GROWTH, YIELD AND QUALITY OF POTATO (*Solanum tuberosum* L.) AS INFLUENCED BY NITROGEN AND PHOSPHORUS LEVELS

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CERTIFICATE

This is to certify that the thesis entitled "GROWTH, YIELD AND QUALITY OF POTATO (*Solanum tuberosum* L.) AS INFLUENCED BY NITROGEN AND PHOSPHORUS LEVELS" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (MS) in AGRONOMY ., embodies the results of a piece of bona fide research work carried out by MST. TANJILA KHATUN, Registration no.- 12-05090 under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

I further certify than such help or source of information as has been availed of during the course of this investigation has duly been acknowledge

Dated:
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ABSTRACT

Potato is one of the most important tuber crops produced in Bangladesh but it's quality is not good enough for processing and export purpose. It is the world's third-largest food crop, following wheat, and rice. An experiment was carried out at Agronomy Research Field and Laboratory of Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 during the winter season of 2016-2017 to know the "Growth, Yield and Quality of Potato cv. "Courage" as Influenced by Nitrogen and Phosphorus Levels. Treatments consisted of four levels of N (0, 150, 160 and 170 kg N ha^{-1}) and four levels of P (0, 45, 50 and 55 kg P ha^{-1}) laid out in split plot design with three replications. Data were collected on growth, yield and quality parameters. Results revealed that application of N and P fertilizer significantly ($P < 0.05$) influenced on plant height, stem number, total tuber number, tuber weight, marketable tuber numbers, total tuber yield, marketable tuber yield, tuber dry matter percentage, total soluble solid and starch. Increasing N application from 0 to170 kg ha^{-1} significantly increased stem number $hill^{-1}$ (from 3.87 to 5.29). The highest plant height (74.13 cm) was measured at the combination of 170 kg N ha^{-1} and 55 kg P ha^{-1}. The maximum total tuber number was recorded for the highest level of nitrogen and phosphorus (14.9 $hill^{-1}$). The highest marketable tuber number (11.54) $hill^{-1}$ was obtained for the combined application of 170 kg N ha^{-1} and 55 kg P ha^{-1}. The highest total tuber yield was recorded for combined application of 170 kg N and 55kg P ha^{-1} (30.27 t ha^{-1}). Combined application of 170 kg N and 55 kg P ha^{-1} gave the highest marketable tuber yield (24.13 t ha^{-1}). The highest average tuber weight (59.89 g) was observed for combined application of 170 kg N ha^{-1} and 50 kg P ha^{-1}. The highest dry matter (23.27%) percentage of potato tuber was recorded from plots that received the combination of N 160 kg $ha^{-1}$and P 50 kg ha $^{-1}$.The highest specific gravity (1.091) was recorded from combined application of 170 kg N ha^{-1} and 55 kg P ha^{-1}.The highest amount of starch (17.41%) was obtained from combined application of 160 kg N ha^{-1} and 50 kg P ha^{-1}. In conclusion the results of this study showed that different nitrogen and phosphorus rates and their interactions have sound and promising impact on growth and yield of potato. Therefore, on the basis of the results of the present study, farmers can be more benefited from using 170 kg $ha^{-1}$of nitrogen in combination with 55 kg P ha^{-1}.

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LIST OF ACRONYMS

ACRONYM	ABBREVIATION
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
Appl.	Applied
Biol.	Biology
Curr.	Current
cm	Centi-meter
CV	Coefficient of Variance
DAP	Days After Planting
Dev.	Development
Ecol.	Ecology
Environ.	Environmental
et al	et alii, And others
Exptl.	Experimental
g	Gram
J.	Journal
kg	Kilogram
LSD	Least Significant Difference
M	Vermicompost
M.S	Master of Science
m^2	Meter squares
Physiol.	Physiological
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
t ha^{-1}	Ton per hectare
cv	Cultivar
%	Percentage
Int.	International
Engr.	Engineer
N	Nitrogen
P	Phosphorus
Bot.	Botany
BARI	Babgladesh Rich Research Institute
Econ.	Economy
Inno.	Innovation
TCRC	Tuber Crop Research Centre
TSS	Total Soluble Solid

CHAPTER I
INTRODUCTION

Potato (*Solanum tuberosum* L.) ranks next to wheat and rice in the world consumption, which is herbaceous plant, and its original place is probably Peru or Bolivia. Potato is one the most important inexpensive source of energy, which has many different vitamins and minerals. In contemporary world because of the importance of potato role in global food, reduction of yield is an alarming problem and beyond a shadow of doubt, it is so important to increase this plant yield in developing countries by comparison with growing countries. The total acreage, production and yield of Bangladesh is 0.47 million hectares,0.947 crore MT and 19.91 t ha^{-1}, respectively (FAOSTAT, 2016). As a carbohydrate rich food crop in Bangladesh it ranks just after rice. Potato is one of the most important tuber crop grown in Bangladesh for its high production, high nutritional values, easy digestibility and many industrial uses.

