EFFECT OF NITROGEN AND PHOSPHORUS ON GROWTH, YIELD AND PROTEIN CONTENT OF BARI Alu-35

MD. FARIDI HASAN

DEPARTMENT OF AGRICULTURAL CHEMISTRY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA -1207

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MD. FARIDI HASAN

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APPROVED BY:

…………………………………	……………………………………
Supervisor	**Co-supervisor**
Dr. Rokeya Begum	**Dr. Md. Abdur Razzaque**
Professor	**Professor**

..……………………………………

Dr. Md. Sirajul Islam Khan
Chairman
Examination Committee

DEPARTMENT OF AGRICULTURAL CHEMISTRY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

Ref. No: **Date:**

CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF NITROGEN AND PHOSPHORUS ON GROWTH, YIELD AND PROTEIN CONTENT OF BARI Alu-35**''submitted to the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in AGRICULTURAL CHEMISTRY**, embodies the results of a piece of *bona fide* research work carried out by **MD. FARIDI HASAN**, Registration No. **12-05213**, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

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

Dated: December, 2017
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Professor Dr. Rokeya Begum
Supervisor

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EFFECT OF NITROGEN AND PHOSPHORUS ON GROWTH, YIELD AND PROTEIN CONTENT OF BARI Alu-35

ABSTRACT

A field experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 2017 to March 2018, to investigate the effect of nitrogen and phosphorus on growth, yield and protein content of BARI Alu-35. The experiment comprised of two factors, Factor A: Nitrogen levels (4): N_0 = control (0 kg N ha^{-1}), N_1 = 75 kg N ha^{-1}, N_2 = 105 kg N ha^{-1} and N_3 = 135 kg N ha^{-1}; and Factor B: Phosphorus levels (3): P_0 = control (0 kg P ha^{-1}), P_1 = 69 kg P ha^{-1} and P_3 = 92 kg P ha^{-1}. The experiment was laid in a Randomized Complete Block Design (RCBD) with three replications. The result revealed that nitrogen and phosphorus had significant effects on most of the growth, yield and quality parameters studied in this experiment. Among the four nitrogen levels, N_3 produced the highest plant height (19.72 cm, 34.56 cm and 60.39 cm respectively) at different days after planting, number of leaves plant^{-1} (11.33, 28.78 and 37.56 respectively) at different days after planting, number of stems hill^{-1} (4.33), stem dry matter content (17.80%), number of tubers hill^{-1} (10.11), average weight of tuber hill^{-1} (74.39 g), yield of tuber (37.73 t ha^{-1}), total soluble solids (7.30%), protein content (7.50%) and N_0 produced the lowest results. On the other hand, among the three phosphorus levels, P_2 produced the highest plant height (17.09 cm, 29.93 cm and 52.33 cm respectively) at different days after planting, number of leaves plant^{-1} (9.33, 24.33 and 32.67 respectively) at different days after planting, number of stems hill^{-1} (3.17), stem dry matter content (12.65%), number of tubers hill^{-1} (8.00), average weight of tuber hill^{-1} (63.17 g), yield of tuber (32.93 t ha^{-1}), total soluble solids (5.96%) and protein content (6.16%) and P_0 produced the lowest results. Among the twelve treatment combinations, N_3P_2 showed highest results and N_0P_0 showed lowest results. Therefore, the application of 135 kg N ha^{-1} with 92 kg P ha^{-1} was suitable for better growth, yield and quality of BARI alu-35.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

%	Percent
@	At the rate of
^0C	Degree Celsius
AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
cm	Centimeter
RCBD	Randomized Complete Randomized Design
CV%	Percentage of Coefficient of Variance
DAP	Days After Planting
e.g.	As for example
et al.	and others
g	Gram
ha	Hectare
i.e.	that is
kg	Kilogram
kg ha^{-1}	kg per hectare
LSD	Least Significant Difference
m	Meter
MoP	Muriate of Potash
N	Nitrogen
P	Phosphorus
ppm	Parts Per Million
S	Sulphur
SAU	Sher-e-Bangla Agricultural University
t ha^{-1}	Ton per hectare
TSP	Triple Super Phosphate

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) belongs to the family Solanaceae is one of the most important vegetable crops of the world. It is originated from the Peru-Bolivian region in the Andes of South America (Grewal *et al*., 1992). It has been introduced to Ethiopia in 1859 by a German Botanist called Schimper (Berga *et al*., 1994). World annual production of potato is about 330 million metric tons with area coverage of 18651838 ha. It is one of the major world food crops in its ability to produce food per unit area per unit time (FAOSTAT, 2010).

It is the 4^{th} major crops of the world on the basis of production and consumption and used as a principal vegetable in most of the Asian countries. In Bangladesh, potato is one of the major crops next to rice and wheat, covers an area of 689730 ha of land producing 9474098 metric tons (BBS, 2016). It is a carbohydrate rich crop, and is consumed almost absolutely as a vegetable in Bangladesh. It contributes as much as 55% of the total vegetable demand in Bangladesh (BBS, 2013).

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 matter, 0.1 to 0.2% crude fats, 0.6% crude fiber and some vitamins (Schoenemann, 1977). Nutritionally, the tuber is rich in carbohydrates or starch and is a good source of protein, vitamin B and C, potassium, phosphorus and iron. It is a staple diet in European countries and its utilization both in processed and fresh food form is increasing considerably in Asian countries (Brown, 2005). 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).

The area and production of potato in Bangladesh has been increasing during last decades but the yield per unit area remains more or less static. The total area under potato crop, national average yield and total production in Bangladesh are 430446 hectares, 19.071 t ha^{-1} and 8205470 metric tons, respectively. 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; 42.1 t ha^{-1} in Denmark and 40.0 t ha^{-1} in UK (FAO, 2009). 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 and Barta, 2001).

Yield and quality of potato depend on nutrient availability in soil, especially regarding nitrogen. Nitrogen (N) is a very dynamic plant nutrient and its uncontrolled application can considerably raise the price of agricultural production. If N is insufficiently utilized by plants environmental pollution can occur. 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 (Hossain, 2011).

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. A plant absorbs most nitrogen and phosphorus in nitrate and phosphate form. Nitrogen and phosphorus are important and essential structural component of chlorophyll and various proteins. Nitrogen is important in fueling growth and providing high yields. It ensures optimal photosynthate production in leaves. Nitrogen fed at an early stage of crop development will help build the overall size of the leaf canopy (Koochaki and Sarmadnia, 2006).

Phosphorus is important for early root and shoot development, providing energy for plant processes such as ion uptake and transport. In case of tuber initiation, an adequate supply of P ensures supplies of optimum numbers of tubers are formed. N and P deficiency decreases growth and yield and N and P excessive application stimulates shoot growth, retards tuber formation and filling period, decreases tuber specific weight and shortens tuber storage time (Rezaee and Sultani, 1996). The application of 165 kg N ha^{-1} and 90 kg P_2O_5 ha^{-1} is needed for optimum potato production on vertisols of Mekelle area (Mulubrhan, 2004).

Under these circumstances, the proposed study was undertaken to examine the effect of nitrogen and phosphorus on growth, yield and quality of potato production in Bangladesh.

- To find out the suitable doses of nitrogen and phosphorus fertilizers for BARI Alu-35 production.
- To study the effect of nitrogen and phosphorus on the yield and quality of BARI Alu-35.
- To find out the optimum interaction effect of nitrogen and phosphorus on the growth, yield, quality and protein content of BARI Alu-35.

CHAPTER II

REVIEW OF LITERATURE

Potato is one of the important vegetable crop in Bangladesh and as well as many countries of the world. For increasing the growth and yield of potato abundant studies were conducted in the country and abroad. But a very few studies related to growth, tuber production and quality of tuber due to nitrogen and phosphorus application have been carried out in our country as well as many other countries of the world. Nevertheless, some of the important and informative works and research findings related to the effects of nitrogen and phosphorus on growth, yield and quality of potato have been reviewed in this chapter-

2.1 Effect of nitrogen on potato

Moreno *et al.* (2003) reported that the crop yield and quality mostly depend on the availability of nutrients in soil. Nitrogen (N) is a very dynamic plant nutrient. Its uncontrolled application can considerably raise the price of agricultural production, and under increased rates of N insufficient utilization by plants may result in environmental pollution.

Neumann *et al*. (2012) stated that potato fields quite often receive too high amounts of N fertilizer, which combined with a shallow root system, creates high risk of N leaching losses.

Fontes *et al*. (2010) reported that several N fertilization rates have been advised as optimal for potato production. In some European countries and the USA that have a potato growth cycle of 4-5 months, the recommended N fertilization rates vary from 70 to 330 kg ha^{-1}, and the most economically efficient rates from 147 to 201 kg ha^{-1} for potato production.

Researchers in the Czech Republic advised a fertilization rate of 140 kg ha^{-1}, 63 kg ha^{-1} and 186 kg ha^{-1} N, P_2O_5 and K_2O, respectively, as the optimal for tuber yield above 30 t ha^{-1}. It has been observed that N dose of 120 kg ha^{-1} applied in the form of mineral fertilizer is the most environmentally acceptable N fertilization rate for potato (Srek *et al*., 2010).

Darwish *et al*. (2006) stated that the application of 130 kg ha^{-1} N by fertigation (fertilization together with irrigation) is sufficient for potato.

Vos (1995) and Goffart *et al*. (2008) reported that low N supply will not only result in lower yield but will also reduce tuber size due to reduced leaf area and early defoliation.

Kumar *et al*. (2007) reported that higher N fertilization rates have positive effect on plant growth parameters, and they increase tuber number and yield. Also, higher N rates also are associated with more foliage and consequently promote photosynthetic action, and hence more translocation to tubers.

Baniuniene and Zekaite (2008) stated that an increased potato yield is mostly associated with nitrogen (N) application, whereas phosphorus (P) and potassium (K) without N have insignificant impact on yield.

Vos (1995) and Goffart *et al*. (2008) reported that excess N fertilization leads to dry matter yield in other parts of the plant than the tubers, promoting excessive stolon and leaf growth; both leaf maturation and tuber differentiation are delayed and the length of tuber bulking period, yield and tuber dry matter are reduced.

Westermann (2005) reported that N must normally be added to fertilizer to achieve maximum economic potato yields. Its efficiency may be substantially improved if it is applied as close as possible to the actual plant growth needs.

Li *et al*. (2006) and Ierna *et al*. (2011) reported that potato crop needs for N are critical because soil N concentration changes with soil water availability.

Nitrogen is the first limiting factor for potato crop which improves vegetative growth and invariably increases yield, tuber per plant, tuber size as well as tuber numbers (Anand and Krishnappa, 1988; Bhowmik and Dandapat, 1991).

Sanderson and White (1987) reported that total tuber yield and size of potato tubers increases with nitrogen.

Zabihi-e-Mahmoodabad *et al*. (2011) reported that increase in nitrogen application raises tuber number, but that too much nitrogen has the opposite effect.

Jamaati-e-Somarin *et al*. (2010) reported that increasing planting density and nitrogen application up to a definite (160 kg N ha^{-1} and 11 plant m^{-2}) point increases tuber yield, but beyond this point decreased them.

Westermann and Kleinkopf (1985) stated that nitrogen plays a major role in the production and maintenance of an optimum plant canopy for continuing tuber growth through long growing period.

Westermann and Davis (1992) reported that soil nitrogen sources and split nitrogen applications have a major role in maintaining an optimum plant canopy and tuber growth.

Kolodziejczyk (2014) reported that nitrogen determines the quantity and structure of potato yield, its chemical composition and tuber quality.

Kumar *et al*. (2007) reported that the application of more N increased size and number of tubers ultimately enhancing total yield.

Alva (2004) reported that excessive application of N leads to delay maturity, produce poor quality tuber and reduce tuber yield.

Zalalem *et al*. (2009) reported that nitrogen is valuable nutrient for plants and plays an important role in tuber size development but overdose of nitrogen lowers the tuber dry matter.

Vaezzadeh and Naderidarbaghshahi (2012) stated that proper level of nitrogen has a positive impact on quality and yield of potatoes. Appropriate use of nitrogen expanded the leaf area index and increases photo assimilates.

Hassanpanah *et al*. (2009) reported that sufficient nitrogen increases both plant growth and leaf surface and tuber size and causes crop to become tolerant to leaf blot disease. Optimum use of N by plant decreases leaching of nitrogen and improves tuber germination and steady leaf area. Excess nitrogen at the last stage of growth causes development of stem and leaves instead of tubers as a result of high amounts of amino acids and amides, not changing to protein. Excess nitrogen has negative effect on tuber yield and quality; deficiency the photosynthesis decreases because lower leaves of plant become yellow and falls.

Hopkins *et al.* (2008) reported that potatoes require a steady supply of nutrients. Deficiencies or fluctuations of soluble nutrients (especially N) cause poor vine health, increased pathogen and insect susceptibility, reduced tuber yields, and diminished tuber quality.

Jenkins and Nelson (1992) observed that the number of tubers varied considerably as a result of N fertilization, and doubled when N level was increased to higher levels.

Zamil *et al*. (2010) have found that the higher dose of nitrogen (254 kg ha^{-1}) results in significantly higher total tuber number in potato tubers.

Zelalem *et al*. (2009) have found that application of 207 kg N/ha increased marketable tuber number by 95.6% compared to the control.

Mulubrhan (2004) reported that the application of nitrogen increased the tubers number of potato per unit area.

