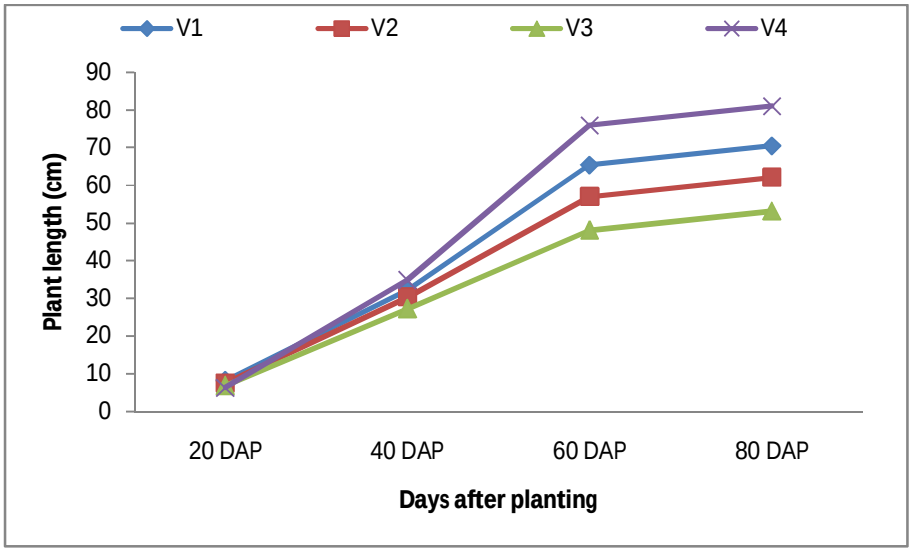

Figure 6. Effect of varieties on plant length (cm) of potato (LSD value = 0.21, 0.41, 0.75 and 0.78 at 20, 40, 60 and 80 DAP, respectively)

Table 2. Interaction effect of nitrogen levels and varieties on plant length of potato at different days after planting

Treatments	Plant length (cm) at			
	20 DAP	40 DAP	60 DAP	80 DAP
N_0V_1	7.20 e	29.20 i	60.33 i	63.03 h
N_0V_2	6.20 g	28.90 i	54.50 k	57.20 k
N_0V_3	6.10 g	24.20 l	43.90 n	46.60 n
N_0V_4	5.50 h	31.50 f	70.10 e	72.80 e
N_1V_1	7.90 d	30.90 gh	64.00 g	67.90 g
N_1V_2	7.20 e	28.80 i	55.50 j	59.40 j
N_1V_3	6.50 f	25.50 k	45.90 m	49.80 m
N_1V_4	6.10 g	32.70 e	75.00 c	78.90 d
N_2V_1	8.50 b	32.50 e	66.20 f	71.20 f
N_2V_2	8.20 c	30.50 h	56.20 j	61.20 i
N_2V_3	7.20 e	28.20 j	48.20 l	53.20 l
N_2V_4	6.50 f	35.30 c	76.90 b	81.90 b
N_3V_1	8.90 a	36.50 b	71.20 d	79.90 c
N_3V_2	8.50 b	33.40 d	62.00 h	70.70 f
N_3V_3	7.80 d	31.20 fg	54.50 k	63.03 h
N_3V_4	7.10 e	39.90 a	81.90 a	90.60 a
$LSD_{(0.05)}$	0.24	0.48	0.87	0.90
CV (%)	2.01	3.91	3.84	4.80

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: N_0 – 0 kg ha^{-1}, N_1 –100 kg ha^{-1}, N_2 – 150 kg ha^{-1}, N_3 – 200 kg ha^{-1} and V_1 – Diamont, V_2 – Asterix, V_3 – Lady rosetta, V_4 – BARI TPS-I

4.1.4 Number of leaves $plant^{-1}$

4.1.4.1 Effect of nitrogen

Different nitrogen levels exhibited significant variation in respect, results revealed that, the number of leaves $plant^{-1}$ of potato increased gradually with increased the rate of nitrogen upto 200 kg N ha^{-1} (N_3) at 20, 40, 60 and 80 DAP (Appendix VII and Figure 7). At 20, 40, 60 and 80 DAP, the maximum leaves number $plant^{-1}$ (12.27, 19.16, 31.81 and 40.83, respectively) was observed from the 200 kg N ha^{-1} (N_3) treatment and the minimum number (7.06, 12.04, 18.13 and 34.00, respectively) was observed from control treatment. The present study referred that 200 kg N ha^{-1} produced maximum number of leaves.

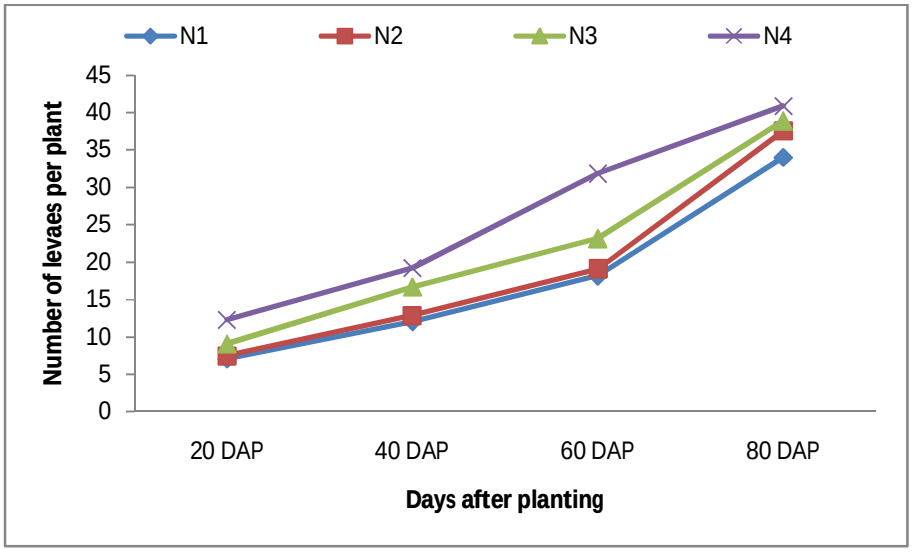

Figure 7. Effect of nitrogen on number of leaves per plant of potato (LSD value = 0.38, 0.49, 0.64 and 0.77 at 20, 40, 60 and 80 DAP, respectively)

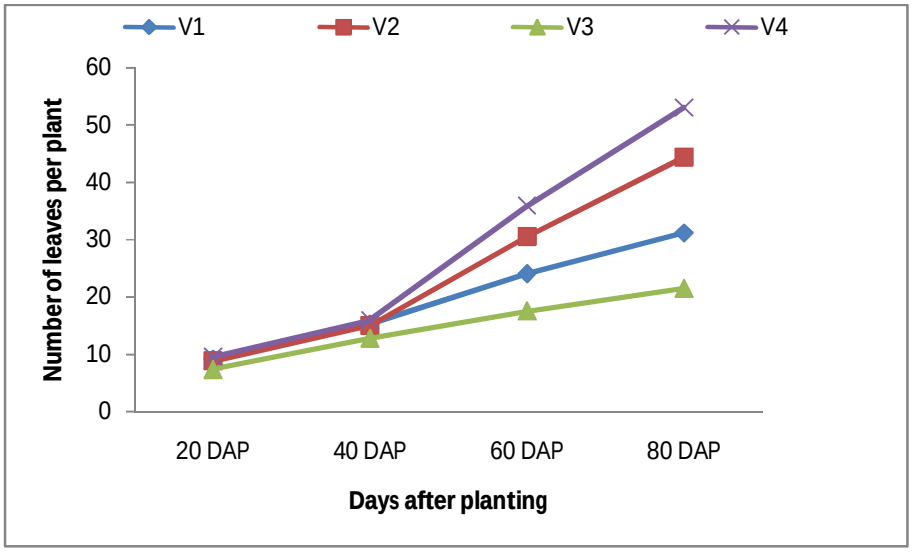

Figure 8. Effect of varieties on number of leaves per plant of potato (LSD value = 0.39, 0.40, 0.54 and 0.62 at 20, 40, 60 and 80 DAP, respectively)

4.1.4.2 Effect of varieties

The number of leaves plant^{-1} was significantly influenced by different varieties at 20, 40, 60 and 80 DAP (Appendix VII and Figure 8). The number of leaves plant^{-1} gradually increased with the advancement of plant age up to 60 DAPS and thereafter more/less remain static with advancing growing period, irrespective of different varieties materials. At 20, 40, 60 and 80 DAP, the maximum leaves number plant^{-1} (9.58, 16.02, 25.92 and 53.05, respectively) was observed from the 'BARI TPS-I' varieties and the minimum number (7.43, 12.83, 17.58 and 21.54, respectively) was observed from 'Lady rosetta' varieties. Among the different varieties, 'BARI TPS-I' showed better performance compared to those of other varieties, irrespective of all growing period.

4.1.4.3 Interaction effect of nitrogen and varieties

There was significant variation among the interaction of nitrogen and varieties on the total numbers of leaves plant^{-1}at 20, 40, 60 and 80 DAP (Appendix VII and Table 3). Number of leaves plant^{-1} increased with advancing growing period up to 80 DAP irrespective of nitrogen and varieties (Table 3). At 20, 40, 60 and 80 DAP, the maximum number of leaves plant^{-1} (13.50, 21.20, 37.90 and 61.50, respectively) was recorded with the combination of '200 kg N ha^{-1}with BARI TPA-I' treatment and the minimum (5.50, 10.50, 14.00 and 18.33, respectively) was recorded from the combination of '0 kg N ha^{-1} with Lady rosetta' treatment. Present study showed that 200 kg N ha^{-1}with BARI TPS-I produced maximum number of leaves.