Potato is one of human kind's most valuable food crops and it is a major part of the diets of more than a billion consumers worldwide (Mondal, 2003). It is regarded as high potential food security crop because of its ability to provide a high yield of high quality product per unit input with a shorter crop cycle (mostly<120 days) than major cereal crops such as, maize. Nevertheless, potato account for 31.05% of the total area of root crop and 16.88% of the total root crop production. The yield of potato is influenced by a number of factors, which include nutrition, cultivar, seed piece spacing, climatic conditions and geographic location.

Application of Nitrogen and phosphorus fertilizers has shown good yield responses for different crops across different locations, indicating low nitrogen and phosphorus status of the soils (Berga *et al*., 1994; Yohannes, 1992). In addition to that lack of optimum nitrogen and phosphorus application rates, there are a number of production problems accounting for low yields of potato. These constrains include limited supply of high quality seed tubers of potato (Gildemacher *et al.,* 2009), inappropriate

agronomic practices and inadequate storage (Tekalign, 2005), and limited knowledge resulting in poor seed tuber selection (Lung'aho *et al.*, 2007). This situation would become more critical in potato production in view of the fact that the crop is one of the heavy feeders of soil nutrients (Powon, 2005). The fate of nitrogen fertilizers used in potato production is an important environmental concern (Maier *et al*., 2002). Nitrogen is an essential element for plant growth and is a main part of proteins. When plant grows up in unfavourable environmental conditions, protein production is reduced and nitrogen accumulates as non protein compounds. Usually, there is a close relationship between light intensity and nitrate reduction in green leaves. Also, nutrient elements deficit has important effect on nitrate pollution. With increasing nitrogen application and plant density, potato yield increases. Haase *et al*. (2007) found that tuber N uptake and nitrate concentration were significantly influenced by amounts of nitrogen fertilizer. Also, nitrogen uptake increases number of tuber, tuber weight, qualitative and quantitative aspects of tuber. But over-usage of nitrogen delays tuber growth and reduces its qualitative and quantitative aspects.

Different recommendations have been reported by different researches at different locations. According to Bereke (1988), application of 150/66 kg ha^{-1} of N/P_2O_5 under rain fed condition resulted in a yield advantage of 32% over the unfertilized control. This blanket application can lead to excessiveness or deficiency in relation to plant nutrient requirement. When excessive nitrogen is applied, it may adversely affect crop yield; increase the cost of production and the environment can be polluted, specially soil and ground water can be highly affected due to nitrate leaching (Madramootoo *etal*., 1992; Honich, 2002). Use of under dose of nitrogen may also bring aboutsignificant yield reductions. This gives an insight to conduct trials for different varieties to develop optimum rate of nitrogen application, to enhance economic return and maintain environmental health.

From the above discussion optimum rate of nitrogen and phosphorus fertilizer may contribute to produce higher and quality potato tuber. In view of this, the present study was conducted with the following objectives:

1. To determine the effectiveness of nitrogen and phosphorus fertilizers and their interaction on growth, yield, yield components and tuber quality of potato, and
2. To find out optimum rate of N and P fertilizers for potato production with good quality.

CHAPTER II
REVIEW OF LITERATURE

The plant potato was first domesticated in the area around Lake Titicaca, which is located 3800 meters above sea level on the border of modern day, Bolivia and Peru, in the Andes mountain range of South America (Hielke *et al*., 2011). It has pinnately compound pattern alternate leaves on its above ground stem and specialized underground storage stems on tubers (Decoteou, 2005). Cultivated potato belongs to the Solanaceae family. It is an annual dicotyledonous, when grown for botanical seed, but it is treated as perennial because the vegetative propagation from tuber for commercial purpose.

Potato has five distinct growth stages: sprout development, vegetative growth, tuberization (tuber formation), tuber bulking, and tuber maturation. It is now one of the staple foods in Bangladesh. The protein content of potato is as like as cereals and is very high in comparison with other roots and tubers. Potato is also rich in antioxidants that are associated with many health benefits, including lower incidences of heart disease, reductions in some types of macular degeneration and characters. With its high carbohydrate content, potato is today a primary food of Western peoples, as well as a source of starch, flour, alcohol, dextrin, and fodder (chiefly in Europe, where more is used for this purpose than for human consumption).