Millard and Marshall (1986) reported that tuber yield improvement as a result of N fertilization could be attributed to increased radiation interception during the first part of the season and lower rates of decline in photosynthetic efficiency of the canopy during the later part.

Westerman *et al*. (1985) reported that the increase in the application of N fertilizer up to a certain level increases the potato yield, but since then, it has no effect on the increase in yield.

Nizamuddin *et al*. (2003) observed optimum tuber yield when nitrogen fertilizer was applied at the rate of 200 kg ha^{-1}. Guler (2009) and Zamil *et al*. (2010) also reported that the maximum tuber yield was obtained when the crop received 300 and 254 kg nitrogen per ha, respectively. They also noted a reduction in tuber yield when N was applied above the aforementioned rates. The yield reduction due to excess rates of N may be explained by the fact that excessive N application stimulates shoot growth more than tuber growth which may result in deterioration of canopy structure and physiological conditions (Sommerfeld and Knutson, 1965; Berga *et al*., 1994; Mulubrhan, 2004 and Zelalem *et al*., 2009).

Mulubrhan (2004) reported that application of N significantly increased average tuber weight by 62% as N application increased from 0 to 165 kg ha^{-1}.

Guler (2009) indicated that mean tuber weight increased with increasing N rate. It was lowest in control and highest in the 300 kg N ha^{-1}.

Zelalem *et al*. (2009) reported that average tuber weight progressively increased with increasing N rate up to 138 kg/ha and tended to decrease at the highest rate of 207 kg ha^{-1}.

Painter and Augustine (1976) and Kleinkopf *et al*. (1981) reported that the specific gravity of tubers decreased with increasing rates of N fertilizer. Similar result was reported by Mulubrhan (2004) that increasing the application of N from 0 to 165 kg ha^{-1} reduced specific gravity from 1.076 to 1.069.

Kandi (2011) reported a reduced percent dry matter of potato tubers as nitrogen rates increased. Similar findings were reported by Wilcox and Hoff (1970) and Painter and Augustine (1976).

Asefa (2005) has indicated that increasing rate of nitrogen and phosphorous application significantly decreased specific gravity and dry matter content of potato tuber.

Cucci and Lacolla (2007) reported that dry matter percentage increased shifting from the control to the application of 200 kg N ha^{-1} and 50 kg P ha^{-1} from 23.0 to 26.2% and decreased at the highest N level, without any difference being observed with the change in the P rate.

Das Gupta and Ghosh (1973) reported that the rate of leaf production and number of axillary branches of potato increased with an increase in the levels of nitrogen. They also concluded that the growth (on dry weight basis) of haulm, tubers and whole plant was higher under the 200 kg N per ha than under the lower levels.

Gupta and Saxena (1976) concluded that dry matter content decreased with increasing levels of nitrogen. The highest dry matter percentage was found in control (0 kg/ha) which was statistically at par with dry matter content of potato tuber produced by applying 60 kg N per ha.

Kumar and Singh (1979) reported that levels of nitrogen increased the plant height in potato and it was significant up to 150 kg N per ha. Beneficial effect of nitrogen was also observed in relation to increase haulm fresh and dry weight but the number of shoots per hill were unaffected by nitrogen levels.

Singh *et al*. (1986) stated that the initial plant emergence (10 days after planting) in potato was low (5-10%) but subsequently the emergence increased at 30^{th} day (57-75%) with increasing levels of nitrogen from 0 to 100 kg/ha.

Gupta and Pal (1989) at Shimla, studied the response of potato varieties to nitrogen fertilization under rain fed condition. They reported that nitrogen fertilization significantly increased shoot per plant and tubers per ha and reported that application of 150kg N per ha was at par with 100 kg N per ha. Satyanarayana and Arora (1985) have also reported similar increase in shoots and tubers with N fertilization.

Singh and Singh (1994) reported that fresh weight of shoot, dry matter content and potato plant height increased with the application of 180 kg N per ha.

Singh (1995) observed that the highest germination percentage (100%) was recorded at 30 days after planting with the application of nitrogen @ 200 kg/ha.

Chaurasia and Singh (1996) reported that increase in the level of nitrogen, delayed the emergence from 15th day onwards.

Anabousi *et al*. (1997) conducted an experiment with three nitrogen fertilizer sources (urea, ammonium sulphate and potassium nitrate) applied at 4 rates (0, 125, 250 and 375 kg N/ha) on potato cv. “Spunta’’ in which they found that with each nitrogen fertilizer increment resulted in a significant increase in plant height, stem number per plant, leaf chlorophyll and leaf N and K contents.

Sharma and Singh (1997) at Udaipur, studied plant growth characters in potato i.e. number of branches and number of leaves per plant and found significant increase by the application of 80 kg N/ha while the higher dose i.e. 120 kg N/ha was found at par with 80 kg N/ha. Dry matter accumulation was improved significantly by increased N application at 30 days after sowing.

Gabr and Sarg (1998) at Egypt studied the effect of nitrogen level (0, 50, 10 and 150 kg N per feddan) on growth, yield and quality of potatoes. Increasing nitrogen doses up to 150 kg N per feddan significantly increased vegetative growth, including plant height, fresh weight and leaf area, while number of main stems was not affected.

Malik *et al*. (1998) found that plant height of potato was influenced significantly by nitrogen application with increased level of nitrogen up to 124 kg per ha.

Gathungu *et al*. (2000) reported that early application of nitrogen followed by split applied fertilizer led to a fast early growth (shoot, tuber, root and total dry matter, leaf area index and plant height) particularly when calcium ammonium nitrate was applied. Later, nitrogen application enhanced the growth of the shoots during the growth season with urea particularly.

Oliveira (2000) reported that the average number of active haulm per plant was increased by applying 200 kg nitrogen. He reported that maximum stem elongation was remaining constant at the highest and lowest nitrogen levels at 70 days after planting.

Patel and Patel (2001) observed that Kufri Badshah recorded a higher tuber yield than TPS C-3. The increase in nitrogen level up to 260 kg per ha resulted in significant increase in plant height, number and fresh weight of tubers per plant.

Kumar *et al*. (2002) observed increased plant height, number of stems per hill and leaf fresh weight with increasing rates of nitrogen.

Malik *et al*. (2002) reported that plant height, fresh weight of foliage increased with the increasing rate of nitrogen.

Das Gupta and Ghosh (1973) reported that greater number and size of tubers accounted for higher yield under high nitrogen fertilization of 200 kg per ha.

Shukla and Singh (1976) found that application of 225 kg and 150 kg N per ha increased the yield of tubers and superior grade tubers significantly over 75 kg N per ha and control, which in turn differed significantly. Application of 200 kg N/ha was found to be the most effective rate of nitrogen.

Hooda and Pandita (1980) observed that tuber yield was significantly higher with the application of 120 kg N per ha, than 80 kg N per ha. There was an increase in number of tubers per hill and large size tuber yield with nitrogen over control.

Kushwah (1989) observed significant increase in number of seed-size tubers up to 150 kg N per ha. Gupta and Pal (1989) reported that nitrogen fertilization not only increased different grade tuber yield but also increased proportion of large and medium tubers and decreased the proportion of small tubers. The highest tuber yield (330.2 q per ha) was obtained at 150 kg N per ha.

Nandekar *et al*. (1992) reported that tuber yield was highest (27.06 t per ha) with 60 kg N at planting + 40 kg N at earthing up + 2 foliar sprays.

Singh and Singh (1994) studied the effect of four rates of nitrogen (60, 120, 180 and 240 kg per ha) and four application methods (0.5 as basal + 0.5 on top dressing, 0.75 basal + 0.25 top dressing, 0.5 basal + 0.25 spray + 0.25 top dressing, 0.75 basal + 0.25 spray). They observed that yield increased by 28.4 per cent with 180 kg N compared with 60 kg N. The highest yield of tubers was achieved with the 0.75 basal dressing + 0.25 spray application.

Singh (1995) found that the application of nitrogen increased the tuber yield significantly with increasing doses up to 200 kg per ha.

Kumar *et al*. (1996) reported that the application of nitrogen increased the tuber yield significantly up to 120 kg nitrogen. But tuber dry matter decreased with increasing nitrogen rate.

Anabousi *et al*. (1997) conducted experiment at Central Jordan Valley and observed that increasing nitrogen application rates up to 250 kg N per ha resulted in significant increases in large and medium sized tuber yield, marketable, total yields and tuber weight with reductions in tuber dry matter.

Roy and Jaiswal (1998) at Jalandhar, Panjab found that total and large size (> 75 g) tuber yield increased by applying up to 240 kg N per ha and medium size tuber increased up to 120 kg N per ha application.

Deka and Dutta (1999) reported that tuber yield increased with increasing nitrogen rate, and the fertilizer also increased the number of tubers per plant, bulking rate, net profit and net production value. The optimum economic rate of nitrogen was calculated to be 247 kg per ha, with expected yield of 15.5 t per ha.

2.1 Effect of phosphorus on potato

Carl *et al*. (2011) reported that phosphorus play a great role in improving the chemical consistent of potato yield, whereas it may be increase the starch, protein, carbohydrate, sugar, N, P, K, Zn, Fe and Cu.

El Gamal (1996) studied the effect of 0, 15.5, 31.0 or 46.5 kg P_2O_5 /Feedam (0.42 ha) and inoculation with phosphorine containing PSB on growth and yield of potato cv. Diamante increased with P application rate and inoculation with phosphorine significantly increased soil P availability. The plant height, number of leaves, fresh weight of shoots, dry weight of shoots and number of stolons were increased with 46.5 kg P_2O_5/Feedam.

Debasish *et al.* (2001) reported the effect of four levels of phosphorus (0, 50, 100, and 150 kg P_2O_5/ha) on the growth and tuber yield of potato. They observed that the application of 100 and 150 kg P_2O_5/ha highly favored the growth parameters, like number of compound leaves per plant, plant height, ground coverage (%), number of stem per plant and yield parameters like grade wise yield and total tuber yield.

Jaggi *et al*. (1995) studied the effect of FYM and phosphorus fertilizer on tuber yield of potato. The highest tuber yield was obtained with the application of 10 tons FYM per ha with 60 kg P/ha.

Singh *et al*. (2002) studied that effect of phosphate solubilizing bacteria (PSB) in combination with 0, 60, 120 or 180 kg P_2O_5/ha applied as di-ammonium phosphate (DAP), single super phosphate (SSP), or rock phosphate on the yield of potato *cv*. Kufri Megha and *cv*. Kufri Jyoti. Crop yield, tuber size and net returns increased with increasing rate of P and were higher with phosphate solubilizing bacteria (PSB) inoculation.

Sommerfeld and Knutson (1965) and Sharma and Arora (1987) reported that P application increases potato yields up to certain levels (application rates), but with P application beyond those rates, yield losses are apparent.

Wallace (1993) stated that appropriate amounts of P will ensure early root development and sufficient P supply during the early growth stage of potatoes will ensure proper crop development and reproduction.

Jenkins and Ali (2000) reported that sufficient P in the soil is essential for early potato development, tuber set, total number of tubers and tuber maturity.

O´Brien *et al*. (1998) found that amount of light absorbed by the crop during the first week of tuber initiation correlated with the total number of tubers initiated, thus it is possible that P fertilization could have a positive effect on tuber set under certain conditions.

Tukaki and Mahler (1990) found that tuber set increased continuously when P concentration in the nutrient solution was increased from 0 to 10 μg/ml, although, increasing the P content in the nutrient solution from 10 to 55 μg/ml did not result in a greater number of tubers produced per plant.

Allison *et al*. (2001) reported that phosphorus fertilization had a significant impact on tuber number, exclusively at sites where P fertilizer had an impact on tuber fresh yield. Increase in total number of tubers was not due to an increase of stems per plant but an increase of tubers per stem.

Ekelöf (2007) and Berisha *et al*. (2014) reported that P fertilization prevents discoloration of tubers; they also noted that fertilization with P increased starch concentration.

Westermann and Kleinkopf (1985) reported that insufficient P may significantly reduce tuber quality, yield and size.

Hahlin and Ericsson (1981); Bennett (1993) stated that when P is deficient in potato plants, the formation of chlorophyll is less affected compared to cell and leaf expansion, resulting in the top side of the leaf becoming dark green. The stem and lower side of the leaves turn purplish and sometimes yield losses may be observed without these symptoms.

Grewal and Trehan (1993) stated that both height and leaf area index was positively related to P fertilizer applications in P deficient soils.

Jenkins and Ali (1999) showed that yield increases as an effect of P fertilizer application due to an increased radiation interception rather than an increased conversion efficiency.

Alvarez-Sanches *et al.* (1999) tested 13 different P application rates varying from 0 to 207 kg/ha. The experiment was carried out in an Andisol (7.8 mg Olsen P/l) in Mexico. The highest yield-increase observed was 6000 kg/ha compared to the control with no P, and the optimum P application rate was 90 kg/ha.

Hahlin (1992) investigated the optimum P fertilizer application rate for potatoes on loamy soils (P-AL 8-10) in the central parts of Sweden. Three application rates was tested 0, 45 and 90 kg/ha. A yield increase from 29.05 to 30.00 t/ha were found when application rates was increased from 45 to 90 kg/ha.

Rending and Taylor (1989) reported that plants supplied with adequate amount of P form good root system, strong stem, mature early and give high yield whereas plants grown on P deficient soils showed stunted growth, low shoot to root ratio, poor fruit and seed formation, purpled colored leaves with reddish coloration of the stem. Biochemically, deficiency causes changes in functions of the plant including accumulation of sucrose and reducing sugars and sometimes of starch.