Table 3. Interaction effect of nitrogen levels and varieties on number of leaves plant^{-1} of potato at different days after planting

Treatments	Number of leaves plant^{-1} at			
	20 DAP	40 DAP	60 DAP	80 DAP
N_0V_1	7.70 g	12.00 g	18.33 j	30.50 i
N_0V_2	7.20 h	14.33 e	20.50 h	50.50 d
N_0V_3	5.50 j	10.50 h	14.00 m	18.33 o
N_0V_4	8.33 ef	13.33 f	19.67 i	50.60 cd
N_1V_1	7.00 h	14.67 e	17.50 k	29.67 j
N_1V_2	8.33 ef	13.00 f	22.67 f	40.50 f
N_1V_3	6.50 i	12.00 g	15.67 l	20.33 n
N_1V_4	8.00 fg	11.67 g	20.50 h	45.50 e
N_2V_1	9.33 cd	15.67 d	25.00 e	26.20 k
N_2V_2	9.00 d	16.67 c	21.67 g	51.20 c
N_2V_3	8.50 e	15.50 d	19.33 i	22.50 m
N_2V_4	9.50 c	18.90 b	26.60 d	55.60 b
N_3V_1	11.60 b	19.90 b	36.50 b	39.50 g
N_3V_2	11.80 b	19.70 b	30.50 c	36.30 h
N_3V_3	10.20 cd	14.33 f	22.33 g	26.00 l
N_3V_4	13.50 a	21.20 a	37.90 a	61.50 a
$LSD_{(0.05)}$	0.39	0.40	0.54	0.62
CV (%)	2.65	1.56	1.40	1.98

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: N_0 – 0 kg ha^{-1}, N_1 –100 kg ha^{-1}, N_2 – 150 kg ha^{-1}, N_3 – 200 kg ha^{-1} and V_1 – Diamont, V_2 – Asterix, V_3 – Lady rosetta, V_4 – BARI TPS-I

4.1.5 Number of stems hill^{-1}

4.1.5.1 Effect of nitrogen

The number of stems hill^{-1} was significantly varied among the nitrogen levels at 20, 40, 60 and 80 DAP (Appendix VIII and Figure 9). Number of stems hill^{-1} increased with advancing growing period up to 100 DAP irrespective of nitrogen and shown that number of stems hill^{-1} increasing with increasing the rate of nitrogen continued up to N_3 level (Figure 9). At 20, 40, 60 and 80 DAP, the maximum stem numbers hill^{-1} (1.57, 2.58, 3.38 and 3.83, respectively) was obtained from 200 kg N ha^{-1}(N_3) treatment and the minimum (1.00, 1.92, 2.67 and 2.80, respectively) was obtained from control treatment. The study referred that 200 kg N ha^{-1} produced maximum number of stem hill^{-1}. This might be due to nitrogen fertilization.

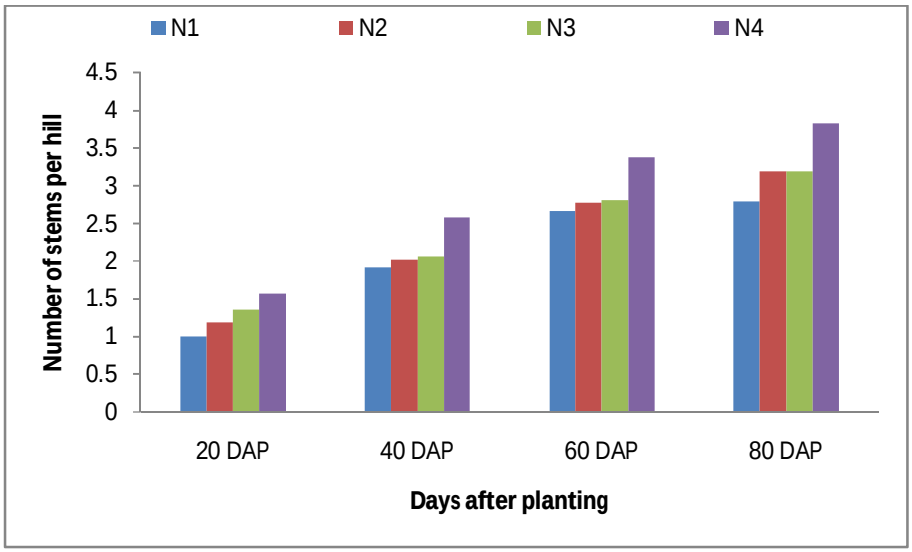

Figure 9. Effect of nitrogen on number of stems hill^{-1} of potato (LSD value = 0.15, 0.20, 0.22 and 0.17 at 20, 40, 60 and 80 DAP, respectively)

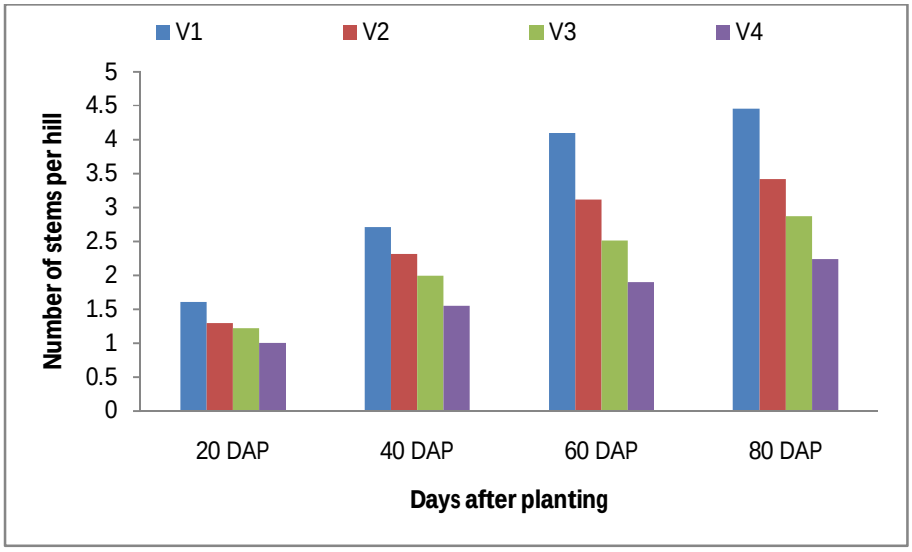

Figure 10. Effect of varieties on number of stems hill^{-1} of potato (LSD value = 0.20, 0.20, 0.19 and 0.13 at 20, 40, 60 and 80 DAP, respectively)

4.1.5.2 Effect of varieties

Different varieties significantly affected the number of stems hill^{-1} of potato at 20, 40, 60 and 80 DAP (Appendix VIII and Figure 10). Number of stems hill^{-1} increased with advancement of age (Figure 10). At 20, 40, 60 and 80 DAP, the maximum number of stems hill^{-1} (1.61, 2.71, 4.10 and 4.46, respectively) was recorded from 'Diamont' (V_1) varietieswhereas, the minimum (1.00, 1.55, 1.90 and 2.24, respectively) was counted from 'BARI TPS-I' (V_4) varieties. Present study showed that 'Diamont' varieties produced maximum number of stems hill^{-1} compare to other varieties in all growing stage.

4.1.5.3 Interaction effect of nitrogen and varieties

Interaction effect of nitrogen and varieties significantly influenced the stem numbers hill^{-1} (Appendix VIII and Table 4). At 20 DAP, the maximum number of stems hill^{-1} (2.24) was recorded from the combination of '200 kg N ha^{-1}with Diamont' (N_3V_1) and the minimum number (1.00) of stems hill^{-1} was recorded from the '0 kg N ha^{-1} with BARI TPS-I' (N_0V_4) treatment which was statistically identical with N_0V_1(1.00), N_0V_2(1.00), N_0V_3(1.00), N_1V_2(1.00), N_1V_3(1.00), N_1V_3(1.00), N_2V_4 (1.00), N_3V_4 (1.00) andstatistically similar with N_2V_3(1.11), N_3V_3 (1.24). At 40, 60 and 80 DAP, the maximum number (3.20, 4.60 and 5.10, respectively) of stems hill^{-1} was counted from the combination of '200 kg N ha^{-1} with Diamont' (N_3V_1) treatment whereas, the minimum number (1.00, 1.30 and 1.50, respectively) was counted from the combination of '0 kg N ha^{-1} with BARI TPS-I' (N_0V_4) treatment.

Table 4. Interaction effect of nitrogen levels and varieties on number of stems hill^{-1} of potato at different days after planting

Treatments	Number of stems hill^{-1} at			
	20 DAP	40 DAP	60 DAP	80 DAP
N_0V_1	1.00 e	2.49 b-d	3.87 c	4.00 d
N_0V_2	1.00 e	2.30 de	3.10 e	3.20 f
N_0V_3	1.00 e	1.89 gh	2.40 f	2.50 i
N_0V_4	1.00 e	1.00 j	1.30 i	1.50 k
N_1V_1	1.33 d	2.70 b	4.10 b	4.50 b
N_1V_2	1.00 e	2.20 ef	3.00 e	3.40 e
N_1V_3	1.00 e	1.67 hi	2.17 g	2.67 h
N_1V_4	1.00 e	1.50 i	1.80 h	2.20 j
N_2V_1	2.00 b	2.44 d	3.84 c	4.24 c
N_2V_2	1.33 d	2.10 e-g	2.90 e	3.20 f
N_2V_3	1.11 e	2.00 fg	2.50 f	2.90 g
N_2V_4	1.00 e	1.70 hi	2.00 gh	2.40 i
N_3V_1	2.24 a	3.20 a	4.60 a	5.10 a
N_3V_2	1.56 c	2.67 bc	3.47 d	3.89 d
N_3V_3	1.24 de	2.45 cd	2.95 e	3.45 e
N_3V_4	1.00 e	2.00 fg	2.50 f	2.87 g
$LSD_{(0.05)}$	0.23	0.23	0.22	0.15
CV (%)	10.90	6.28	4.47	2.77

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: N_0 – 0 kg ha^{-1}, N_1 –100 kg ha^{-1}, N_2 – 150 kg ha^{-1}, N_3 – 200 kg ha^{-1} and V_1 – Diamont, V_2 – Asterix, V_3 – Lady rosetta, V_4 – BARI TPS-I

4.1.6Above ground stem dry matter content (%)

4.1.6.1 Effect of nitrogen

Above ground stem dry matter content (%) significantly influenced by nitrogen at 20, 40, 60, 80 DAP and harvest (Appendix IX and Figure 11). At 20, 40, 60, 80 DAP and harvest, 200 kg N ha^{-1} produced higher stem dry matter content (7.99, 9.54, 13.90, 15.64 and 18.57 %, respectively) whereas, the minimum (5.73, 6.74, 9.74, 12.03 and 13.20 %, respectively) was recorded from the control treatment followed by 200 kg N ha^{-1} (10.27 %).This might be due to the effect of nitrogen fertilization.