Potato is widely cultivated in all the districts of Bangladesh during winter. In Bangladesh, potato is primarily used as a vegetable, although in many countries of the world it constitutes the staple food and contributes more than 90% of the carbohydrate food source. Phosphorus is a key nutrient for the development of the potato plant and tubers. The status of P in the plant, deficient or sufficient, is closely related to yield. With the high value of a potato crop and the influence of proper phosphorus nutrition on plant and tuber development, the 4Rs and especially timing of phosphorus availability are critical to maximizing yield per acre. Improvement of growth, yield and quality attributes of potato is much more important for growing hungry people around the world through processing and exporting industry. Some more related

research findings regarding tuber yield and quality of potato against nitrogen and phosphorus fertilizers levels have been reviewed under this chapter.

Lalnunpuia *et al.* (2018) carried out an experiment at Research Farm of Soil Science and Agricultural Chemistry, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, during the winter season of 2017- 2018 to know the "Effect of different levels of fertilizers and Neem cake on soil health, growth and yield of Potato (*Solanum tuberosum* L.) cv. Kufri Jyoti". The experiment was laid out in 3×3 Factorial Randomized Block Design (RBD) with three replicates for each treatment. The fertilizer applied for the crop was NPK and Neem cake @ 120 kg ha^{-1}, 100kg ha^{-1}, 120kg ha^{-1} and 1250t ha^{-1} respectively, which showed significant influence on the soil, growth and yield of Potato crop. Based on the above research work, it is concluded that application of NPK followed by Neem cake (100% and 100%) *i.e.,* the treatment T8@ [NPK 100% Recommended Dose of Fertilizer (RDF)+ Neem cake 100 kg ha-1] was found more beneficial and significantly improved soil, growth parameters and tuber yield of Potato grown under Allahabad Agro-climatic conditions. This treatment also showed maximum gross return, net return and benefit: cost ratio *i.e.,* (2.74) respectively.

Fazily and Alemi (2019) conducted a field experiment during the spring season of 2014-15 on clayey soils of Agriculture Faculty of Baghlan University, to study the effect of different doses of nitrogen and phosphorus on growth, yield and economics of potato (*Solanum tuberosum* L.). The experiment was laid in a randomized block design (RBD) comprised of 3 replication and sixteen Treatments. .The significantly higher yield was recorded with treatments receiving nitrogen 250 kg+ phosphorus 175 kg ha^{-1}. The increase in yield and yield attributing characters and final yield were mainly governed by vegetative growth such as plant height, number of leaves per plant, number of branches per plant and leaf area which were higher with the application of nitrogen250 kg+ phosphorus 175 kg ha^{-1}. Application of Nitrogen 250 kg+ Phosphorus 175 kg ha^{-1} produced taller plants (41.83 cm), higher number of leaves (30.41 $plant^{-1}$), number of branches (4.73 $plant^{-1}$), significantly wider leaf area

(113.43 cm), significantly higher tuber yield (14.70 t ha^{-1}) and B:C (5.49). There was a significant increase in tuber weight (216.11 g $plant^{-1}$) and numbers of tuber $plant^{-1}$ (4.14) were noticed with the application of nitrogen 250 kg+ phosphorus 175 kg ha^{-1}. The higher yield was also attributed due to sufficient availability of balanced nutrient and their positive interaction together.

Suh *et al.* (2015) undertook an experiment at Cameroon in 2014 to evaluate the influence of organic and inorganic fertilizer on the growth and yield of potato and soil properties in the Western Highlands agro-ecological zone of Cameroon. The treatments comprised an unfertilized control, cow dung, NPK 20:10:10 + urea, foliar fertilizer, cow dung + foliar fertilizer, NPK 20:10:10 + foliar fertilizer + urea and NPK 20:10:10 +cow dung +urea arranged in a randomized complete block design. CIPIRA potato variety was used as test crop. While the inorganic fertilizers appeared to reduce the soil pH, cow dung increased the organic carbon, organic matter and exchangeable cat-ions in the soil. The combination of organic (cow dung: 200 t ha^{-1}) and inorganic (NPK: 200 kg ha^{-1} or foliar 5l ha^{-1}) fertilizer use significantly ($p<0.05$) enhanced potato yields. Thus, the combined use of organic and inorganic fertilizers appears to be the most appropriate treatment for the cultivation of potato in this agro-ecological zone. Combining inorganic fertilizer and organic manure showed significant effect particularly on yield parameters of potato. Potato yield can therefore be increased by improving soil fertility management through the combined use of animal manure and inorganic fertilizer. This research therefore recommends at least 3.3 t ha^{-1} of Cow dung and 5 l ha^{-1} of foliar fertilizer for cultivation of potato for better growth, high tuber yield, and for maintaining soil fertility in the Western Highland of Cameroon.