Sharma and Arora (1987) reported that potato tuber yield is known to be influenced by P fertilizers through its effect on the number of tubers produced, the size of the tubers and the time at which maximum yield is obtained. They showed that yield response to increasing levels of P fertilizer was generally positive up to a particular level, above which the response became negative. They also noted that excess use of P fertilizers is usually associated with reduced tuber weight by hastening the maturation period and reducing tuber size.

Sanderson *et al.* (2002) stated that increases in tuber set increase with P application. Applied P has been found to increase the yield of small and medium size tubers (Hanle*y et al.*, 1985).

Zelalem *et al*. (2009) have found that application of 60 kg P/ha increased marketable tuber number 43.5% over the control.

Mulubrhan (2004) noted that increasing P application from 0 to 39.6 kg ha^{-1} highly significantly increased total tuber yield by 24.27%. He also indicated the existence of a room for further increases in tuber yield through application of more P fertilizers beyond 39.6 kg ha^{-1}.

Rosen *et al*. (2014) stated that phosphorus promotes root growth, rapid formation of tubers and starch synthesis. The deficiency of P causes retardation in root growth, delayed tuber formation and reduction in starch synthesis. The poorly developed plant root system leads to reduction in its capacity to absorb soil nutrients and affects its growth and development. It will delay tuber formation and this will decrease the size of the tubers produced within the lifespan of the potato crop. The reduction of starch synthesis leads to smaller amounts of sugar stored in the tubers which translates to small sized tubers and low yields.

Houghland (1960) reported that P functions in cell division, synthesis and storage of starch in the tubers. Thus, P can increase the size and percentage of dry matter (DM) (indicated by specific gravity) of the tubers (Freeman *et al*., 1998; Rosen *et al*., 2014). Rosen and Bierman (2008) reported that under high availability of soil P, its supply can decrease the production of larger tubers without changing the tuber specific gravity.

Klein *et al*. (1980) stated that P fertilization increases the concentrations of ascorbic acid, nitrogen (N) and protein in tubers. In addition to increasing the specific gravity of tubers, P fertilization can also change the texture, color and flavor of cooked tubers (Sheared and Johnston, 1958).

Zewide *et al*. (2012) reported that P fertilization provided an increase in tuber mean weight up to 24.5%.

Rosen and Bierman (2008) reported that besides being essential for the establishment of a great number of tubers per plant, P participates in a number of key enzymes involved in the regulation of starch synthesis (sucrose phosphate synthase, fructose 1, 6-bisphosphate and ADP-glucose pyrophosphorylase) (Taiz and Zeiger, 2013) and is also part of its composition, being connected to the amylopectin fraction of starch, in the form of phosphate ester (Nielsen *et al*., 1994).

Houghland (1960) reported that P plays great importance in starch metabolism and is required in relatively large amounts in the potato plant for the phosphorylation of starch during the filling of the tuber.

Freeman *et al*. (1998) reported that in soil with low P availability, P fertilization promoted a slight reduction in the percentage of tuber dry matter (DM) (indicated by the specific gravity), possibly caused by the dilution effects.

Lachman *et al*. (2005) found that P fertilization not changed the tuber protein content but increased the yield of marketable tubers which consequently results in a higher protein yield per area.

CHAPTER III

MATERIALS AND METHODS

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

3.1 Experimental period

The experiment was conducted during the period from November 2017 to March 2018 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 23º41' N latitude and 90º22' E longitude at an altitude of 8.6 meter above the sea level.

3.2.2 Agro-ecological region

The experimental site belongs to the agro-ecological zone of “Madhupur Tract”, AEZ-28. This was a region of complex relief and soils developed over the Madhupur clay, where floodplain sediments buried the dissected edges of the Madhupur Tract leaving small hillocks of red soils as “islands” surrounded by floodplain. The experimental site was shown in the map of AEZ of Bangladesh in Appendix I and the morphological characteristics of the experimental field was shown in Appendix II.

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 III.

3.2.4 Climate of the experimental site

Experimental site was located in the sub-tropical monsoon climatic zone, set aparted by winter during the months from November, 10 to March, 10 (Rabi season). Plenty of sunshine and moderately low temperature prevails during experimental period, which is suitable for potato growing in Bangladesh.

3.3 Details of the Experiment

3.3.1 Experimental treatments

The experiment consisted of two factors such as nitrogen (N) and phosphorus (P) fertilizers. The treatments were as follows:

Factor A: Four different levels of nitrogen

N_0: Control (0 Kg N ha^{-1})

N_1: 75 Kg N ha^{-1}

N_2: 105 Kg N ha^{-1}

N_3: 135 Kg N ha^{-1}

Factor B: Three different levels of phosphorus

P_0: Control (0 Kg P ha^{-1})

P_1: 69 Kg P ha^{-1}

P_2: 92 Kg P ha^{-1}

Treatment combinations = 4 × 3 = 12

Replications = 3

3.3.2 Experimental design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications thus comprised 36 plots. The layout of the experiment was prepared for distributing the combination of nitrogen and phosphorus. The size of each plot 2.0 m × 1.5 m. The layout is shown in Appendix IV.

3.4 Planting material

BARI Alu-35 was developed by the scientists of BARI (Bangladesh Agricultural Research Institute) and was officially released by National Seed Board of Bangladesh in 2012. The average yield of BARI Alu-35 is 30-45 t/ha. Its crop duration is 90-95 days.

3.5 Crop management

3.5.1 Collection of seed

The planting material (seed potato) was collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701, Dhaka.

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, 2017 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 Source application

The crop was fertilized as per recommendation of TCRC (2004). The experimental plot was fertilized with following dose of muriate of potash (MoP), gypsum, zinc sulphate and boric acid.

Fertilizers	Dose (Kg ha^{-1})	Dose (g $plot^{-1}$)
Cowdung	10,000	3000
MoP	300	90
Gypsum	120	27.10
Zinc Sulphate	14	3.2
Boric Acid	6	1.4

Source: Mondal *et al.*, 2011.

Cowdung was applied 10 days before final land preparation. Total amount of muriate of potash (MoP), gypsum, zinc sulphate and boric acid were applied at basal doses during final land preparation. Different doses of urea and TSP were applied as per treatment. One third of urea was applied at final land preparation and one third was applied at 30 DAS. Finally rest amount was applied at 45 DAS.

3.5.5 Planting of seed tuber

The well sprouted healthy and uniform sized (45-50 mm) potato tubers were planted according to treatment and a whole potato was used as a seed potato. Tubers were planted in such a way that tuber does not go much under soil or does not remain in shallow. On an average the tubers were planted at a depth of 5-8 cm furrow as schedule of spacing.

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, 2018 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, 2018 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 30 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.

i. Days to first emergence
ii. Days to final emergence
iii. Plant height at 30, 60 and 90 DAP
iv. Number of leaves plant^{-1} at 30, 60 and 90 DAP
v. Number of stems hill^{-1}
vi. Stem dry matter
vii. Number of tubers hill^{-1}
viii. Average weight of tuber hill^{-1}
ix. Yield of tuber
x. Tuber dry matter
xi. Total soluble solid
xii. Protein content

3.5.8 Experimental measurements

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

i. Days to first and final emergence

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

ii. Plant height (cm)

Plant height refers to the height of the plant from ground levels to the tip of the tallest stem. It was measured at an interval of 30 days starting from 30 DAP till 90 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 30 days starting from 30 DAP till 90 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 30 days starting from 30 DAP till 90 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 harvest was calculated with the following formula (Elfnesh *et al.,* 2011).

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

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 hill^{-1}

Average weight of tuber hill^{-1} 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

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

ix. Tuber dry matter

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

x. Total soluble solid

Total soluble solid 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.

xi. Protein content

The amount of protein present in potato was calculated from total nitrogen present in potato multiplied by 6.25 (conversion factor) (Ma and Zuazaga, 1942).

xii. Determination of nitrogen for protein content (%)

The Macro Kjeldahl method was used to determine the total Nitrogen in root, shoot and grain of plant samples. Three steps were followed in this method. These are as follows:-

A. Digestion: In this step the organic nitrogen was converted to ammonium sulphate by sulphuric acid and digestion accelerators (Catalyst Mixture) at a temperature of 360-440º C.

$$N + H_2SO_4 = (NH_4)_2SO_4$$

B. Distillation: In this step, the solution was made alkaline from the distillation of ammonia. The distilled ammonia was received in boric acid solution.

$$(NH_4)_2SO_4 + NaOH = Na_2SO_4 + NH_3 + H_2O$$

$$2NH_3 + H_3BO_3 = (NH_4)_3BO_3$$

C. Titration: To determine the amount of NH_3, ammonium borate was titrated with standard sulfuric acid.

$$(NH_4)_3BO_3 + H_2SO_4 = (NH_4)_2SO_4 + H_3BO_3$$

Reagents: 4% Boric Acid solution, Mixed indicator (Bromocresol green and Methyl red), 40% Sodium Hydroxide solution, Standard Sulphuric Acid solution 0.05 N and 0.05 N Na_2CO_3 solution.

Procedure: About 1.0 g of oven dried sample was weighed and then taken into a 250 mL Kjeldahl flask. Then 5g catalysts mixer (K_2SO_4:$CuSO_4.5H_2O$:Se=100:1:1) was added in to flask. Then about 25 mL concentrated H_2SO_4 was also added to the flask. The flask was heated until the solution become clear and then allowed to cool and then about 120 mL of distilled water was added and 5-6 glass bead into the flask. After digestion, 40% NaOH 125 mL was added to the conical flask and attached quickly to the distillation set. Then the flask was heated continuously. In the meantime, 25 mL of 4% boric acid solution and 2-4 drops of mixed indicator was taken in a 500 mL receiver conical flask. After distillation, about 150 ml distillate was collected into receiver conical flask. The distillate was then titrated with standard H_2SO_4 taken from a burette until the green color completely turns to pink color at the end point. The same procedure was followed for a blank sample. The result was calculated using the following formula-

%N= (T-B) × N× 1.4/S (Ma and Zuazaga, 1942)

Where, T= Titration value for sample (mL), B= Titration value for blank (mL), N= Normality of H_2SO_4 (N), S= Weight of the sample (g), 1.4= conversion factor

Protein (%) = (%) N × 6.25 (Ma and Zuazaga, 1942)

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 program. 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

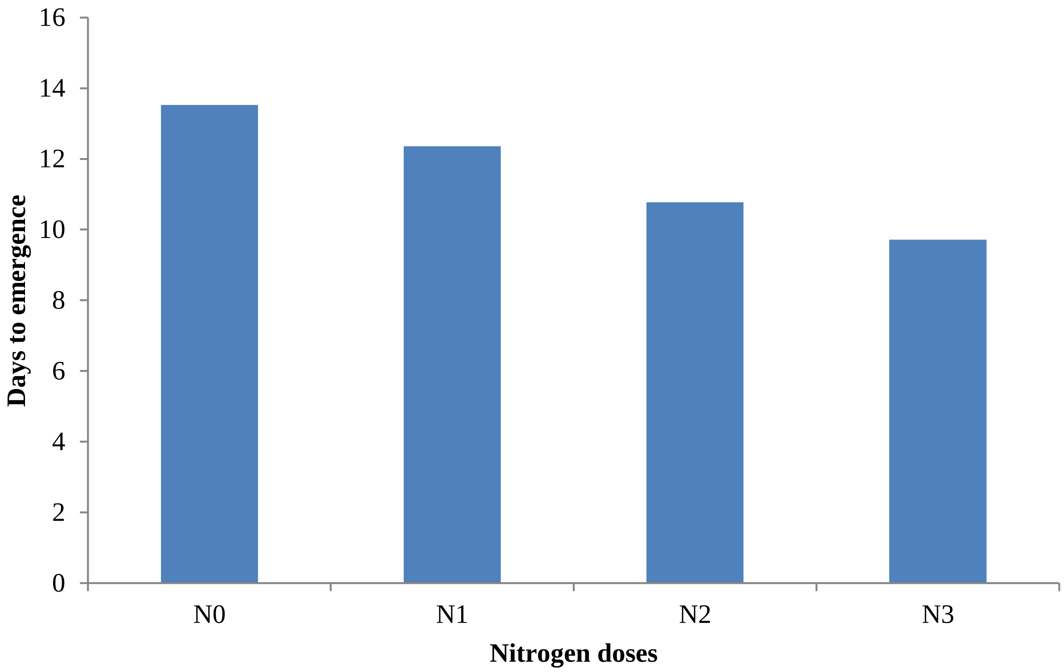
RESULTS AND DISCUSSION

The experiment was conducted to find out the response of nitrogen and phosphorus on the growth, yield, quality and protein content of BARI Alu-35. 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 IX-XII. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following headings.

4.1 Days to first emergence

Effect of nitrogen

Days to first emergence were significantly influenced by the application of different nitrogen levels; results revealed that, the duration of emergence decreased gradually with increasing the level of nitrogen (Figure 1 and Appendix V). The control treatment (N_0) took the maximum days (13.53 days) for first emergence, whereas, the minimum days (9.71 days) was taken by N_3. Emergence depends on soil moisture, soil temperature, seed temperature, disease and physiological age of seed.