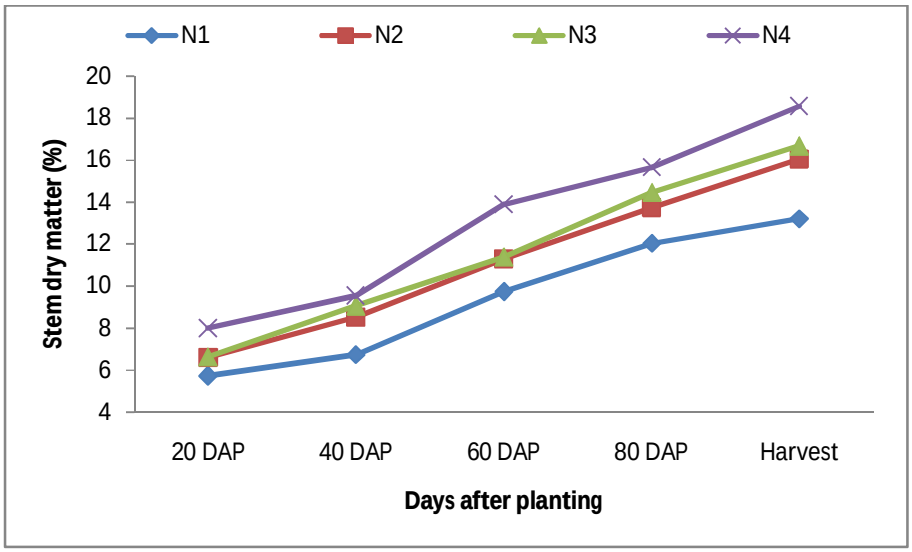

Figure 11. Effect of nitrogen on stem dry matter (%) of potato (LSD value = 0.28, 0.20, 0.33, 0.29 and 0.20 at 20, 40, 60, 80 DAP and harvest, respectively)

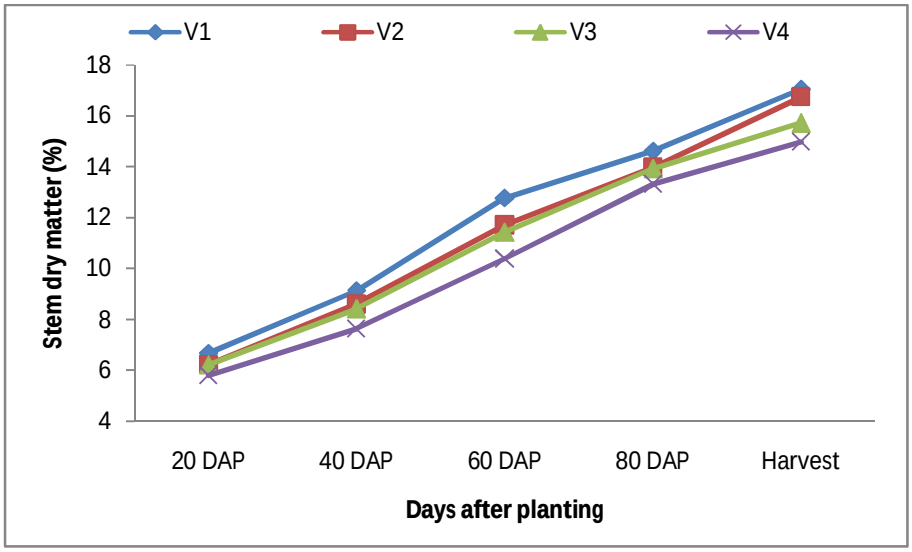

Figure 12. Effect of varieties on stem dry matter (%) of potato (LSD value = 0.23, 0.33, 0.36, 0.33 and 0.24 at 20, 40, 60, 80 DAP and harvest, respectively)

4.1.6.2 Effect of varieties materials

Dry matter content of above ground stem varied significantly with different varieties at 20, 40, 60, 80 DAP and harvest (Appendix IX and Figure 12). At 20, 40, 60, 80DAP and harvest, the maximum stem dry matter content (6.68, 9.15, 12.77, 14.62 and 17.05 %, respectively) was produced from the 'Diamont' varieties while, the minimum (5.81, 7.65, 10.39, 13.33 and 14.97%, respectively)

was found from the 'BARI TPS-I' varieties. Present study showed that stem dry matter content (%) of potato was statistically affected up to 'Diomant'varieties to others.

4.1.6.3 Interaction effect of nitrogen and varieties

Interaction effect of nitrogen and varieties influenced the above ground stem dry matter content at 20, 40, 60, 80 DAP and harvest (Appendix IX and Table 5). At 20, 40, 60, 80 DAP and harvest, it was observed that the maximum dry matter content of above ground stem (8.79, 10.50, 15.72, 16.68 and 19.23 %, respectively) was obtained from the combination of'200 kg N $ha^{-1}$with Diamont' treatment whereas, the minimum (4.51, 5.61, 8.89, 11.38 and 11.78%, respectively) was recorded from thecombination of '0 kg N ha^{-1} with BARI TPS-I' treatment.

Table 5. Interaction effect of nitrogen levels and varieties on stem dry matter (%) of potato at different days after planting

Treatments	Stem dry matter (%) at				
	20 DAP	40 DAP	60 DAP	80 DAP	Harvest
N_0V_1	6.73 d	7.72 h	10.37 f	12.38 g	14.39 h
N_0V_2	5.18 h	7.03 i	10.19 f	12.37 g	14.37 h
N_0V_3	6.50 de	6.61 j	9.51 g	12.01 g	12.27 i
N_0V_4	4.51 i	5.61 k	8.89 h	11.38 h	11.78 j
N_1V_1	5.20 h	9.47 cd	12.51 c	14.75 c	18.20 c
N_1V_2	5.77 g	7.77 gh	11.25 e	13.44 f	17.30 d
N_1V_3	5.23 h	8.41 f	11.17 e	13.44 f	15.83 f
N_1V_4	6.24 ef	8.38 f	10.24 f	13.29 f	15.37 g
N_2V_1	6.00 fg	8.89 e	12.49 c	14.67 cd	16.39 e
N_2V_2	5.91 g	9.98 b	11.38 e	14.35 de	16.37 e
N_2V_3	5.24 h	9.21 de	11.24 e	14.52 c-e	16.03 f
N_2V_4	5.39 h	8.14 fg	10.43 f	14.29 e	15.37 g
N_3V_1	8.79 a	10.50 a	15.72 a	16.68 a	19.23 a
N_3V_2	8.08 b	9.67 bc	14.06 b	15.79 b	18.94 b
N_3V_3	8.00 b	9.53 cd	13.83 b	15.73 b	18.74 b
N_3V_4	7.10 c	8.47 f	11.98 d	14.35 de	17.38 d
$LSD_{(0.05)}$	0.27	0.38	0.41	0.38	0.28
CV (%)	2.58	2.66	2.12	1.61	1.03

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: N_0 – 0 kg ha^{-1}, N_1 –100 kg ha^{-1}, N_2 – 150 kg ha^{-1}, N_3 – 200 kg ha^{-1} and V_1 – Diamont, V_2 – Asterix, V_3 – Lady rosetta, V_4 – BARI TPS-I

4.2 Yield and yield components

4.2.1 Number of tubers hill^{-1}

4.2.1.1 Effect of nitrogen

Number of tubers hill^{-1} significantly influenced by the nitrogen (Appendix X and Table 6). The maximum number of tubers hill^{-1} (8.76) was recorded from 150 kg N ha^{-1} and the minimum (6.49) was found from the control treatment (N_0).

4.2.1.2 Effect of varieties

Number of tubers hill^{-1} significantly influenced by different varieties (Appendix IX and Table 7). The maximum number of tubers hill^{-1} (8.33) was produced from the 'Diamont' varieties (V_1) whereas, the minimum (7.22) was counted from the 'BARI TPS-I' varieties (V_4) treatment. Present study showed that tuber numbers increased with 'Diamont' varieties and increased the size of tuber. Thus the increased sized tuber influenced on total yield of tuber.

4.2.1.3 Interaction effect of nitrogen and varieties

Interaction effect of nitrogen and varieties showed significant variation in respect of number of tubers hill^{-1} (Appendix X and Table 8). The maximum number of tubers hill^{-1} (9.20) was recorded from the combination of '150 kg N ha^{-1} with Diamont' (N_2V_1) treatment whereas, the minimum (5.65) was recorded from the combination of '0 kg N ha^{-1} with BARI TPS-I' (N_0V_4) treatment.

4.2.2 Average tuber weight (g)

4.2.2.1 Effect of nitrogen

The average tuber weight varied significantly due to different nitrogen levels (Appendix X and Table 6). The maximum average tuber weight (58.94 g) was recorded from 150 kg N ha^{-1} whereas, the minimum (44.18 g) was obtained from the control treatment.

4. 2.2.2 Effect of varieties

The average tuber weight significantly affected by the different varieties (Appendix X and Table 7). The highest average tuber weight (62.65 g) was recorded from the 'Diamont' varieties (V_1) treatment and the lowest (34.36 g) was recorded from the 'BARI TPS-I' varieties(V_4).

4.2.2.3 Interaction effect of nitrogen and varieties

Interaction of nitrogen and varieties had significant effect on average tuber weight (Appendix IX and Table 8). The maximum average tuber weight(85.65 g) was recorded from the combination of 150 kg N $ha^{-1}$with 'Diamont' varieties (N_2V_1) treatment whereas, the minimum (31.52 g) was recorded from the combination of 0 kg N ha^{-1} with 'BARI TPS-I' varieties (N_0V_4) treatment.