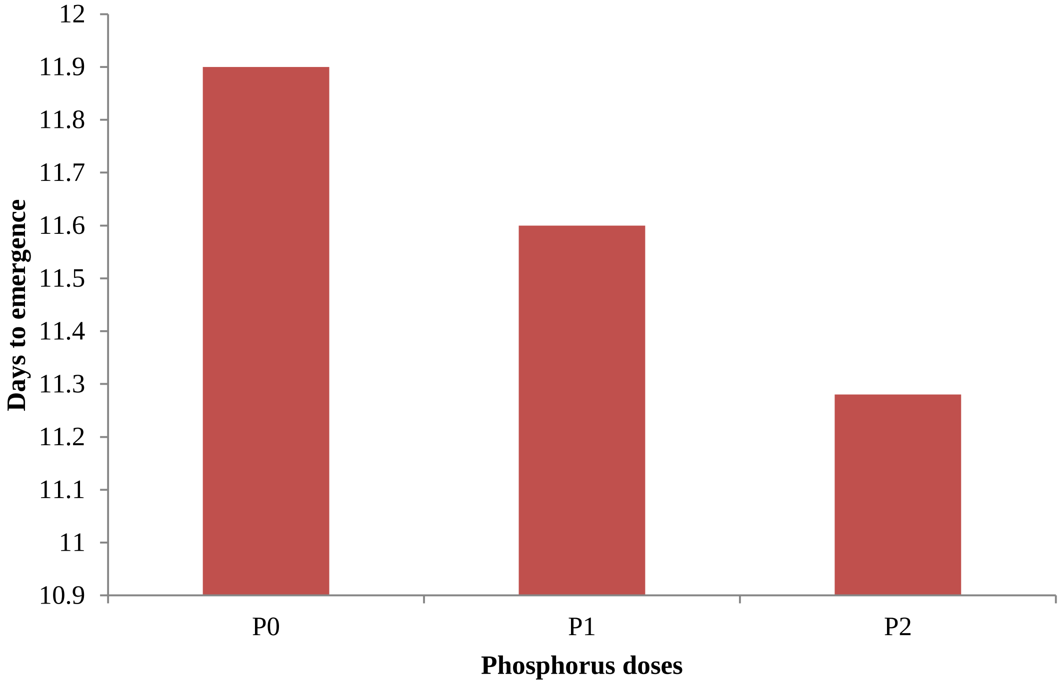


N_0 = 0 Kg, N_1 = 75 Kg, N_2 = 105 Kg, N_3 = 135 Kg ha^{-1}

Figure 1. Effect of nitrogen on first days to emergence

Effect of phosphorus

Days to first emergence were significantly influenced by the application of different phosphorus levels; results revealed that, the duration of emergence decreased gradually with increasing the level of phosphorus (Figure 2 and Appendix VI). The control treatment (P_0) took the maximum days (11.90 days) for first emergence, whereas, the minimum days (11.28 days) was taken by P_2.



P_0 = 0 Kg, P_1 = 69 Kg, P_2 = 92 Kg ha^{-1}

Figure 2. Effect of phosphorus on first days to emergence

Interaction effect of nitrogen and phosphorus

Interaction of different doses of nitrogen and phosphorus showed significant variation on days to first emergence of BARI Alu-35 (Table 1). The maximum duration for first emergence (13.87 days) was recorded from N_0P_0 treatment whereas; the minimum duration (9.39 days) was recorded from the N_3P_2 treatment.

Table 1. Interaction effect of nitrogen and phosphorus on days to first emergence, days to final emergence and plant height at different days after planting

Treatments		Days to first emergence	Days to final emergence	Plant height (cm)		
				30 DAP	60 DAP	90 DAP
N_0	P_0	13.87 a	19.38 a	12.22 l	21.35 l	37.41 l
	P_1	13.55 b	19.16 b	12.94 k	22.65 k	39.67 k
	P_2	13.18 c	18.95 c	13.72 j	23.93 j	41.93 j
N_1	P_0	12.67 d	18.58 d	14.47 i	25.30 i	44.25 i
	P_1	12.32 e	18.31 e	15.22 h	26.58 h	46.55 h
	P_2	12.08 f	18.09 f	15.94 g	27.95 g	48.94 g
N_2	P_0	11.12 g	17.66 g	16.75 f	29.29 f	51.24 f
	P_1	10.72 h	17.39 h	17.47 e	30.60 e	53.52 e
	P_2	10.47 i	17.12 i	18.25 d	31.91 d	55.82 d
N_3	P_0	9.94 j	16.71 j	18.94 c	33.22 c	58.11 c
	P_1	9.80 k	16.52 k	19.75 b	34.54 b	60.42 b
	P_2	9.39 l	16.24 l	20.47 a	35.92 a	62.64 a
$LSD_{(0.05)}$		0.05355	0.05355	0.05355	0.05355	0.05355
CV (%)		8.28	8.13	7.18	7.09	7.04
Significant level		*	*	*	*	*

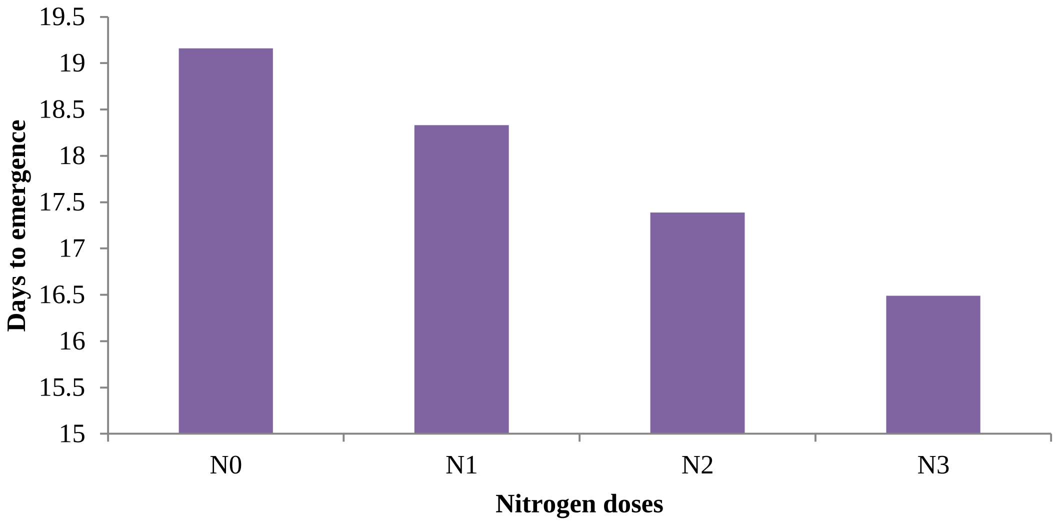
* - Significant at 5% level

N_0 = 0 Kg, N_1 = 75 Kg, N_2 = 105 Kg, N_3 = 135 Kg ha^{-1}; P_0 = 0 Kg, P_1 = 69 Kg, P_2 = 92 Kg ha^{-1}

4.2 Days to final emergence

Effect of nitrogen

Days to final emergence were significantly influenced by the application of different nitrogen levels; results revealed that, the duration of emergence decreased gradually with increasing the level of nitrogen (Figure 3 and Appendix V). The control treatment (N_0) took the maximum days (19.16 days) for final emergence, whereas, the minimum days (16.49 days) was taken by N_3.

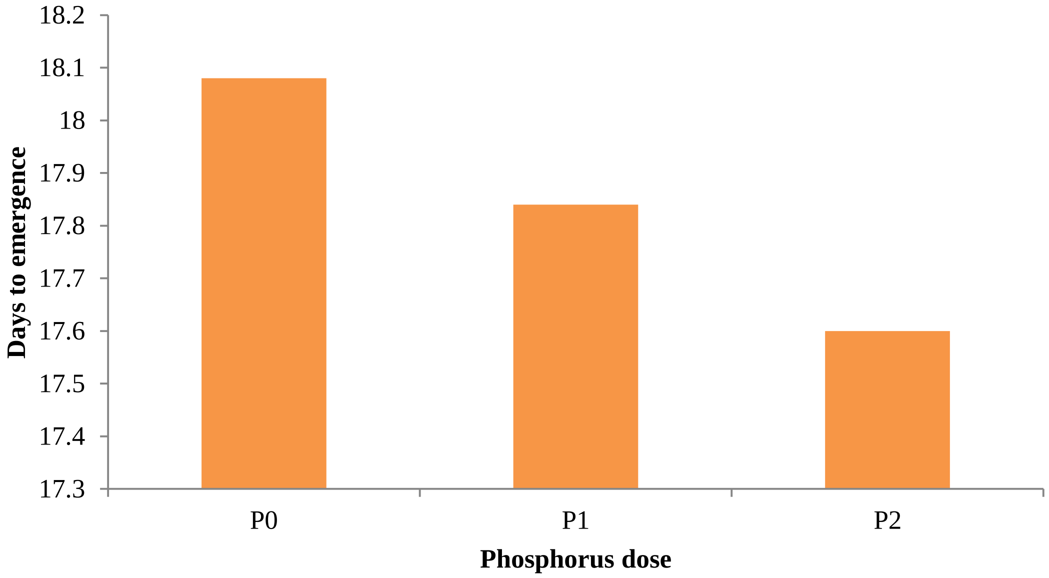


N_0 = 0 Kg, N_1 = 75 Kg, N_2 = 105 Kg, N_3 = 135 Kg ha^{-1}

Figure 3. Effect of nitrogen on final days to emergence

Effect of phosphorus

Days to final emergence were significantly influenced by the application of different phosphorus levels; results revealed that, the duration of emergence decreased gradually with increasing the level of phosphorus (Figure 4 and Appendix VI). The control treatment (P_0) took the maximum days (18.08 days) for final emergence, whereas, the minimum days (17.60 days) was taken by P_2.



P_0 = 0 kg, P_1 = 69 kg, P_2 = 92 kg ha^{-1}

Figure 4. Effect of phosphorus on final days to emergence

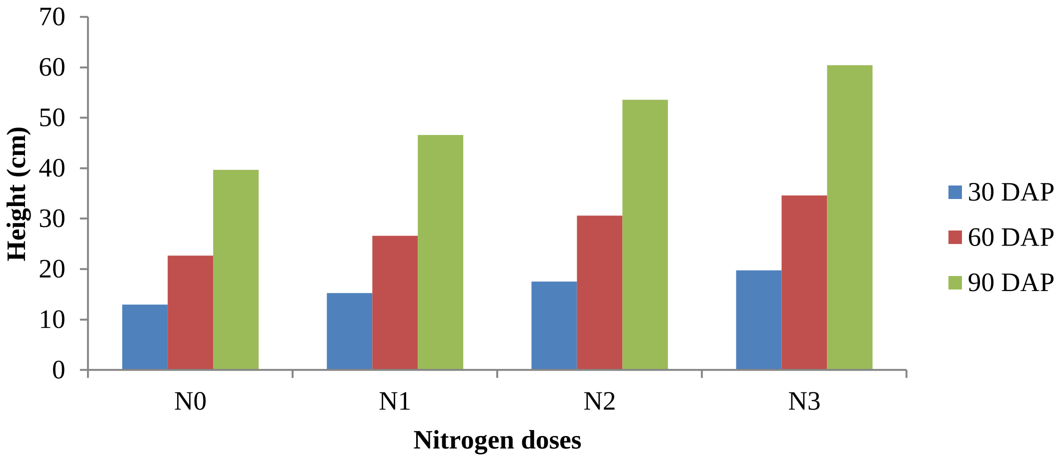
Interaction effect of nitrogen and phosphorus

Interaction of different doses of nitrogen and phosphorus showed significant variation on days to final emergence of BARI Alu-35 (Table 1). The maximum duration for final emergence (19.38 days) was recorded from N_0P_0 treatment whereas; the minimum duration (16.24 days) was recorded from the N_3P_2 treatment.

4.3 Plant height (cm)

Effect of nitrogen

The plant height (cm) of BARI Alu-35 was significantly influenced by different doses of nitrogen at 30, 60 and 90 DAP (Figure 5 and Appendix V). The results revealed that at 30, 60 and 90 DAP, the treatment N_0 produced the shortest plant (12.96 cm, 22.64 cm and 39.67 cm respectively) and the treatment N_3 produced the tallest plant (19.72 cm, 34.56 cm and 60.39 cm respectively). This increase in plant height might be due to the fact that higher nitrogen concentration stimulated the assimilation of carbohydrates and protein, which in turn enhanced cell division and formation of more tissues that resulted in enhanced vegetative growth of the plant (Meyer and Anderson, 1970).

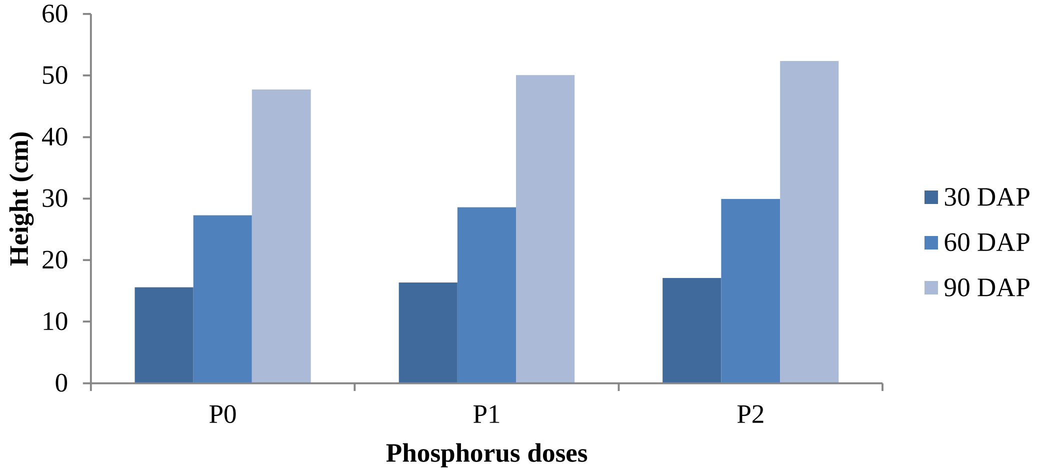


N_0 = 0 Kg, N_1 = 75 Kg, N_2 = 105 Kg, N_3 = 135 Kg ha^{-1}

Figure 5. Effect of nitrogen on plant height at different days after planting

Effect of phosphorus

The plant height (cm) of BARI Alu-35 was significantly influenced by different doses of phosphorus at 30, 60 and 90 DAP (Figure 6 and Appendix VI). The results revealed that at 30, 60 and 90 DAP, the treatment P_0 produced the shortest plant (15.60 cm, 27.29 cm and 47.75 cm respectively) and the treatment P_2 produced the tallest plant (17.09 cm, 29.93 cm and 52.33 cm respectively). Debasish *et al.* (2001) reported that plant height significantly varied with different doses of phosphorus.



P_0 = 0 Kg, P_1 = 69 Kg, P_2 = 92 Kg ha^{-1}

Figure 6. Effect of phosphorus on plant height at different days after planting

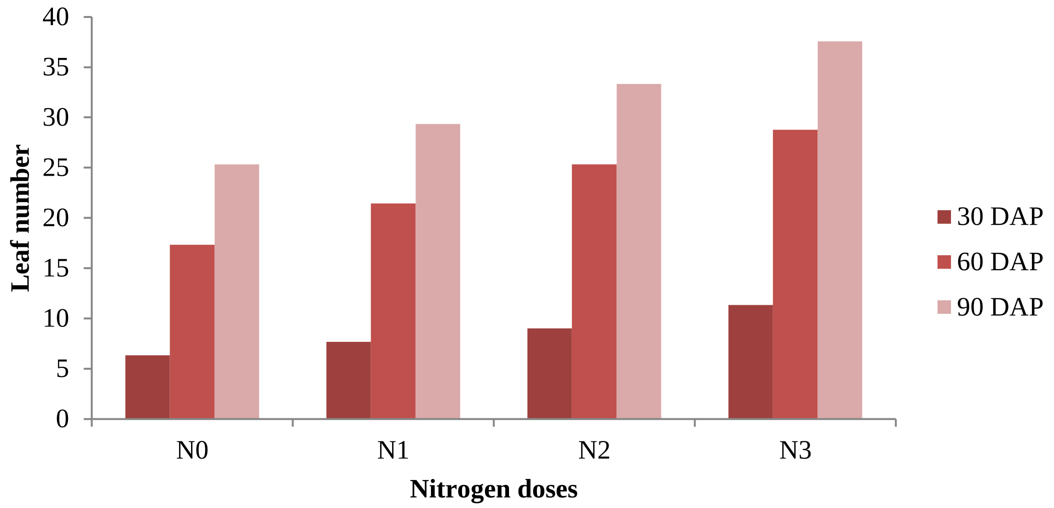
Interaction effect of nitrogen and phosphorus

Interaction of different doses of nitrogen and phosphorus showed significant variation on plant height of BARI Alu-35 at 30, 60 and 90 DAP (Table 1). At 30, 60 and 90 DAP, the lowest plant height (12.22 cm, 21.35 cm and 37.41 cm respectively) was observed from the N_0P_0 treatment and the highest plant height (20.47 cm, 35.92 cm and 62.64 cm respectively) was observed from N_3P_2 treatment.

4.4 Number of leaves plant^{-1}

Effect of nitrogen

The number of leaves plant^{-1} of BARI Alu-35 was significantly influenced by different doses of nitrogen at 30, 60 and 90 DAP (Figure 7 and Appendix VII). The results revealed that at 30, 60 and 90 DAP, the treatment N_0 produced minimum number of leaves plant^{-1} (6.33, 17.33 and 25.33 respectively) and the treatment N_3 (11.33, 28.78 and 37.56 respectively) produced maximum number of leaves plant^{-1}. This increase may be due to increased uptake of nutrients, which resulted in increased synthesis of carbohydrates, which are utilized in building up of new cell. These results are in conformity with the findings of Lal *et al*. (1982) and Singh *et al*. (1986).

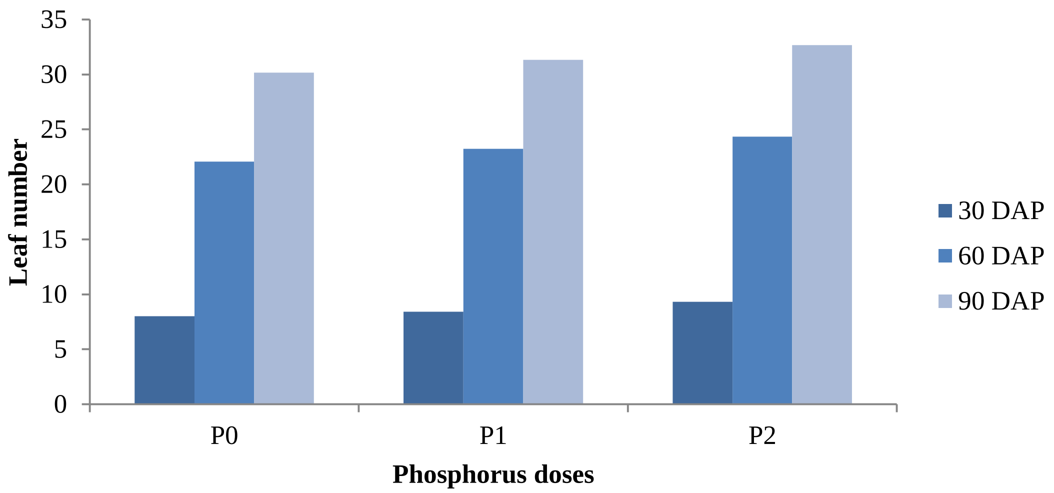


N_0 = 0 kg, N_1 = 75 kg, N_2 = 105 kg, N_3 = 135 kg ha^{-1}

Figure 7. Effect of nitrogen on number of leaves $plant^{-1}$ at different days after planting

Effect of phosphorus

The number of leaves $plant^{-1}$ of BARI Alu-35 was significantly influenced by different doses of phosphorus at 30, 60 and 90 DAP (Figure 8 and Appendix VIII). The results revealed that at 30, 60 and 90 DAP, the treatment P_0 produced minimum number of leaves $plant^{-1}$ (8.00, 22.08 and 30.17 respectively) and the treatment P_2 (9.33, 24.33 and 32.67 respectively) produced maximum number of leaves $plant^{-1}$. Debasish *et al.* (2001) reported that the number of compound leaves per plant increases with increased level of phosphorus.



P_0 = 0 kg, P_1 = 69 kg, P_2 = 92 kg ha^{-1}

Figure 8. Effect of phosphorus on number of leaves $plant^{-1}$ at different days after planting

Interaction effect of nitrogen and phosphorus

Interaction of different doses of nitrogen and phosphorus showed significant variation on plant number of leaves plant^{-1} of BARI Alu-35 at 30, 60 and 90 DAP (Table 2). At 30 DAP, the lowest number of leaves plant^{-1} (6.00) was observed from the N_0P_0 treatment which was statistically similar with N_0P_1 (6.33), N_0P_2 (6.67), N_1P_0 (7.33), N_1P_1 (7.67) and N_1P_2 (8.00) whereas, the highest number of leaves plant^{-1} (12.67) was observed from N_3P_2 treatment which was statistically similar with N_3P_1 (11.00).

Table 2. Interaction effect of nitrogen and phosphorus on number of leaves plant^{-1} at different days after planting, number of stems hill^{-1} and stem dry matter

Treatments		Number of leaves plant^{-1}			Number of stems hill^{-1}	Stem dry matter (%)
		30 DAP	60 DAP	90 DAP		
N_0	P_0	6.00 g	17.00 g	25.00 h	1.00 i	4.25 l
	P_1	6.33 fg	17.33 g	25.33 h	1.33 hi	5.35 k
	P_2	6.67 efg	17.67 g	25.67 h	1.67 ghi	6.91 j
N_1	P_0	7.33 efg	20.00 fg	28.00 gh	2.00 f-i	8.15 i
	P_1	7.67 efg	21.67 ef	29.33 fg	2.33 e-h	9.18 h
	P_2	8.00 d-g	22.67 def	30.67 efg	2.67 d-g	10.22 g
N_2	P_0	8.33 c-f	24.00 cde	32.00 def	3.00 c-f	12.26 f
	P_1	8.67 cde	25.33 bcd	33.33 cde	3.33 b-e	13.31 e
	P_2	10.00b cd	26.67 bc	34.67 bcd	3.67 a-d	14.59 d
N_3	P_0	10.33 bc	27.33 abc	35.67 bc	4.00 abc	16.67 c
	P_1	11.00 ab	28.67 ab	37.33 ab	4.33 ab	17.87 b
	P_2	12.67 a	30.33 a	39.67 a	4.67 a	18.87 a
LSD $_{(0.05)}$		2.130	3.356	3.570	1.285	0.05355
CV (%)		14.66	8.54	6.72	6.78	8.26
Significant level		*	*	*	*	*

* - Significant at 5% level

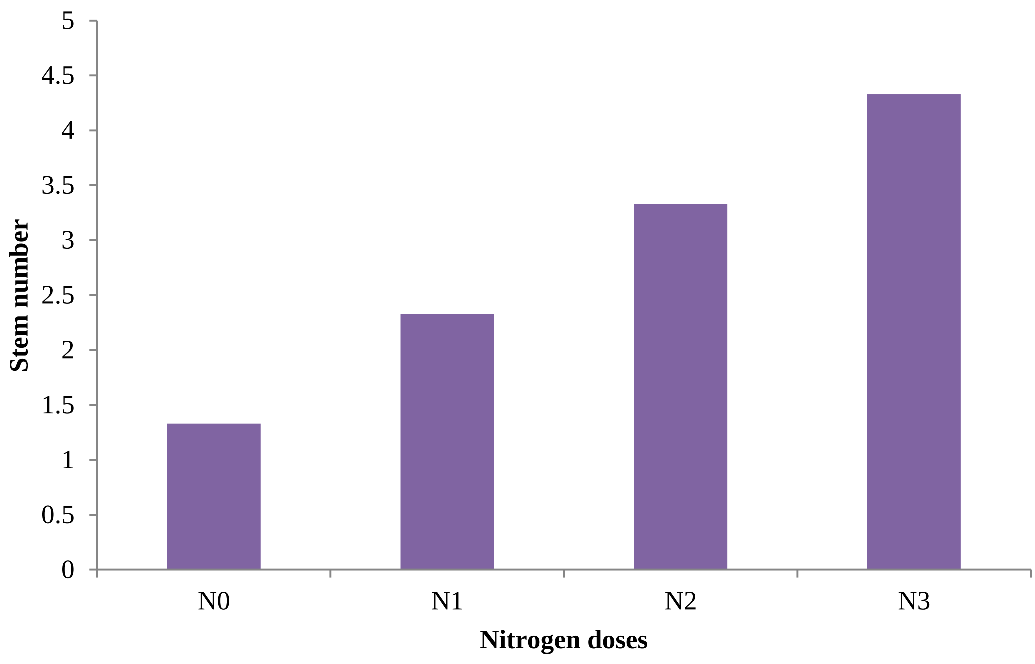
N_0 = 0 Kg, N_1 = 75 Kg, N_2 = 105 Kg, N_3 = 135 Kg ha^{-1}; P_0 = 0 Kg, P_1 = 69 Kg, P_2 = 92 Kg ha^{-1}

At 60 DAP, the lowest number of leaves plant^{-1} (17.00) was observed from the N_0P_0 treatment which was statistically similar with N_0P_1 (17.33), N_0P_2 (17.67) and N_1P_0 (20.00) whereas, the highest number of leaves plant^{-1} (30.33) was observed from N_3P_2 which was statistically similar with N_3P_1 (28.67) and N_3P_0 (27.33). At 90 DAP, the lowest number of leaves plant^{-1} (25.00) was observed from the N_0P_0 treatment which was statistically similar with N_0P_1 (25.33), N_0P_2 (25.67) and N_1P_0 (28.00) whereas, the highest number of leaves plant^{-1} (39.67) was observed from N_3P_2 which was statistically similar with N_3P_1 (37.33).

4.5 Number of stems hill^{-1}

Effect of nitrogen

The number of stems hill^{-1} of BARI Alu-35 was significantly influenced by different doses of nitrogen (Figure 9 and Appendix VII). The results revealed that the treatment N_0 produced minimum number of stems hill^{-1} (1.33) and the treatment N_3 (4.33) produced maximum number of stems hill^{-1}. Anabousi *et al*. (1997) reported that stem number per plant increases with increased level of nitrogen.