Table 6. Effect of nitrogen levels on number of tubers hll^{-1}, average tuber weight and yield of potato

Nitrogen levels	Number of tubers $hill^{-1}$	Average tuber weight (g)	Yield (ton ha^{-1})
N_0	6.49 c	48.85 c	18.97 d
N_1	7.81 b	44.18 d	22.53 c
N_2	8.76 a	58.94 a	26.66 a
N_3	7.91 b	49.74 b	24.63 b
$LSD_{(0.05)}$	0.30	0.50	0.52
CV (%)	2.34	1.55	1.94

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability
Note: N_0 – 0 kg ha^{-1}, N_1 –100 kg ha^{-1}, N_2 – 150 kg ha^{-1} and N_3 – 200 kg ha^{-1}

Table 7. Effect of varieties on number of tubers hll^{-1}, average tuber weight and yield of potato

Varieties	Number of tubers $hill^{-1}$	Average tuber weight (g)	Yield (ton ha^{-1})
V_1	8.33 a	62.65 a	25.83 a
V_2	7.84 b	54.70 b	24.03 b
V_3	7.58 b	50.00 c	22.16 c
V_4	7.22 c	34.36 d	20.75 d
$LSD_{(0.05)}$	0.27	0.40	0.32
CV (%)	2.34	1.55	1.94

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability
Note: V_1 – Diamont, V_2 – Asterix, V_3 – Lady rosetta and V_4 – BARI TPS-I

Table 8. Interaction effect of nitrogen levels and varieties on number of tubers hll^{-1}, average tuber weight and yield of potato

Treatments	Number of tubers hill^{-1}	Average tuber weight (g)	Yield (ton ha^{-1})
N_0V_1	7.06 fg	58.69 c	22.48 g
N_0V_2	6.76 gh	56.51 d	20.38 i
N_0V_3	6.50 h	48.67 g	17.52 k
N_0V_4	5.65 i	31.52 m	15.48 l
N_1V_1	8.56 b	48.00 h	25.60 e
N_1V_2	7.94 c	48.40 gh	23.47 f
N_1V_3	7.53 d	46.42 i	21.57 h
N_1V_4	7.20 ef	33.92 l	19.48 j
N_2V_1	9.20 a	85.65 a	28.45 a
N_2V_2	8.67 b	59.50 b	26.40 c
N_2V_3	8.60 b	54.09 e	26.10 cd
N_2V_4	8.56 b	36.51 j	25.67 e
N_3V_1	8.50 b	58.27 c	26.80 b
N_3V_2	8.00 c	54.38 e	25.89 de
N_3V_3	7.70 cd	50.83 f	23.47 f
N_3V_4	7.45 de	35.49 k	22.35 g
$LSD_{(0.05)}$	0.31	0.47	0.37
CV (%)	2.34	1.55	1.94

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: N_0 – 0 kg ha^{-1}, N_1 –100 kg ha^{-1}, N_2 – 150 kg ha^{-1}, N_3 – 200 kg ha^{-1} and V_1 – Diamont, V_2 – Asterix, V_3 – Lady rosetta, V_4 – BARI TPS-I

4.2.3 Yield (t ha^{-1})

4.2.3.1 Effect of nitrogen

Nitrogen levels had significant effect on the yield of tuber ha^{-1} (Appendix X and Table 6). The highest tuber yield ha^{-1} (26.66 t ha^{-1}) was obtained from 150 kg N ha^{-1} while, the minimum (18.97 t ha^{-1}) was found from the control treatment.

4.2.3.2 Effect of varieties

Yield of tuber ha^{-1} was significantly affected by different varieties(Appendix X and Table 7). The highest tuber yield ha^{-1} (25.83t ha^{-1}) was recorded from the 'Diamont' varieties (V_1) and the minimum (20.75 t ha^{-1}) was recorded from the 'BARI TPS-I' varieties(V_4).

4.2.3.3 Interaction effect of nitrogen and varieties

Interaction between nitrogen and varieties played an important role for promoting the yield. Yield of tuber ha^{-1} was significantly influenced by the Interaction effects of nitrogen and varieties (Appendix X and Table 8). Among the treatments, the highest yield of tuber ha^{-1} was observed in 150 kg N ha^{-1} and 'Diamont' varieties (N_2V_1) treatment (28.45 t ha^{-1})whereas, the minimum (15.48t ha^{-1}) was found from the 0 kg N ha^{-1} and 'BARI TPS-I' varieties (N_0V_4) treatment.

4.3 Quality parameter

4.3.1 Tuber flesh dry matter (%)

4.3.1.1 Effect of nitrogen

Tuber flesh dry matter content showed significant variations among the different levels nitrogen (Appendix XI and Table 9). The maximum dry matter content of tuber flesh (22.08 %) was recorded from 150 kg N ha^{-1}. The minimum tuber flesh dry matter content (14.86 %) was recorded from the control treatment. The variation in dry matter content among the potato with nitrogen was also observed by Suyre*et al.* (1975), Lana *et al.* (1970) and Capezio (1987). Variation in tuber dry matter content may be attributed to nitrogen uptake difference in the production of total solids. Dry matter content is subjected to the influence of both the environment and cultural practice (Miller *et al.*, 1975; Tai and Coleman, 1999).

4.3.1.2 Effect of varieties

Dry matter content of tuber flesh diverse significantly with different varieties (Appendix XI and Table 10). The maximum dry matter content (20.28 %) was obtained from the 'Lady rosetta' varieties (V_3) and the minimum (17.24 %) was found from the 'BARI TPS-I' varieties.

4.3.1.3 Interaction effect of nitrogen and varieties

Interaction effect of different nitrogen levels and varieties significantly influenced the dry matter content (%) of tuber flesh (Appendix XI and Table 11). The maximum dry matter content of tuber flesh (24.52 %) was obtained from the combination of 150 kg N ha^{-1} with 'Lady rosetta' varieties (N_2V_3) whereas, the minimum (13.76%) was obtained from the combination of 0 kg N ha^{-1} with 'BARI TPS-I' varieties (N_0V_4).

4.3.2 Specific gravity

4.3.2.1 Effect of nitrogen

In present study nitrogen had significant effect on specific gravity (Appendix XI and Table 9). The highest specific gravity (1.09 g cm^{-3}) was obtained from 150 kg N ha^{-1} (N_2) which was statistically similar N_1 (1.07 g cm^{-3}), N_3 (1.06 g cm^{-3}) whereas, the lowest (1.04 g cm^{-3}) specific gravity was found from the control (N_0) treatment.

4.3.2.2 Effect of varieties

Different varieties showed significant effect on the specific gravity (Appendix XI and Table 10). Highest specific gravity (1.10 g cm^{-3}) was found from the 'Lady rosetta' varieties (V_3) which was statistically identical V_2 (1.08 g cm^{-3}) while the lowest (1.04 g cm^{-3}) was obtained from the 'BARI TPS-1'varieties(V_4).

4.3.2.3 Interaction effect of nitrogen and varieties

Specific gravity differed significantly due to Interaction effect of nitrogen and varieties (Appendix XII and Table 11). 150 kg N ha^{-1} with 'Lady rosetta' varieties (N_2V_3) treatment combinations showed the maximum specific gravity (1.12g cm^{-3}) while the minimum (1.01 g cm^{-3}) was recorded from the combination of N_0V_4 (0 kg N ha^{-1} with 'BARI TPS-I'varieties).

Table 9. Effect of nitrogen levels on flesh dry matter (%), specific gravity, total soluble solid, firmness and starch of potato

Nitrogen levels	Flesh dry matter (%)	Specific gravity (g cm^{-3})	Total soluble solids	Firmness	Starch (%)
N_0	14.86 d	1.04 c	4.58 c	32.34 a	5.55 c
N_1	19.07 b	1.07 b	5.13 b	31.24 b	11.25 b
N_2	22.08 a	1.09 a	5.58 a	25.50 d	14.01 a
N_3	18.70 c	1.06 b	5.15 b	28.42 c	11.10 b
$LSD_{(0.05)}$	0.18	0.02	0.20	0.09	0.21
CV (%)	3.57	1.20	2.58	2.27	1.22

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: N_0 – 0 kg ha^{-1}, N_1 –100 kg ha^{-1}, N_2 – 150 kg ha^{-1} and N_3 – 200 kg ha^{-1}

Table 10. Effect of varieties on flesh dry matter (%), specific gravity, total soluble solid, firmness and starch of potato

Varieties	Flesh dry matter (%)	Specific gravity (g cm^{-3})	Total soluble solids	Firmness	Starch (%)
V_1	17.92 c	1.06 c	4.98 c	28.60 c	8.03 c
V_2	19.27 b	1.08 b	5.33 b	27.22 d	13.63 b
V_3	20.28 a	1.10 a	5.58 a	32.82 a	15.36 a
V_4	17.24 d	1.04 d	4.55 d	28.86 b	4.91 d
$LSD_{(0.05)}$	0.15	0.01	0.19	0.11	0.19
CV (%)	3.57	1.20	2.58	2.27	1.22

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability
Note: V_1 – Diamont, V_2 – Asterix, V_3 – Lady rosetta and V_4 – BARI TPS-I

4.3.3 Total soluble solids (TSS) (% Brix)

4.3.3.1 Effect of nitrogen

Nitrogen levels differed significantly between themselves regarding TSS (Appendix XI and Table 9). The maximum TSS (5.58 %) was recorded from 150 kg N ha^{-1} (N_2) whereas; the minimum (4.58 %) was obtained from the control treatment. Study referred that the 150 kg N ha^{-1} expressed best result in terms of TSS.

4.3.3.2 Effect of varieties

Different varieties had significant effect on TSS of potato (Appendix XI and Table 10). The maximum TSS (5.58 %) was found from the 'Lady rosetta' varietieswhich was statistically identical V_2 (5.33 %) and the minimum (4.55 %) was found from the 'BARI TPS-I' varieties.

4.3.3.3 Interaction effect of nitrogen and varieties

It was found that TSS was affected significantly due to theinteraction of nitrogen and varieties (Appendix XI and Table 11). The highest TSS (6.00 %) was recorded from the combination of 150 kg N ha^{-1} with 'Lady rosetta' varieties (N_2V_3) which was statistically similar N_2V_2 (5.70 %) and N_3V_2 (5.70 %) whereas, the minimum (4.10 %) was found from N_0V_4 treatment.