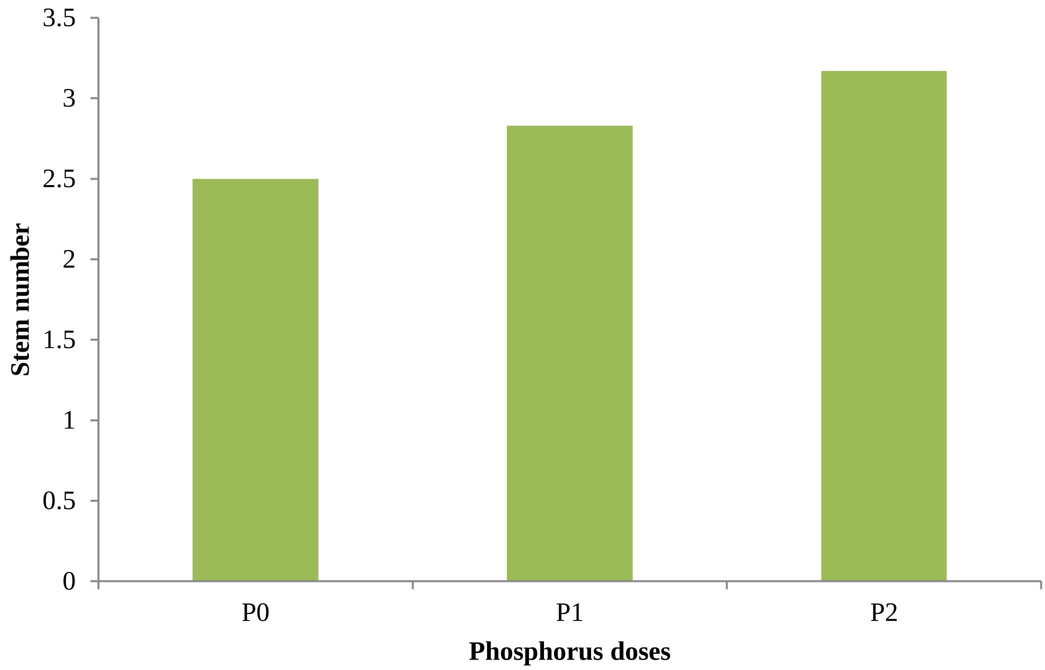


N_0 = 0 Kg, N_1 = 75 Kg, N_2 = 105 Kg, N_3 = 135 Kg ha^{-1}

Figure 9. Effect of nitrogen on number of stems hill^{-1}

Effect of phosphorus

The number of stems hill^{-1} of BARI Alu-35 was significantly influenced by different doses of phosphorus (Figure 10 and Appendix VIII). The results revealed that the treatment P_0 produced minimum number of stems hill^{-1} (2.50) and the treatment P_2 (3.17) produced maximum number of stems hill^{-1}. Debasish *et al.* (2001) reported that increasing the level of phosphorus increases the number of stem per plant.



P_0 = 0 Kg, P_1 = 69 Kg, P_2 = 92 Kg ha^{-1}

Figure 10. Effect of phosphorus on number of stems hill^{-1}

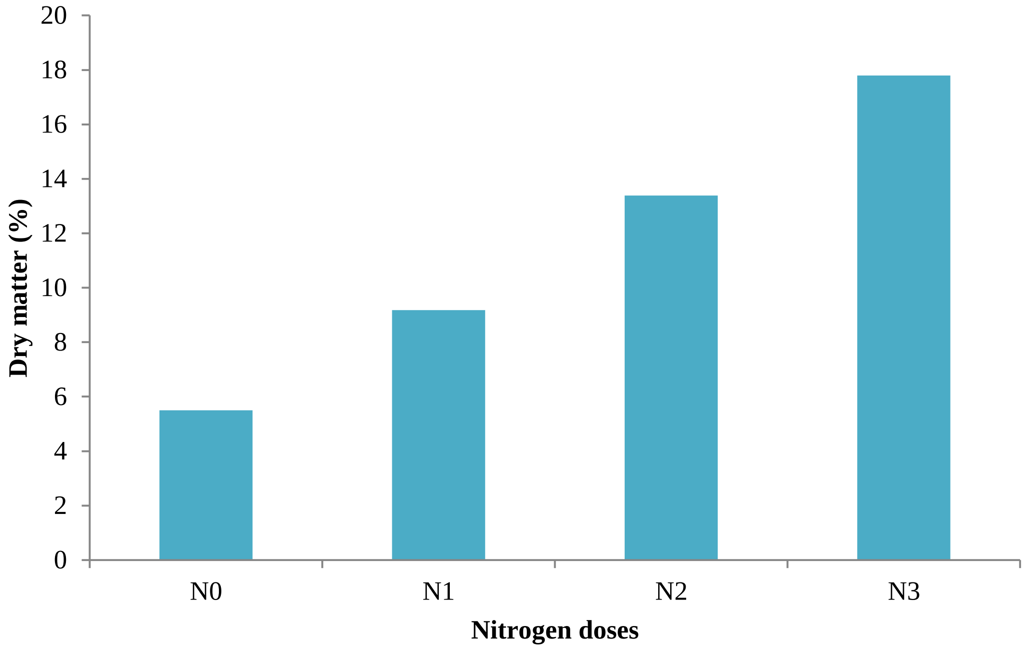
Interaction effect of nitrogen and phosphorus

Interaction of different doses of nitrogen and phosphorus showed significant variation on number of stems hill^{-1} of BARI Alu-35 (Table 2). The minimum number of stems per hill^{-1} (1.00) was recorded from N_0P_0 treatment which was statistically similar with N_0P_1 (1.33), N_0P_2 (1.67) and N_1P_0 (2.00) whereas; the maximum number of stems per hill^{-1} (4.67) was recorded from the N_3P_2 treatment which was statistically similar with N_3P_1 (4.33), N_3P_0 (4.00) and N_2P_2 (3.67).

4.6 Stem dry matter

Effect of nitrogen

The stem dry matter (%) of BARI Alu-35 was significantly influenced by different doses of nitrogen (Figure 11 and Appendix VII). The results revealed that the treatment N_0 produced lower stem dry matter (5.50%) and the treatment N_3 (17.80%) produced higher stem dry matter. Singh and Singh (1994) reported that stem dry matter content increased with increased application nitrogen.

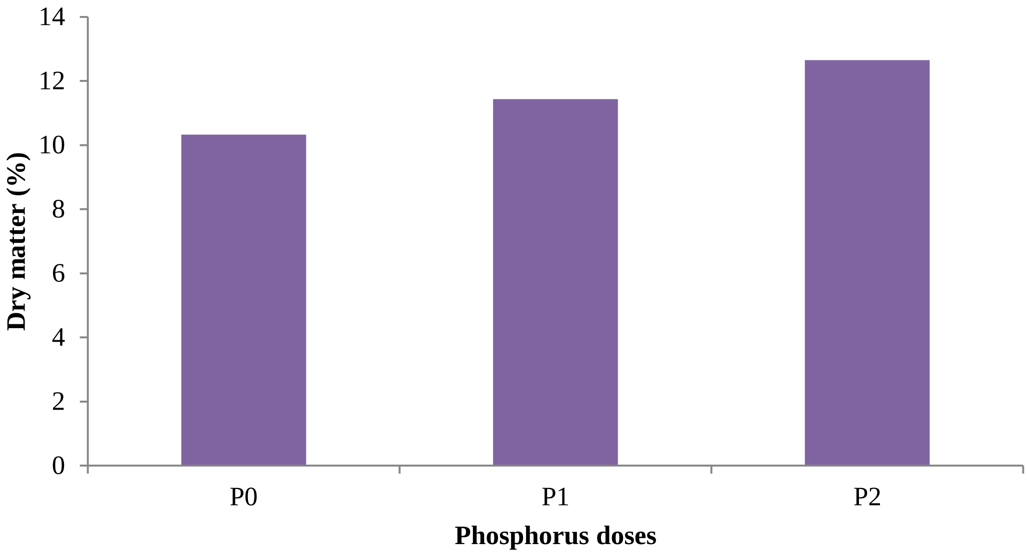


N_0 = 0 Kg, N_1 = 75 Kg, N_2 = 105 Kg, N_3 = 135 Kg ha^{-1}

Figure 11. Effect of nitrogen on stem dry matter

Effect of phosphorus

The stem dry matter (%) of BARI Alu-35 was significantly influenced by different doses of phosphorus (Figure 12 and Appendix VIII). The results revealed that the treatment P_0 produced lower stem dry matter (10.33%) and the treatment P_2 (12.65%) produced higher stem dry matter. Debasish *et al.* (2001) reported the same result as dry matter increased with increased level of phosphorus.



P_0 = 0 Kg, P_1 = 69 Kg, P_2 = 92 Kg ha^{-1}

Figure 12. Effect of phosphorus on stem dry matter

Interaction effect of nitrogen and phosphorus

Interaction of different doses of nitrogen and phosphorus showed significant variation on stem dry matter (%) of BARI Alu-35 (Table 2). The minimum stem dry matter (4.25%) was recorded from N_0P_0 treatment and the maximum stem dry matter (18.87%) was recorded from the N_3P_2 treatment.

4.7 Number of tubers hill^{-1}

Effect of nitrogen

The number of tubers hill^{-1} of BARI Alu-35 was significantly influenced by different doses of nitrogen (Table 3). The results revealed that the treatment N_0 produced lowest number of tubers hill^{-1} (4.67) and the treatment N_3 (10.11) produced highest number of tubers hill^{-1}. The increased number of tubers per hill^{-1} may be due to increased absorption of nutrients which would have increased photosynthetic activity as well as translocation of photosynthates for formation of tubers. Mulubrhan (2004) reported that the application of nitrogen increased the tubers number of potato per unit area.

Table 3. Effect of nitrogen on number of tubers hill^{-1}, average weight of tuber hill^{-1} and yield of tuber

Treatments	Number of tubers hill^{-1}	Average weight of tuber hill^{-1} (g)	Yield of tuber (t ha^{-1})
N_0	4.67 d	47.66 d	25.63 d
N_1	7.67 c	56.53 c	29.70 c
N_2	8.67 b	65.72 b	33.72 b
N_3	10.11 a	74.39 a	37.73 a
LSD $_{(0.05)}$	0.6947	0.03092	0.03092
CV (%)	15.70	9.04	8.09
Significant level	*	*	*

* - Significant at 5% level

N_0 = 0 Kg, N_1 = 75 Kg, N_2 = 105 Kg, N_3 = 135 Kg ha^{-1}

Effect of phosphorus

The number of tubers hill^{-1} of BARI Alu-35 was significantly influenced by different doses of phosphorus (Table 4). The results revealed that the treatment P_0 produced lowest number of tubers hill^{-1} (7.08) and the treatment P_2 (8.00) produced highest number of tubers hill^{-1} which was statistically similar with P_1 (7.50).

Table 4. Effect of phosphorus on number of tubers hill^{-1}, average weight of tuber hill^{-1} and yield of tuber

Treatments	Number of tubers hill^{-1}	Average weight of tuber hill^{-1} (g)	Yield of tuber (t ha^{-1})
P_0	7.08 b	59.18 c	30.45 c
P_1	7.50 ab	60.88 b	31.70 b
P_2	8.00 a	63.17 a	32.93 a
LSD $_{(0.05)}$	0.6017	0.02677	0.02677
CV (%)	15.70	9.04	8.09
Significant level	*	*	*

* - Significant at 5% level

P_0 = 0 Kg, P_1 = 69 Kg, P_2 = 92 Kg ha^{-1}

Jenkins and Ali (2000) reported that sufficient P in the soil is essential for early potato development, tuber set, total number of tubers and tuber maturity.

Interaction effect of nitrogen and phosphorus

Interaction of different doses of nitrogen and phosphorus showed significant variation on number of tubers hill^{-1} of BARI Alu-35 (Table 5). The minimum number of tubers hill^{-1} (4.33) was recorded from N_0P_0 treatment which was statistically similar with N_0P_1 (4.67) and N_0P_2 (5.00) whereas; the maximum number of tubers hill^{-1} (11.00) was recorded from the N_3P_2 treatment which was statistically similar with N_3P_1 (10.00).

Table 5. Interaction effect of nitrogen and phosphorus on number of tubers hill^{-1}, average weight of tuber hill^{-1} and yield of tuber

Treatments		Number of tubers hill^{-1}	Average weight of tuber hill^{-1} (g)	Yield of tuber (t ha^{-1})
N_0	P_0	4.33 e	45.67 l	24.37 l
	P_1	4.67 e	46.72 k	25.63 k
	P_2	5.00 e	49.60 j	26.89 j
N_1	P_0	6.33 d	54.70 i	28.47 i
	P_1	6.67 d	56.16 h	29.67 h
	P_2	7.00 d	58.74 g	30.95 g
N_2	P_0	8.33 c	63.92 f	32.47 f
	P_1	8.67 c	65.38 e	33.75 e
	P_2	9.00 bc	67.86 d	34.93 d
N_3	P_0	9.33 bc	72.42 c	36.51 c
	P_1	10.00 ab	74.28 b	37.76 b
	P_2	11.00 a	76.47 a	38.93 a
LSD $_{(0.05)}$		1.203	0.05355	0.05355
CV (%)		15.70	9.04	8.09
Significant level		*	*	*

* - Significant at 5% level

N_0 = 0 Kg, N_1 = 75 Kg, N_2 = 105 Kg, N_3 = 135 Kg ha^{-1}; P_0 = 0 Kg, P_1 = 69 Kg, P_2 = 92 Kg ha^{-1}

4.8 Average weight of tuber hill^{-1}

Effect of nitrogen

The average weight of tuber hill^{-1} (g) of BARI Alu-35 was significantly influenced by different doses of nitrogen (Table 3). The results revealed that the treatment N_0 produced lowest average weight of tuber hill^{-1} (47.66 g) and the treatment N_3 produced highest average weight of tuber hill^{-1} (74.39 g). Zelalem *et al*. (2009) reported that average tuber weight progressively increased with increasing N rate.