Table 11. Interaction effect of nitrogen levels and varieties on flesh dry matter (%), specific gravity, total soluble solid, firmness and starch of potato

Treatments	Flesh dry matter (%)	Specific gravity (g cm^{-3})	Total soluble solids	Firmness	Starch (%)
N_0V_1	14.11 l	1.04 f	4.50 f	30.18 e	5.00 f
N_0V_2	15.33 k	1.05 ef	4.70 ef	27.28 k	5.60 e
N_0V_3	16.25 j	1.06 de	5.00 d	37.78 a	7.60 d
N_0V_4	13.76 m	1.01 g	4.10 g	34.11 c	4.01 g
N_1V_1	18.17 h	1.06 de	4.80 de	29.59 g	7.60 d
N_1V_2	19.64 f	1.08 c	5.60 b	28.15 j	14.50 c
N_1V_3	20.74 d	1.10 b	5.60 b	35.28 b	17.90 a
N_1V_4	17.72 i	1.04 f	4.50 f	31.92 d	5.01 f
N_2V_1	21.10 c	1.08 c	5.60 b	25.47 m	14.50 c
N_2V_2	22.88 b	1.10 b	5.70 b	27.16 k	17.90 a
N_2V_3	24.52 a	1.12 a	6.00 a	28.35 i	18.05 a
N_2V_4	19.84 e	1.05 ef	5.00 d	21.02 n	5.60 e
N_3V_1	18.30 h	1.04 f	5.00 d	29.15 h	5.00 f
N_3V_2	19.23 g	1.07 cd	5.30 c	26.27 l	16.50 b
N_3V_3	19.61 f	1.10 b	5.70 b	29.88 f	17.90 a
N_3V_4	17.66 i	1.04 f	4.60 ef	28.38 i	5.01 f
$LSD_{(0.05)}$	0.18	0.02	0.22	0.13	0.21
CV (%)	3.57	1.20	2.58	2.27	1.22

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: N_0 – 0 kg ha^{-1}, N_1 –100 kg ha^{-1}, N_2 – 150 kg ha^{-1}, N_3 – 200 kg ha^{-1} and V_1 – Diamont, V_2 – Asterix, V_3 – Lady rosetta, V_4 – BARI TPS-I

4.3.4 Firmness of potato

4.3.4.1 Effect of nitrogen

Firmness of potato showed statistically significant variation for different nitrogen levels under the present study (Appendix XI and Table 9). The highest (32.34 %) firmness of potato was found from the control treatment, whereas minimum (25.50 %) was recorded from 150 kg N ha^{-1} treatment.

4.3.4. 2 Effect of varieties

Firmness of potato showed statistically significant variation for different varieties under the present study (Appendix XIand Table 10). The highest (32.82 %) firmness of potato was found from the ‘Lady rosetta’ varieties, whereas minimum (28.60 %) was recorded from ‘Diamont’ varieties.

4.3.4.3 Interaction effects of nitrogen and varieties

Firmness of potato showed statistically significant variation for different nitrogen levels and varieties under the present study (Appendix XI and Table 11). The highest (37.78 %) firmness of potato was found from N_0V_3 treatment, whereas minimum (21.02 %) was recorded from in N_2V_4 treatment.

4.3.5 Starch content (%)

4.3.5.1 Effect of nitrogen

Starch content (%) of potato showed statistically significant variation for different nitrogen levels under the present study (Appendix XI and Table 9). The maximum (14.01 %) starch of potato was found from N_2treatment, whereas minimum (5.55 %) was recorded from N_0 treatment.

4.3.5.2Effect of varieties

Starch content (%) of potato showed statistically significant variation for different varieties under the present study (Appendix XI and Table 10). The maximum (15.36 %) starch of potato was found from the 'Lady rosetta' varieties, whereas minimum (4.91 %) was recorded from 'BARI TPS-I' varieties. Its percentage varied both with varieties and environment (Gall *et al.*, 1965); however, several other factors, including environmental conditions, and cultural practices during growth are also important (Kumar *et al.*, 2004). Specific gravity showed a positive correlation with starch content (Feltran*et al.*, 2004). Starch content was proportional to the dry matter (Uppal, 1999). Since the dry matter content of potato tuber is mostly dependent on starch (Dean and Thornton, 1992).Starch content is influenced by genotypes and it was found to be positively correlated to dry matter and specific gravity(Abbas *et al.*, 2011). The differences in starch content and its component among the cultivars may be due to difference in morphology of tubers as well as internal distribution of nutrients(Kroner and Volksen, 1950; Talburt and Smith, 1975), due to their differential root absorption

pattern and translocation to aerial parts, finally distribution to potato tubers for theirvarious metabolic activities (Sood*et al.,* 2008).

4.3.5.3Interaction effects of nitrogen and varieties

Starch content (%) of potato showed statistically significant variation for different nitrogen levels and varieties under the present study (Appendix XI and Table 12). The highest (18.05 %) starch of potato was found from N_2V_3 treatment, whereas minimum (4.01 %) was recorded from in N_0V_4 treatment.

4.3.6Skin color (L*, a*, b*, hue angle and chroma) of potato

4.3.6.1 Effect of nitrogen

Skin color (L*, a*, b*, hug angle and chroma) of potato showed statistically significant variation for different nitrogen levels under the present study (Appendix XII and Table 12). The maximum (67.22 %) skin color 'L*' was found from 150 kg N ha^{-1} treatment, whereas minimum (63.40 %) was recorded from the control treatment. The maximum (2.85 %) skin color 'a*' was found from 150 kg N ha^{-1} treatment, whereas minimum (-1.50 %) was recorded from the control treatment. The maximum (20.15 %) skin color 'b*' was found from 150 kg N ha^{-1} treatment, whereas minimum (10.35 %) was recorded from the control treatment.

Chroma and hue angle were significantly affected by varieties. Among N_2 treatment, the chroma (20.64) was the highest and lowest was exhibited in N_1 (15.75) treatment. It was observed that N_3 treatment had the highest hue angle (7.48), while the minimum and negative value (-7.08) for hue angle was noted for N_0 treatment.

4.3.6.2 Effect of varieties

Skin color (L*, a*, b*, hug angle and chroma) of potato showed statistically significant variation for different varieties under the present study (Appendix XII and Table 13). The maximum (70.95 %) skin color 'L*' was found from the 'Asterix' varieties, whereas minimum (58.40 %) was recorded from the 'Diamont'

varieties. The maximum (4.05 %) skin color 'a*' was found from the 'Asterix' varieties, whereas minimum (-1.58 %) was recorded from the 'Diamont' varieties. The maximum (22.70 %) skin color 'b*' was found from the 'Asterix' varieties, whereas minimum (8.53 %) was recorded from the 'Diamont' varieties.

Chroma and hue angle were significantly affected by varieties. Among the varieties the chroma of 'Astarix' (23.10) was the highest and lowest was exhibited in 'Diamont' (14.26). It was observed that 'Asterix' had the highest hue angle (9.88), while the minimum and negative value (-6.45) for hue angle was noted for 'Diamont'.

Table 12. Effect of nitrogen levels on skin color (L*, a*, b*, huc angle and chroma) of potato

Nitrogen levels	L*	a*	b*	Huc angle	Chroma
N_0	63.40 c	-1.50 d	10.35 d	-7.08 d	16.08 c
N_1	66.00 b	-1.28 c	16.20 c	-6.78 c	15.75 d
N_2	67.22 a	2.85 a	20.15 a	7.01 b	20.64 a
N_3	66.40 b	2.58 b	18.30 b	7.48 a	18.53 b
$LSD_{(0.05)}$	0.77	0.22	0.43	0.11	0.23
CV (%)	0.90	20.67	4.32	4.67	2.78

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability
Note: N_0 – 0 kg ha^{-1}, N_1 –100 kg ha^{-1}, N_2 – 150 kg ha^{-1} and N_3 – 200 kg ha^{-1}

Table 13. Effect of varieties on skin color (L*, a*, b*, huc angle and chroma) of potato

Varieties	L*	a*	b*	Huc angle	Chroma
V_1	58.40 d	-1.58 d	8.53 d	-6.45 d	14.26 d
V_2	70.95 a	4.05 a	22.70 a	9.88 a	23.10 a
V_3	69.18 b	0.85 b	18.27 b	1.40 b	18.32 b
V_4	64.50 c	-0.68 c	15.50 c	-4.20 c	15.32 c
$LSD_{(0.05)}$	0.49	0.11	0.59	0.31	0.20
CV (%)	0.90	20.67	4.32	4.67	2.78

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability
Note: V_1 – Diamont, V_2 – Asterix, V_3 – Lady rosetta and V_4 – BARI TPS-I

Table 14. Interaction effect of nitrogen levels and varieties on skin color (L*, a*, b*, huc angle and chroma) of potato

Treatments	L*	a*	b*	Huc angle	Chroma
N_0V_1	52.00 j	-4.60 k	20.90 i	-12.47 k	20.39 e
N_0V_2	66.20 e	2.00 e	20.10 c	5.68 e	20.20 e
N_0V_3	64.40 f	-2.40 hi	12.90 f	-10.51 i	12.67 k
N_0V_4	62.00 g	-2.20 h	11.30 g	-11.02 j	11.08 l
N_1V_1	59.00 i	-2.50 i	8.40 h	-16.57 l	8.02 m
N_1V_2	70.90 c	2.30 d	23.80 a	5.51 e	23.91 b
N_1V_3	69.60 d	0.60 g	18.40 d	1.87 g	18.47 g
N_1V_4	64.50 f	-4.30 j	13.30 f	-17.91 m	12.59 k
N_2V_1	61.60 gh	0.40 g	12.90 f	1.77 gh	12.91 j
N_2V_2	73.40 a	6.80 a	24.70 a	15.39 a	25.52 a
N_2V_3	71.90 b	2.60 c	22.40 b	6.62 d	22.55 c
N_2V_4	62.00 g	1.60 f	21.50 b	4.25 f	21.56 d
N_3V_1	61.00 h	0.40 g	15.70 f	1.46 h	15.71 i
N_3V_2	73.30 a	5.10 b	22.20 b	12.94 b	22.78 c
N_3V_3	70.80 c	2.60 c	19.40 cd	7.63 c	19.57 f
N_3V_4	69.50 d	2.20 de	15.90 e	7.88 c	16.05 h
$LSD_{(0.05)}$	0.99	0.23	1.18	0.36	0.23
CV (%)	0.90	20.67	4.32	4.67	2.78

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: N_0 – 0 kg ha^{-1}, N_1 –100 kg ha^{-1}, N_2 – 150 kg ha^{-1}, N_3 – 200 kg ha^{-1} and V_1 – Diamont, V_2 – Asterix, V_3 – Lady rosetta, V_4 – BARI TPS-I

4.3.6.3 Interaction effect of nitrogen and varieties

The statistical analysis showed that there were significant differences ($p<0.05$) on different varieties for lightness (L*), green-red chromatically (a*), blue-yellow chromatically (b*), chroma and hue angle of potato skin. (Appendix XII and Table 14).The maximum (73.40 %) skin color 'L*' was found from 150 kg N $ha^{-1}$with 'Asterix' varieties, whereas minimum (52.00 %) was recorded from 0 kg N ha^{-1} with 'Diamont' varieties. The maximum (6.80 %) skin color 'a*' was found from 150 kg N ha^{-1} with 'Asterix' varieties, whereas minimum (-4.60 %) was recorded from 0 kg N ha^{-1} with 'Diamont' varieties. The maximum (24.70 %) skin color 'b*' was found from 150 kg N ha^{-1} with 'Asterix' varieties, whereas minimum (8.40 %) was recorded from 100 kg N ha^{-1} with 'Diamont' varieties.

Chroma and hue angle were significantly affected by varieties. Among the treatment, the chroma of '150 kg N ha^{-1} with Astarix' (15.39) was the highest and lowest was exhibited in '100 kg N ha^{-1} with BARI TPS-I' (-17.91). It was observed that '150 kg N ha^{-1} with Asterix' had the highest hue angle (25.52), while the minimum (8.02) for hue angle was noted for '100 kg N ha^{-1} with BARI TPS-I'.

4.3.7 Flesh color (L*, a*, b*, hue angle and chroma) of potato

4.3.7.1 Effect of nitrogen

Flesh color (L*, a*, b*, hug angle and chroma) of potato showed statistically significant variation for different nitrogen levels under the present study (Appendix XIII and Table 15). The maximum (70.97 %) flesh color 'L*' was found from 150 kg N ha^{-1} treatment, whereas minimum (67.41 %) was recorded from the control treatment. The maximum (10.35 %) flesh color 'a*' was found from 150 kg N ha^{-1} treatment, whereas minimum (6.30 %) was recorded from the control treatment. The maximum (26.25 %) flesh color 'b*' was found from 150 kg N ha^{-1} treatment, whereas minimum (19.90 %) was recorded from the control treatment.

Chroma and hue angle were significantly affected by varieties. Among N_2 treatment, the chroma (28.22) was the highest and lowest was exhibited in N_1 (20.91) treatment. It was observed that N_3 treatment had the highest hue angle (21.47), while the minimum and negative value (18.13) for hue angle was noted for N_0 treatment.

4.3.7.2 Effect of varieties

Flesh color (L*, a*, b*, hug angle and chroma) of potato showed statistically significant variation for different varieties under the present study (Appendix XIII and Table 16). The maximum (71.47 %) flesh color 'L*' was found from the 'Asterix' varieties, whereas minimum (65.98 %) was recorded from the 'Diamont'

varieties. The maximum (9.88 %) flesh color 'a*' was found from the 'Asterix' varieties, whereas minimum (7.40 %) was recorded from the 'Diamont' varieties. The maximum (26.65 %) flesh color 'b*' was found from the 'Asterix' varieties, whereas minimum (19.77 %) was recorded from the 'Diamont' varieties.

Chroma and hue angle were significantly affected by varieties. Among the varieties the chroma of 'Astarix' (28.47) was the highest and lowest was exhibited in 'Diamont' (21.14). It was observed that 'Diamont' had the highest hue angle (20.62), while the minimum (18.80) for hue angle was noted for 'Lady rosseta'.

Table 15. Effect of nitrogen levels on flesh color (L*, a*, b*, huc angle and chroma) of potato

Nitrogen levels	L*	a*	b*	Huc angle	Chroma
N_0	67.41 d	6.30 d	19.90 d	18.13 d	20.91 d
N_1	69.07 c	8.08 c	21.80 c	20.37 b	23.25 c
N_2	70.97 a	10.35 a	26.25 a	21.47 a	28.22 a
N_3	70.00 b	8.75 b	24.42 b	19.58 c	25.98 b
$LSD_{(0.05)}$	0.59	0.35	0.23	0.24	0.33
CV (%)	1.13	2.52	1.50	1.66	2.81

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability
Note: N_0 – 0 kg ha^{-1}, N_1 –100 kg ha^{-1}, N_2 – 150 kg ha^{-1} and N_3 – 200 kg ha^{-1}

Table 16. Effect of varieties on flesh color (L*, a*, b*, huc angle and chroma) of potato

Varieties	L*	a*	b*	Huc angle	Chroma
V_1	65.98 c	7.40 d	19.77 d	20.62 a	21.14 d
V_2	71.47 a	9.88 a	26.65 a	20.13 b	28.47 a
V_3	70.25 b	8.25 b	24.15 b	18.80 c	25.53 b
V_4	69.75 b	7.95 c	21.80 c	20.00 b	23.22 c
$LSD_{(0.05)}$	0.66	0.17	0.29	0.19	0.29
CV (%)	1.13	2.52	1.50	1.66	2.81

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability
Note: V_1 – Diamont, V_2 – Asterix, V_3 – Lady rosetta and V_4 – BARI TPS-I

Table 17. Interaction effect of nitrogen levels and varieties on flesh color (L*, a*, b*, huc angle and chroma) of potato

Treatments	L*	a*	b*	Huc angle	Chroma
N_0V_1	64.03 g	5.90 l	14.50 l	22.14 b	15.66 k
N_0V_2	69.50 cd	6.80 j	25.80 d	14.76 j	26.68 d
N_0V_3	68.40 de	6.40 k	21.90 h	16.30 i	22.82 h
N_0V_4	67.70 e	6.30 k	17.40 k	19.32 g	18.48 j
N_1V_1	66.00 f	7.10 ij	18.80 j	20.69 e	20.10 i
N_1V_2	71.07 b	8.80 f	25.10 e	19.32 g	26.60 d
N_1V_3	69.10 d	8.40 g	22.10 h	20.81 e	23.64 g
N_1V_4	71.10 b	8.00 h	21.20 i	20.67 e	22.66 h
N_2V_1	68.60 de	9.20 e	23.60 g	21.23 d	25.33 f
N_2V_2	72.80 a	12.60 a	29.30 a	23.27 a	31.89 a
N_2V_3	71.10 b	10.00 c	27.90 b	19.72 f	29.64 b
N_2V_4	70.70 bc	9.60 d	24.20 f	21.64 c	26.03 e
N_3V_1	66.30 f	7.40 i	22.20 h	18.43 h	23.47 g
N_3V_2	71.30 b	11.30 b	26.40 c	23.17 a	28.72 c
N_3V_3	71.20 b	8.20 gh	24.70 ef	18.37 h	26.03 e
N_3V_4	69.50 cd	8.10 gh	24.40 f	18.36 h	25.71 e
$LSD_{(0.05)}$	1.32	0.35	0.58	0.22	0.33
CV (%)	1.13	2.52	1.50	1.66	2.81

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: N_0 – 0 kg ha^{-1}, N_1 –100 kg ha^{-1}, N_2 – 150 kg ha^{-1}, N_3 – 200 kg ha^{-1} and V_1 – Diamont, V_2 – Asterix, V_3 – Lady rosetta, V_4 – BARI TPS-I

4.3.7.3 Interaction effect of nitrogen and varieties

The statistical analysis showed that there were significant differences ($p<0.05$) on different varieties for lightness (L*), green-red chromatically (a*), blue-yellow chromatically (b*), chroma and hue angle of potato skin. (Appendix XIII and Table 17). The maximum (72.80 %) flesh color 'L*' was found from 150 kg N ha^{-1} with 'Asterix' varieties, whereas minimum (64.03 %) was recorded from 0 kg N ha^{-1} with 'Diamont' varieties. The maximum (12.60 %) flesh color 'a*' was found from 150 kg N ha^{-1} with 'Asterix' varieties, whereas minimum (5.90 %) was recorded from 0 kg N ha^{-1} with 'Diamont' varieties. The maximum (29.30 %) flesh color 'b*' was found from 150 kg N ha^{-1} with 'Asterix' varieties, whereas minimum (14.50 %) was recorded from 0 kg N ha^{-1} with 'Diamont' varieties.

Chroma and hue angle were significantly affected by varieties. Among the treatment, the chroma of '150 kg N ha^{-1} with Astarix' (23.27) was the highest and lowest was exhibited in '0 kg N ha^{-1} with Asterix' (14.76). It was observed that '150 kg N ha^{-1} with Asterix' had the highest hue angle (31.89), while the minimum 15.66) for hue angle was noted for '0 kg N ha^{-1} with Diamont'.

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted at the experimental plot of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka -1207 during the period from October, 2013 to March, 2014 in Rabi season to find out the influence of nitrogen on the growth, yield and quality of some potato varieties. The experiment had two factors. Factor A: 4 level of nitrogen; N_0 - control (No nitrogen), N_1 - 100 kg N ha^{-1}, N_2 - 150 kg N ha^{-1}, N_3 - 200 kg N ha^{-1} and Factor B: Potato (4 varieties) ;V_1 – Diamont, V_2 – Asterix, V_3 – Lady rosetta,V_4 – BARI TPS-I. The experiment was laid out in a split-plot design with three replications thus comprised 48 plots. Nitrogen was assigned to main plots and varieties to sub-plots. Data on different growth parameter, yield and quality of potato were recorded and significant variation was recorded for different treatment.

In case of nitrogen, the maximum days (11.33 and 19.43 days) for 1st and final emergence were recorded from the control treatment. But the growth parameter, the highest plant length (76.06 cm), number of leaves per plant (40.83), number of stems per hill (3.83), stem dry matter (18.57 %) was recorded from 200 kg N ha^{-1}. The yield parameter, number of tubers per hill (8.76), average tuber weight (58.94 g) and yield (26.66 t ha^{-1}) was recorded from 150 kg N ha^{-1}. The quality parameter, flesh dry matter (22.08 %), specific gravity (1.09 g cm^{-3}), total soluble solids (5.58) and starch (14.01 %)was recorded from 150 kg N ha^{-1}. The skin color L* (67.22), a* (2.85), b* (20.15), huc angle (7.48), chroma (20.64) and the flesh color L* (70.97), a* (10.35), b* (26.25), huc angle (21.47) and chroma (28.22) was recorded from 150 kg N ha^{-1}.

In case of varieties, the maximum days (11.25 and 17.83 days) for 1stand final emergence was recorded from the ‘BARI TPS-I’ varieties. The growth parameter, the highest plant length (81.05 cm), number of leaves per plant (53.05) was recorded from ‘BARI TPS-I’ varieties and number of stems per hill (4.46), stem

dry matter (17.05 %) was recorded from 'Diamont' varieties. The yield parameter, number of tubers per hill (8.33), average tuber weight (62.65 g) and yield (25.83 t ha^{-1}) was recorded from 'Diamont' varieties. The quality parameter, flesh dry matter (20.28 %), specific gravity (1.10gcm^{-3}), total soluble solids (5.58), firmness (32.82) and starch (15.36 %) was recorded from 'Lady rosetta' varieties. The skin color L* (70.95), a* (4.05), b* (22.70), huc angle (9.88), chroma (23.10) and the flesh color L* (71.47), a* (9.88), b* (26.65), huc angle (20.13) and chroma (28.47) was recorded from 'Asterix' varieties.