Effect of phosphorus

The average weight of tuber hill^{-1} (g) of BARI Alu-35 was significantly influenced by different doses of phosphorus (Table 4). The results revealed that the treatment P_0 produced lowest average weight of tuber hill^{-1} (59.18 g) and the treatment P_2 produced highest average weight of tuber hill^{-1} (63.17 g). Zewide *et al*. (2012) reported that P fertilization provided an increase in tuber mean weight up to 24.5%.

Interaction effect of nitrogen and phosphorus

Interaction of different doses of nitrogen and phosphorus showed significant variation on average weight of tuber hill^{-1} (g) of BARI Alu-35 (Table 5). The minimum average weight of tuber hill^{-1} (45.67 g) was recorded from N_0P_0 treatment and the maximum average weight of tuber hill^{-1} (76.47 g) was recorded from the N_3P_2 treatment.

4.9 Yield of tuber

Effect of nitrogen

The yield of tuber (t ha^{-1}) of BARI Alu-35 was significantly influenced by different doses of nitrogen (Table 3). The results revealed that the treatment N_0 produced lowest yield of tuber (25.63 t ha^{-1}) and the treatment N_3 produced highest yield of tuber (37.73 t ha^{-1}). Application of more N increased size and number of tubers ultimately enhancing total yield (Kumar *et al*., 2007).

Effect of phosphorus

The yield of tuber (t ha^{-1}) of BARI Alu-35 was significantly influenced by different doses of phosphorus (Table 4). The results revealed that the treatment P_0 produced lowest yield of tuber (30.45 t ha^{-1}) and the treatment P_2 produced highest yield of tuber (32.93 t ha^{-1}). Applied P has been found to increase the yield of small and medium size tubers (Hanley *et al.*, 1985).

Interaction effect of nitrogen and phosphorus

Interaction of different doses of nitrogen and phosphorus showed significant variation on yield of tuber (t ha^{-1}) of BARI Alu-35 (Table 5). The minimum yield of tuber (24.37 t ha^{-1}) was recorded from N_0P_0 treatment and the maximum yield of tuber (38.93 t ha^{-1}) was recorded from the N_3P_2 treatment.

4.10 Tuber dry matter

Effect of nitrogen

The tuber dry matter (%) of BARI Alu-35 was significantly influenced by different doses of nitrogen (Table 6). The results revealed that the treatment N_3 produced lowest tuber dry matter (14.82%) and the treatment N_0 produced highest tuber dry matter (22.89%). Kandi (2011) reported a reduced percent dry matter of potato tubers as nitrogen rates increased.

Table 6. Effect of nitrogen on tuber dry matter, total soluble solids and protein content

Treatments	Tuber dry matter (%)	Total soluble solids (%)	Protein content (%)
N_0	22.89 a	3.62 d	3.82 d
N_1	19.51 b	5.06 c	5.26 c
N_2	17.33 c	6.44 b	6.64 b
N_3	14.82 d	7.30 a	7.50 a
LSD $_{(0.05)}$	0.03092	0.03092	0.03092
CV (%)	10.15	9.44	6.43
Significant level	*	*	*

* - Significant at 5% level

N_0 = 0 Kg, N_1 = 75 Kg, N_2 = 105 Kg, N_3 = 135 Kg ha^{-1}

Effect of phosphorus

The tuber dry matter (%) of BARI Alu-35 was significantly influenced by different doses of phosphorus (Table 7). The results revealed that the treatment P_2 produced lowest tuber dry matter (17.68%) and the treatment P_0 produced highest tuber dry matter (19.58%). Asefa (2005) has indicated that increasing rate of phosphorous application significantly decreased specific gravity and dry matter content of potato tuber.

Table 7. Effect of phosphorus on tuber dry matter, total soluble solids and protein content

Treatments	Tuber dry matter (%)	Total soluble solids (%)	Protein content (%)
P_0	19.58 a	5.26 c	5.46 c
P_1	18.64 b	5.59 b	5.79 b
P_2	17.68 c	5.96 a	6.16 a
LSD $_{(0.05)}$	0.02677	0.02677	0.02677
CV (%)	10.15	9.44	6.43
Significant level	*	*	*

* - Significant at 5% level

P_0 = 0 Kg, P_1 = 69 Kg, P_2 = 92 Kg ha^{-1}

Interaction effect of nitrogen and phosphorus

Interaction of different doses of nitrogen and phosphorus showed significant variation on tuber dry matter (%) of BARI Alu-35 (Table 8). The minimum tuber dry matter (14.17%) was recorded from N_3P_2 treatment and the maximum tuber dry matter (24.59%) was recorded from the N_0P_0 treatment.

4.11 Total soluble solid

Effect of nitrogen

The total soluble solid (%) of BARI Alu-35 was significantly influenced by different doses of nitrogen (Table 6). The results revealed that the treatment N_0 produced lowest total soluble solid (3.62%) and the treatment N_3 produced highest total soluble solid (7.30%).

Effect of phosphorus

The total soluble solid (%) of BARI Alu-35 was significantly influenced by different doses of phosphorus (Table 7). The results revealed that the treatment P_0 produced lowest total soluble solid (5.26%) and the treatment P_2 produced highest total soluble solid (5.96%).

Interaction effect of nitrogen and phosphorus

Interaction of different doses of nitrogen and phosphorus showed significant variation on total soluble solid (%) of BARI Alu-35 (Table 8). The minimum total soluble solid (3.33%) was recorded from N_0P_0 treatment and the maximum total soluble solid (7.60%) was recorded from the N_3P_2 treatment. Kandi (2011) reported a reduced percent dry matter of potato tubers as nitrogen rates increased.

4.12 Protein content

Effect of nitrogen

The protein content (%) of BARI Alu-35 was significantly influenced by different doses of nitrogen (Table 6). The results revealed that the treatment N_0 produced lowest protein content (3.82%) and the treatment N_3 produced highest protein content (7.50%).

Effect of phosphorus

The protein content (%) of BARI Alu-35 was significantly influenced by different doses of phosphorus (Table 7). The results revealed that the treatment P_0 produced lowest protein content (5.46%) and the treatment P_2 produced highest protein content (6.16%).

Interaction effect of nitrogen and phosphorus

Interaction of different doses of nitrogen and phosphorus showed significant variation on protein content (%) of BARI Alu-35 (Table 8). The minimum protein content (3.53%) was recorded from N_0P_0 treatment and the maximum protein content (7.80%) was recorded from the N_3P_2 treatment.

Table 8. Interaction effect of nitrogen and phosphorus on tuber dry matter, total soluble solids and protein content

Treatments		Tuber dry matter (%)	Total soluble solids (%)	Protein content (%)
N_0	P_0	24.59 a	3.33 l	3.53 l
	P_1	22.92 b	3.61 k	3.81 k
	P_2	21.17 c	3.91 j	4.11 j
N_1	P_0	20.37 d	4.63 i	4.83 i
	P_1	19.49 e	4.95 h	5.15 h
	P_2	18.67 f	5.60 g	5.80 g
N_2	P_0	17.91 g	6.10 f	6.30 f
	P_1	17.35 h	6.51 e	6.71 e
	P_2	16.72 i	6.72 d	6.92 d
N_3	P_0	15.47 j	6.99 c	7.19 c
	P_1	14.81 k	7.31 b	7.51 b
	P_2	14.17 l	7.60 a	7.80 a
$LSD_{(0.05)}$		0.05355	0.05355	0.05355
CV (%)		10.15	9.44	6.43
Significant level		*	*	*

* - Significant at 5% level

N_0 = 0 Kg, N_1 = 75 Kg, N_2 = 105 Kg, N_3 = 135 Kg ha^{-1}; P_0 = 0 Kg, P_1 = 69 Kg, P_2 = 92 Kg ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

Different growth and yield parameters varied significantly due to difference in the doses of nitrogen and phosphorus. Different doses of nitrogen had significant effect on growth and yield of BARI Alu-35. Among the treatments, the treatment N_0 took the maximum days (13.53 days) for first emergence and N_3 took the minimum days (9.71 days). The treatment N_0 took the maximum days (19.16 days) for final emergence and N_3 took the minimum days (16.49 days). At 30, 60 and 90 DAP, the treatment N_0 produced the shortest plant (12.96 cm, 22.64 cm and 39.67 cm respectively) and the treatment N_3 produced the tallest plant (19.72 cm, 34.56 cm and 60.39 cm respectively). At 30, 60 and 90 DAP, the treatment N_0 produced minimum number of leaves plant^{-1} (6.33, 17.33 and 25.33 respectively) and the treatment N_3 (11.33, 28.78 and 37.56 respectively) produced maximum number of leaves plant^{-1}. Among the treatments, the treatment N_0 produced minimum number of stems hill^{-1} (1.33) and the treatment N_3 (4.33) produced maximum number of stems hill^{-1}. The treatment N_0 produced lower stem dry matter content (5.50%) and the treatment N_3 (17.80%) produced higher stem dry matter content. The treatment N_0 produced lowest number of tubers hill^{-1} (4.67) and the treatment N_3 (10.11) produced highest number of tubers hill^{-1}. The treatment N_0 produced lowest average weight of tuber hill^{-1} (47.66 g) and the treatment N_3 produced highest average weight of tuber hill^{-1} (74.39 g). The treatment N_0 produced lowest yield of tuber (25.63 t ha^{-1}) and the treatment N_3 produced highest yield of tuber (37.73 t ha^{-1}). The treatment N_3 produced lowest tuber dry matter content (14.82%) and the treatment N_0 produced highest tuber dry matter content (22.89%). The treatment N_0 produced lowest total soluble solid (3.62%) and the treatment N_3 produced highest total soluble solid (7.30%). The treatment N_0 produced lowest protein content (3.82%) and the treatment N_3 produced highest protein content (7.50%).

Different doses of phosphorus had significant effect on growth and yield of BARI Alu-35. Among the treatments, the treatment P_0 took the maximum days (11.90 days) for first emergence and P_2 took the minimum days (11.28 days). The treatment P_0 took the maximum days (18.08 days) for final emergence and P_2 took the minimum days (17.60 days). At 30, 60 and 90 DAP, the treatment P_0 produced the shortest plant

(15.60 cm, 27.29 cm and 47.75 cm respectively) and the treatment P_2 produced the tallest plant (17.09 cm, 29.93 cm and 52.33 cm respectively). At 30, 60 and 90 DAP, the treatment P_0 produced minimum number of leaves plant^{-1} (8.00, 22.08 and 30.17 respectively) and the treatment P_2 (9.33, 24.33 and 32.67 respectively) produced maximum number of leaves plant^{-1}. Among the treatments, the treatment P_0 produced minimum number of stems hill^{-1} (2.50) and the treatment P_2 (3.87) produced maximum number of stems hill^{-1}. The treatment P_0 produced lower stem dry matter content (10.33%) and the treatment P_2 (12.65%) produced higher stem dry matter content. The treatment P_0 produced lowest number of tubers hill^{-1} (7.08) and the treatment P_2 (8.00) produced highest number of tubers hill^{-1}. The treatment P_0 produced lowest average weight of tuber hill^{-1} (59.18 g) and the treatment P_2 produced highest average weight of tuber hill^{-1} (63.17 g). The treatment P_0 produced lowest yield of tuber (30.45 t ha^{-1}) and the treatment P_2 produced highest yield of tuber (32.93 t ha^{-1}). The treatment P_2 produced lowest tuber dry matter content (17.68%) and the treatment P_0 produced highest tuber dry matter content (19.58%). The treatment P_0 produced lowest total soluble solid (5.26%) and the treatment P_2 produced highest total soluble solid (5.96%). The treatment P_0 produced lowest protein content (5.46%) and the treatment P_2 produced highest protein content (6.16%).

Among the treatments, the treatment N_0P_0 took the maximum days (13.87 days) for first emergence and N_3P_2 took the minimum days (9.39 days). The treatment N_0P_0 took the maximum days (19.38 days) for final emergence and N_3P_2 took the minimum days (16.24 days). At 30, 60 and 90 DAP, the treatment N_0P_0 produced the shortest plant (12.22 cm, 21.35 cm and 37.41 cm respectively) and the treatment N_3P_2 produced the tallest plant (20.47 cm, 35.92 cm and 62.64 cm respectively). At 30, 60 and 90 DAP, the treatment N_0P_0 produced minimum number of leaves plant^{-1} (6.00, 17.00 and 25.00 respectively) and the treatment N_3P_2 (12.67, 30.33 and 39.67 respectively) produced maximum number of leaves plant^{-1}. Among the treatments, the treatment N_0P_0 produced minimum number of stems hill^{-1} (1.00) and the treatment N_3P_2 (4.67) produced maximum number of stems hill^{-1}. The treatment N_0P_0 produced lower stem dry matter content (4.25%) and the treatment N_3P_2 (18.87%) produced higher stem dry matter content. The treatment N_0P_0 produced lowest number of tubers hill^{-1} (4.33) and the treatment N_3P_2 (11.00) produced highest number of tubers hill^{-1}.

The treatment N_0P_0 produced lowest average weight of tuber hill^{-1} (45.67 g) and the treatment N_3P_2 produced highest average weight of tuber hill^{-1} (76.47 g). The treatment N_0P_0 produced lowest yield of tuber (24.37 t ha^{-1}) and the treatment N_3P_2 produced highest yield of tuber (38.93 t ha^{-1}). The treatment N_3P_2 produced lowest tuber dry matter content (14.17%) and the treatment N_0P_0 produced highest tuber dry matter content (24.59%). The treatment N_0P_0 produced lowest total soluble solid (3.33%) and the treatment N_3P_2 produced highest total soluble solid (7.60%). The treatment N_0P_0 produced lowest protein content (3.53%) and the treatment N_3P_2 produced highest protein content (7.80%).