In case of nitrogen and varieties, the maximum days (15.00 and 22.00 days) for 1st and final emergence was recorded from the '0 kg N ha^{-1} with BARI TPS-I' treatment. The growth parameter, the highest plant length (90.60 cm), number of leaves per plant (61.50) was recorded from '200 kg N ha^{-1} with BARI TPS-I' treatment and number of stems per hill (5.10), stem dry matter (19.23 %) was recorded from '200 kg N ha^{-1} with Diamont' treatment. The yield parameter, number of tubers per hill (9.20), average tuber weight (85.65 g) and yield (28.45 t ha^{-1}) was recorded from '150 kg N ha^{-1} with Diamont' treatment. The quality parameter, flesh dry matter (24.52 %), specific gravity (1.12 g cm^{-3}), total soluble solids (6.00) was recorded from '150 kg N ha^{-1} with Lady rosetta' treatment and firmness (37.78) was recorded from '0 kg N ha^{-1} with Lady rosetta' treatment and starch (18.05 %) was recorded from '150 kg N ha^{-1} with Lady rosetta' treatment. The skin color L* (73.40), a* (6.80), b* (24.70), huc angle (15.39), chroma (25.52) and the flesh color L* (72.80), a* (12.60), b* (29.30), huc angle (23.27) and chroma (31.89) was recorded from '150 kg N ha^{-1} with Asterix' treatment.

Based on the experimental results, it may be concluded that-

i) The effect of nitrogen had positive effect on morphological and growth characters, yield attributes and quality in potato.

ii) Application of 150 kg N $ha^{-1}$with'Diamont' varieties seemed to be more suitable for getting higher tuber yield but for the production of quality tuber application of 150 kgN$ha^{-1}$with 'Ladyrosetta' varieties seemed to be more suitable.

RECOMMENDATION

Considering the above observation of the present study further investigation in the following areas may be suggested.

1. Further study may be needed for ensuring the different nitrogen levels in relation to growth, yield, and quality in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability.
2. Closer treatments of nitrogen levels and other varieties may be needed to include for future study as sole or different combination.

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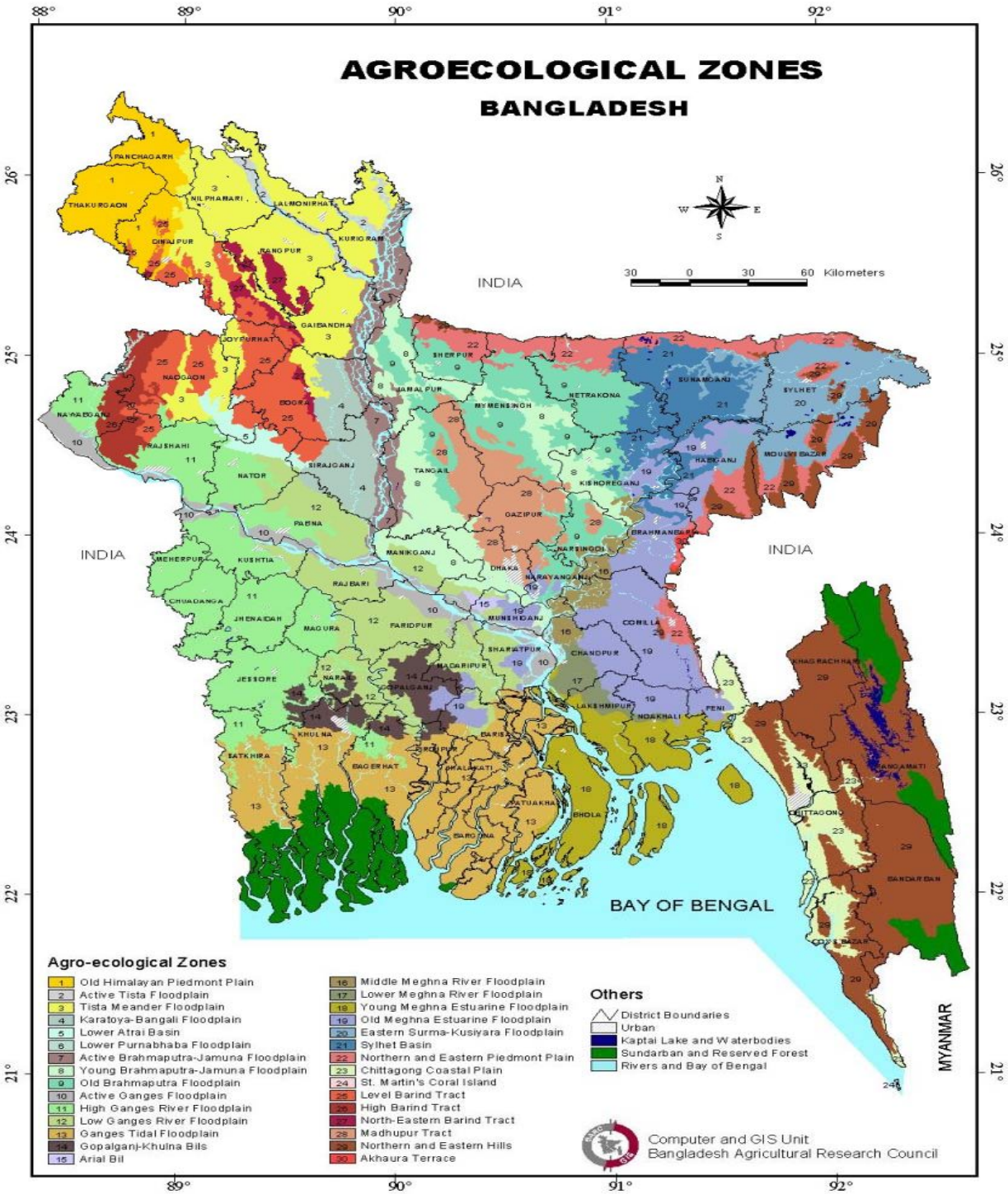
APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh



Appendix II. Characteristics of soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Experimental field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Amon rice- Potato

B. Physical and chemical properties of the initial soil

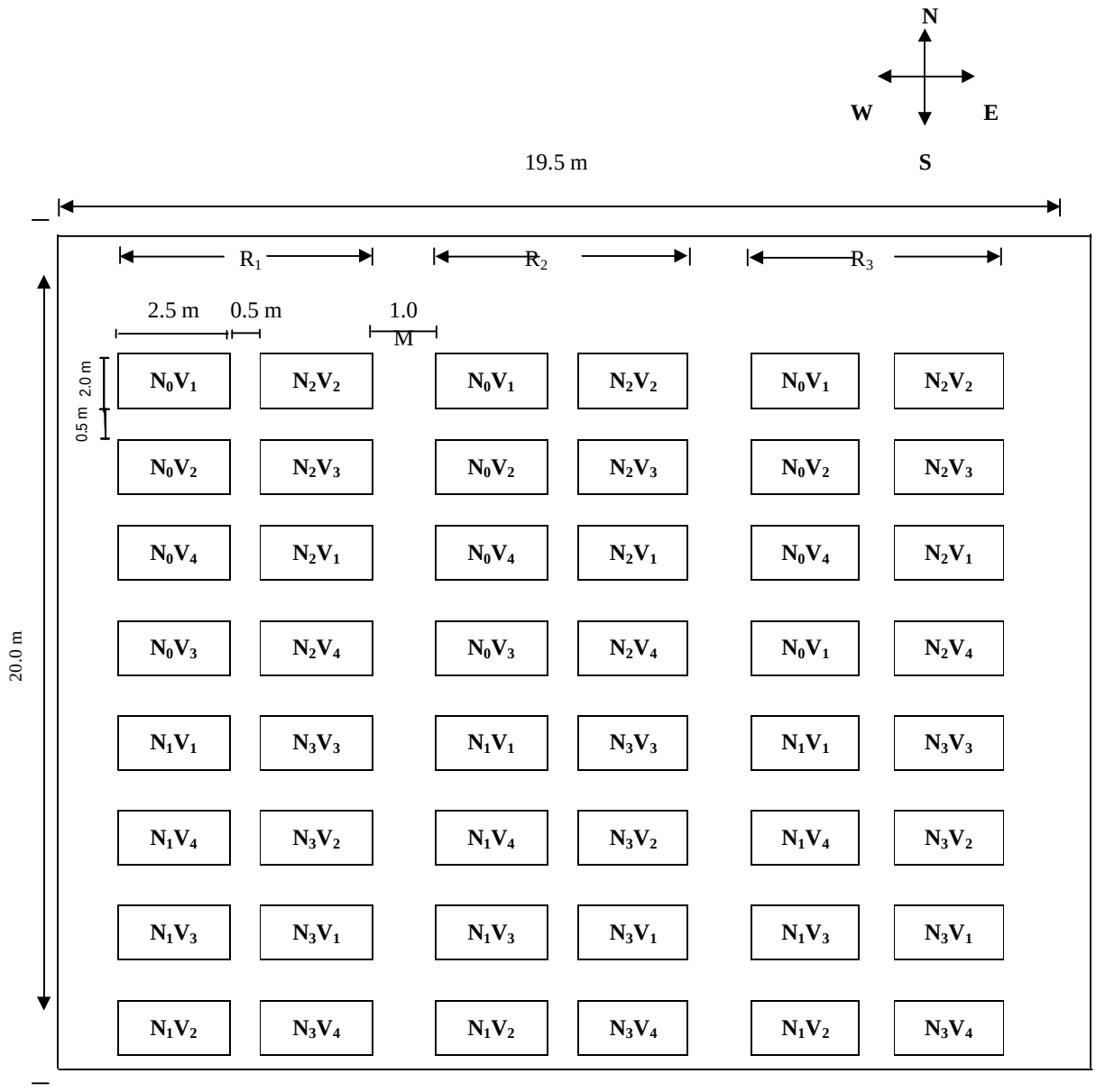
Characteristics	Value
%Sand	27
%Silt	43
%clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (mel 1 00 g soil)	0.10
Available S (ppm)	45

Source : SRDI, 2013

Appendix III. Monthly record of air temperature, rainfall, relativehumidity, soil temperature and Sunshine of the experimental site during the period from November 2013 to March 2014