From the above results it can be concluded that,

- The application of nitrogen and phosphorus had positive effect on the growth, yield and quality of BARI Alu-35.
- Application of 135 kg N ha^{-1} with 92 kg P ha^{-1} produced better result for most of parameters studied.

From the above conclusions, the following recommendations can be made:

- ✓ Effect of different doses of nitrogen and phosphorus may be studied for growing potato crop.
- ✓ Beside nitrogen and phosphorus, the effect of other nutrients on the potato crop as well as nutrient uptake by different varieties may also be studied.

CHAPTER VI

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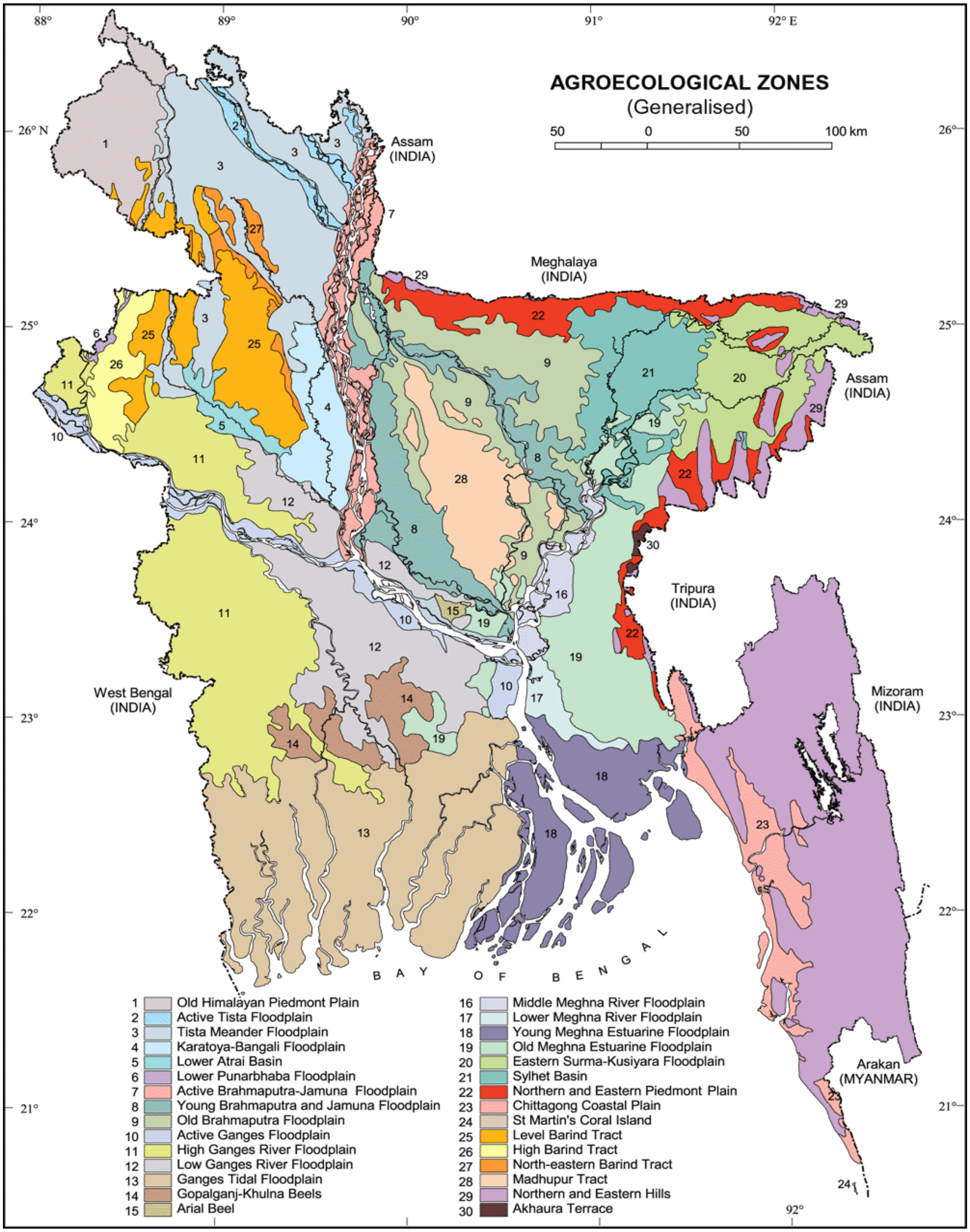
APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. Morphological characteristics of the experimental field

Morphology	Characteristics
Location	SAU Farm, Dhaka
Agro-ecological zone	Madhupur Tract (AEZ- 28)
General Soil Type	Deep Red Brown Terrace Soil
Parent material	Madhupur Terrace
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

(SAU Farm, Dhaka)

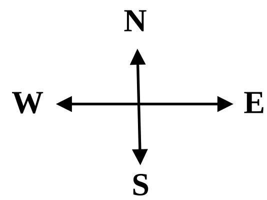
Appendix III. Initial physical and chemical characteristics of the soil

Characteristics	Value
Mechanical fractions:	
% Sand (2.0-0.02 mm)	22.26
% Silt (0.02-0.002 mm)	56.72
% Clay (<0.002 mm)	20.75
Textural class	Silt Loam
pH (1: 2.5 soil- water)	5.9
Organic Matter (%)	1.09
Total N (%)	0.028
Available K (ppm)	15.625
Available P (ppm)	7.988
Available S (ppm)	2.066

(SAU Farm, Dhaka)

Appendix IV. Layout of the experimental field

N_0P_2	N_0P_0	N_1P_2
N_0P_1	N_3P_1	N_1P_1
N_0P_0	N_3P_2	N_1P_0
N_1P_2	N_2P_0	N_0P_2
N_1P_1	N_2P_1	N_0P_1
N_1P_0	N_2P_2	N_0P_0
N_2P_2	N_1P_0	N_3P_2
N_2P_1	N_1P_1	N_3P_1
N_2P_0	N_1P_2	N_3P_0
N_3P_2	N_0P_0	N_2P_2
N_3P_1	N_0P_1	N_2P_1
N_0P_0	N_0P_2	N_2P_0



Length = 24.5 m

Width = 8 m

Area = 24.5 × 8 = 196 m^2

Plot length = 2 m

Plot width = 1.5 m

Plot area = 2 × 1.5 = 3 m^2

Plot to plot spacing = 0.5 m

N_0: Control (0 kg N ha^{-1})

N_1: 75 Kg N ha^{-1}

N_2: 105 Kg N ha^{-1}

N_3: 135 Kg N ha^{-1}

P_0: Control (0 kg P ha^{-1})

P_1: 69 Kg P ha^{-1}

P_2: 92 Kg P ha^{-1}

Appendix V. Effect of nitrogen on days to first emergence, days to final emergence and plant height at different days after planting

Treatments	Days to first emergence	Days to final emergence	Plant height (cm)		
			30 DAP	60 DAP	90 DAP
N_0	13.53 a	19.16 a	12.96 d	22.64 d	39.67 d
N_1	12.36 b	18.33 b	15.21 c	26.61 c	46.58 c
N_2	10.77 c	17.39 c	17.49 b	30.60 b	53.53 b
N_3	9.71 d	16.49 d	19.72 a	34.56 a	60.39 a
LSD $_{(0.05)}$	0.0392	0.0392	0.0392	0.0392	0.0392
CV (%)	8.28	8.13	7.18	7.09	7.04
Significant level	*	*	*	*	*

* - Significant at 5% level

N_0 = 0 Kg, N_1 = 260 Kg, N_2 = 300 Kg, N_3 = 340 Kg ha^{-1}

Appendix VI. Effect of phosphorus on days to first emergence, days to final emergence and plant height at different days after planting

Treatments	Days to first emergence	Days to final emergence	Plant height (cm)		
			30 DAP	60 DAP	90 DAP
P_0	11.90 a	18.08 a	15.60 c	27.29 c	47.75 c
P_1	11.60 b	17.84 b	16.34 b	28.59 b	50.04 b
P_2	11.28 c	17.60 c	17.09 a	29.93 a	52.33 a
LSD $_{(0.05)}$	0.02677	0.02677	0.02677	0.02677	0.02677
CV (%)	8.28	8.13	7.18	7.09	7.04
Significant level	*	*	*	*	*

* - Significant at 5% level

P_0 = 0 Kg, P_1 = 69 Kg, P_2 = 92 Kg ha^{-1}

Appendix VII. Effect of nitrogen on number of leaves plant^{-1} at different days after planting, number of stems hill^{-1} and stem dry matter

Treatments	Number of leaves plant^{-1}			Number of stems hill^{-1}	Stem dry matter (%)
	30 DAP	60 DAP	90 DAP		
N_0	6.33 d	17.33 d	25.33 d	1.33 d	5.50 d
N_1	7.67 c	21.44 c	29.33 c	2.33 c	9.18 c
N_2	9.00 b	25.33 b	33.33 b	3.33 b	13.39 b
N_3	11.33 a	28.78 a	37.56 a	4.33 a	17.80 a
LSD $_{(0.05)}$	1.230	1.938	2.061	0.7420	0.0392
CV (%)	14.66	8.54	6.72	6.78	8.26
Significant level	*	*	*	*	*

* - Significant at 5% level

N_0 = 0 Kg, N_1 = 260 Kg, N_2 = 300 Kg, N_3 = 340 Kg ha^{-1}

Appendix VIII. Effect of phosphorus on number of leaves plant^{-1} at different days after planting, number of stems hill^{-1} and stem dry matter

Treatments	Number of leaves plant^{-1}			Number of stems hill^{-1}	Stem dry matter (%)
	30 DAP	60 DAP	90 DAP		
P_0	8.00 b	22.08 b	30.17 b	2.50 b	10.33 c
P_1	8.42 ab	23.25 ab	31.33 ab	2.83 ab	11.43 b
P_2	9.33 a	24.33 a	32.67 a	3.17 a	12.65 a
LSD $_{(0.05)}$	1.065	1.678	1.785	0.6426	0.02677
CV (%)	14.66	8.54	6.72	6.78	8.26
Significant level	*	*	*	*	*

* - Significant at 5% level

P_0 = 0 Kg, P_1 = 69 Kg, P_2 = 92 Kg ha^{-1}

Appendix IX. Analysis of variance of the data on days to first emergence, days to final emergence and plant height at different days after planting

Source of variation	Degrees of freedom	Mean square				
		Days to first emergence	Days to final emergence	Plant height (cm)		
				30 DAP	60 DAP	90 DAP
Replication	2	0.004	0.008	0.002	0.003	0.007
Factor A	3	25.695*	12.039*	76.344**	236.851**	716.363**
Factor B	2	1.153*	0.0698*	6.750*	20.857*	62.929
(A×B)	6	0.012*	0.002*	0.002*	0.003*	0.006*
Error	22	0.001	0.001	0.001	0..01	0.001

* = Significant at 5% level, ** = Significant at 1% level

Appendix X. Analysis of variance of the data on number of leaves plant^{-1} at different days after planting, number of stems hill^{-1} and stem dry matter

Source of variation	Degrees of freedom	Mean square				
		Number of leaves plant^{-1}			Number of stems hill^{-1}	Stem dry matter (%)
		30 DAP	60 DAP	90 DAP		
Replication	2	0.250	13.778	0.111	0.333	0.004
Factor A	3	40.917*	219.481**	248.111**	15.00*	253.844**
Factor B	2	5.583*	15.194*	18.778*	1.333*	16.093*
(A×B)	6	0.583*	0.898*	1.444*	0.001*	0.068*
Error	22	1.583	3.929	4.444	0.576	0.001

* = Significant at 5% level, ** = Significant at 1% level

Appendix XI. Analysis of variance of the data on number of tubers hill^{-1}, average weight of tuber hill^{-1} and yield of tuber

Source of variation	Degrees of freedom	Mean square		
		Number of tubers hill^{-1}	Average weight of tuber hill^{-1} (g)	Yield of tuber (t ha^{-1})
Replication	2	0.778	0.008	0.005
Factor A	3	50.694*	1198.094**	243.941**
Factor B	2	2.528*	48.091*	18.323*
(A×B)	6	0.194*	0.096*	0.003*
Error	22	0.505	0.001	0.001

* = Significant at 5% level, ** = Significant at 1% level

Appendix XII. Analysis of variance of the data on tuber dry matter, total soluble solids and protein content

Source of variation	Degrees of freedom	Mean square		
		Tuber dry matter (%)	Total soluble solids (%)	Protein content (%)
Replication	2	0.004	0.006	0.006
Factor A	3	105.571**	23.479*	23.479*
Factor B	2	10.859*	1.450*	1.450*
(A×B)	6	0.805*	0.038*	0.038*
Error	22	0.001	0.001	0.001

* = Significant at 5% level, ** = Significant at 1% level

PLATES

Plate 1. Experimental plot

Plate 2: Land preparation

Plate 3. Planting of seed tuber

Plate 4. Mature potato plant

Plate 5. Data collection from plot

Plate 6. Harvesting of potato

Plate 7: Grinding of samples

Plate 8: Weighing of samples

Plate 9: Digestion and distillation of samples

Plate 10: Titration of samples