Month	Average air temperature (°C)			Average relative humidity (%)	Total rainfall (mm)	Total Sunshine per day(hrs)
	Maximum	Minimum	Mean			
November, 2013	29.7	20.1	24.9	65	5	6.4
December, 2013	26.9	15.8	21.35	68	0	7.0
January, 2014	24.6	12.5	18.7	66	0	5.5
February, 2014	36.0	24.6	30.3	83	37	4.1
March, 2014	36.0	23.6	29.8	81	45	3.9

Appendix IV. Field layout of the two-factor experiment in split-plot design



Number of treatment combinations = 16, Unit plot size = 2.5 m ×2.0 m
Plot spacing: = 0.5 m
Between replication = 1.0 m

Factor A: Nitrogen Fertilizer
N_0 = Control (No N ha^{-1})
N_1 = 100 kg N ha^{-1}
N_2 = 150 kg N ha^{-1}
N_3 = 200 kg N ha^{-1}

Factor B: Variety
V_1 = Diamont
V_2 = Asterix
V_3 = Lady rosetta
V_4 = BARI TPS-I

Appendix V. Analysis of variance (mean square) of 1st Days to emergence and final days to emergence

Source of variation	Degrees of freedom	1st Days to emergence	Final days to emergence
Replication	2	10.021	12.250
Nitrogen (A)	3	10.583*	146.764*
Error	6	1.771	58.194
Variety (B)	3	23.028**	52.306*
A×B	9	3.824*	11.713*
Error	24	2.417	14.903

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

Appendix VI. Analysis of variance (mean square) of plant length at different DAP

Source of variation	Degrees of freedom	Plant length			
		20 DAP	40 DAP	60 DAP	80 DAP
Replication	2	5.852	80.983	156.225	51.114
Nitrogen (A)	3	10.897*	49.245*	170.324*	250.475*
Error	6	2.916	4.894	43.111	109.411
Variety (B)	3	6.051*	49.026*	110.420*	251.181*
A×B	9	0.549**	3.452**	9.923**	13.757**
Error	24	1.305	8.520	29.517	62.111

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

Appendix VII. Analysis of variance (mean square) of number of leaves plant^{-1} at different DAP

Source of variation	Degrees of freedom	Number of leaves plant^{-1}			
		20 DAP	40 DAP	60 DAP	80 DAP
Replication	2	1.970	41.200	149.040	22.600
Nitrogen (A)	3	50.408*	119.856*	205.300*	238.898**
Error	6	2.805	15.578	11.556	7.721
Variety (B)	3	9.672*	26.023*	79.191*	204.436**
A×B	9	0.577*	6.475*	3.825*	27.453*
Error	24	2.327	13.856	25.211	11.441

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

Appendix VIII. Analysis of variance (mean square) of number of stems hill^{-1} at different DAP

Source of variation	Degrees of freedom	Number of stems hill^{-1}			
		20 DAP	40 DAP	60 DAP	80 DAP
Replication	2	0.030	0.043	0.007	0.030
Nitrogen (A)	3	0.362*	0.533*	0.645*	1.423*
Error	6	0.033	0.029	0.029	0.064
Variety (B)	3	0.040*	0.213*	0.971**	1.924**
A×B	9	0.007*	0.070*	0.051*	0.328**
Error	24	0.017	0.039	0.045	0.062

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

Appendix IX. Analysis of variance (mean square) of dry matter plant^{-1} at different DAP

Source of variation	Degrees of freedom	Dry matter plant^{-1}				
		20 DAP	40 DAP	60 DAP	80 DAP	Harvest
Replication	2	0.014	1.567	16.115	8.038	7.589
Nitrogen (A)	3	11.172**	15.230*	39.874*	82.572*	121.619*
Error	6	0.007	6.905	5.405	3.504	3.204
Variety (B)	3	11.431**	21.646**	65.472**	43.932**	55.751**
A×B	9	0.617**	0.625**	0.450**	0.806**	0.908**
Error	24	0.024	2.261	1.503	3.561	4.177

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

Appendix X. Analysis of variance (mean square) of yield and yield components

Source of variation	Degrees of freedom	No. of tuberhill^{-1}	Tuber average weight	Yield
Replication	2	0.239	7.238	1.646
Nitrogen (A)	3	13.411*	571.676*	207.136*
Error	6	1.677	2.702	8.452
Variety (B)	3	16.141**	546.668**	167.304**
A×B	9	0.396*	8.145**	0.001**
Error	24	0.283	0.825	6.063

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

Appendix XI. Analysis of variance (mean square) of flesh dry matter (%), specific gravity, total soluble solid, firmness and starch

Source of variation	Degrees of freedom	Flesh dry matter (%)	Specific gravity (g cm^{-3})	Total soluble solids	Firmness	Starch (%)
Replication	2	51.790	51.790	126.064	126.009	0.422
Nitrogen (A)	3	235.357*	217.394*	20.475**	485.28*	29.584**
Error	6	9.512	9.512	85.745	85.754	0.422
Variety (B)	3	237.546**	226.549**	328.594*	38.647*	12.586**
A×B	9	9.733*	9.265*	3.584*	3.966*	1.385*
Error	24	2.516	2.516	7.787	7.785	0.422

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

Appendix XII. Analysis of variance (mean square) of skin color (L, a and b) at different DAS

Source of variation	Degrees of freedom	Skin color				
		L*	a*	b*	Hue angle	Chroma
Replication	2	2.533	0.057	2.218	16.644	0.062
Nitrogen (A)	3	32.732**	67.493**	216.900**	1.094**	0.528**
Error	6	0.596	0.049	0.193	0.020	0.0 12
Variety (B)	3	377.422**	73.223**	423.765**	0.157*	0.109*
A×B	9	43.409**	3.968**	34.105**	3.571**	3.828**
Error	24	0.347	0.019	0.494	0.043	0.024

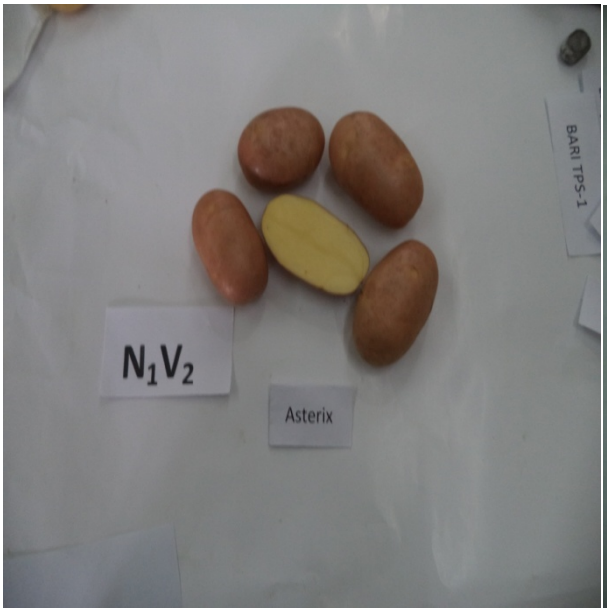
* and ** indicate significant at 5% and 1% level of probability, respectively

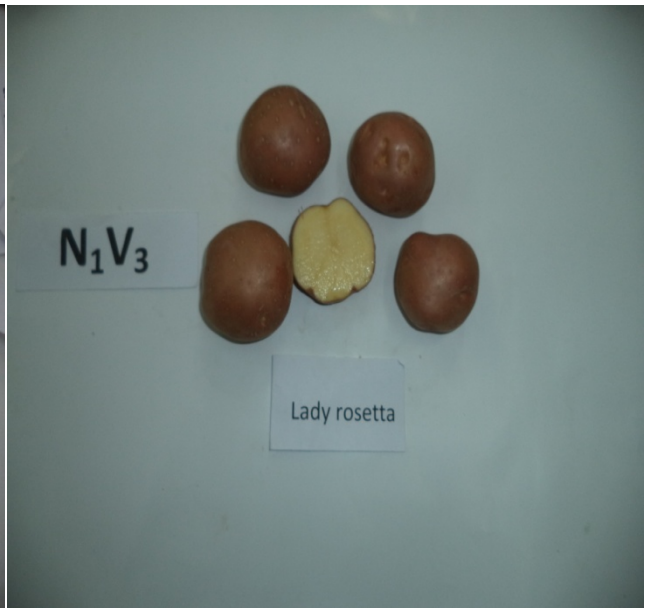
Appendix XIII. Analysis of variance (mean square) of flesh color (L, a and b) at different DAS

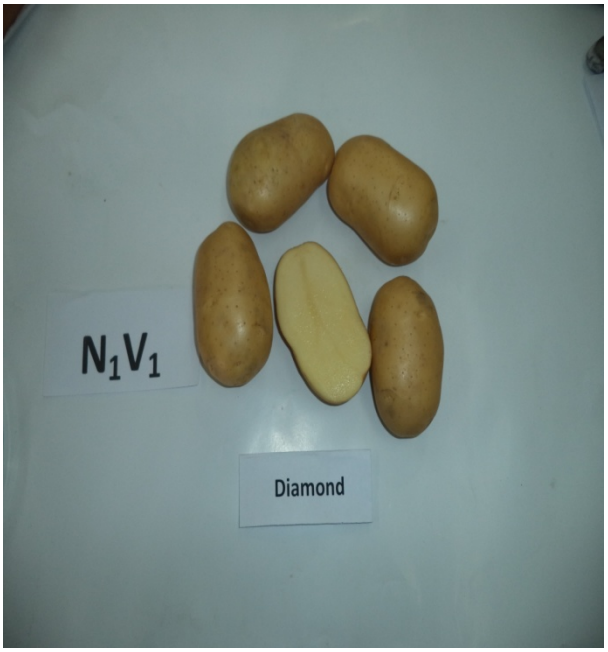
Source of variation	Degrees of freedom	Flesh color				
		L*	a*	b*	Hue angle	Chroma
Replication	2	9.978	0.529	0.312	62.647	100.047
Nitrogen (A)	3	27.651**	33.747**	94.432**	16.332*	166.143**
Error	6	0.357	0.129	0.055	0.972	0.021
Variety (B)	3	67.136**	13.587**	105.802**	31.892**	86.208**
A×B	9	2.393*	1.527*	6.979**	63.432**	13.801**
Error	24	0.619	0.044	0.119	0.741	0.027

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

Field View of Potato Plants







Some varieties of tuber potato