Peter *et al*. (2015) carried out an experiment to determine the effects of split nitrogen application and different nitrogen fertilizer rates on the productivity of Irish potatoes (*Solanum tuberosum L*) in smallholder farming in Zimbabwe. The experiment was laid out in a randomized complete block design with three nitrogen application levels (15g m^{-2}, 30g m^{-2} and 45g m^{-2}) and three split application levels (1, 2 and 3), and was replicated three times. The results of the study showed that nitrogen rate had a significant effect ($p<0.05$) on number of tubers, tuber size and on the final yield of the potato. The highest yield was obtained in a at 30g N m^{-2} with the 15g N m^{-2} producing the least. Split application had a significant effect ($p<0.05$) on number of potato tubers, size of potato tubers as well as the overall yield of the potatoes. From the study findings, it can be concluded that three (3) split applications applied at 30g m^{-2} had the potential to increase the yield compared to the other treatments. Farmers were therefore urged to apply top dressing nitrogenous fertilizer in three treatments to ensure a higher productivity of Irish potatoes.

Kumar *et al.* (2017) studied the effect of different nitrogen and potash levels on growth and yield parameters in potato var. Kufri pukhraj. The experiment was laid out in a randomized block design with treatments consisting of ten nitrogen and potash levels replicated four times and concluded that application of NPK-150:50:75 kg ha^{-1} from the overall experimental finding was proved to be most effective to grow parameters like increased plant height, number of leaves, number of shoots per plant fresh weight and dry weight of shoots , yield attributes and yield of potato *viz.*, maximum number of stolen, fresh weight and dry weight of tuber, number of tuber per plant, grade wise number of tuber, number of tuber, grade wise yield of tuber and tuber yield per plot . It was said from the findings that, optimum NPK application is essential to improve potato tuber yield. Although with the increase in NPK levels, vegetative parameters of crop growth increased with maximum values achieved on application of 100, 50, 60 kg NPK ha^{-1} but application of 100, 50, 75 kg NPK ha^{-1} proved to be superior for obtaining higher yield and yield attributing characters. Thus, application of optimum dose of 150, 50 and 75 kg NPK ha^{-1} was observed to be

superior in terms of yield, as well as more profitable and can, therefore, be economically recommended for cultivation of potato variety Kufri pukhraj under Uttar Pradesh plains agro-climatic zone.

Yourtchi *et al.***(**2013) studied the effect of nitrogen fertilizer and vermicompost on vegetative growth, yield and NPK uptake by tuber of potato, a field experiment was carried out in the form of factorial based on randomized complete block design with three replication per treatment in research field of Ran Firoozkoh Company in 2011. Experimental factors included nitrogen fertilizer with three levels (50, 100 and 150 kg ha^{-1} as urea) and vermicompost with 4 levels (0(control), 4.5, 9, and 12 ton ha^{-1}). Results illustrated that the highest amount of plant height, leaf and stem dry weight, Leaf Area Index(LAI), fresh and dry weight of tuber, total tuber weight, total number of tuber, tuber diameter, nitrogen percent of tuber, potassium percent of tuber and phosphorous percent of tuber were found from application of 150 kg N ha^{-1}. Data also demonstrated that vermicompost application at the rate of 12 ton ha^{-1} promoted all above traits except plant height in compared to control treatment. Furthermore, the interaction effects between different nitrogen rates and vermicompost application significantly improved growth parameters, yield and NPK content of tuber compared with nitrogen and/or vermicompost alone treatments. It also appeared that application of vermicompost had the positive effect on vegetative growth and yield of potato. Since, in most of measured traits 9 and 12 ton ha^{-1} vermicompost treatments had no significant difference to each other, so in order to prevent excessive costs, utilize of 9 ton ha^{-1} vermicompost was suggested. Vermicompost (12 ton ha^{-1}) + nitrogen(150kg ha^{-1}) was more favorable for vegetative growth, yield and NPK content in tuber but (9 ton ha^{-1}) + nitrogen(100kg ha^{-1}) can be economically and environmentally suitable.

Qadri *et al.* (2015) conducted an experiment in Vegetable Experimental Area, Institute of Horticultural Science, University of Agriculture, Faisalabad during 2013-2014 to evaluate the effect of soil applied phosphorus (DAP) and foliar application of nitrogenous fertilizer (urea) on growth, yield and quality of potato. The experiment

was comprised of four different treatments of phosphorus (DAP, 46% P) and nitrogen (urea, 46% N) including a control which was laid out in Randomized Complete Block Design (RCBD) with three replications. Treatments were T_0 (DAP 160 + Urea 300 kg acre^{-1}), T_1 (DAP 160 + Urea 5kg acre^{-1}), T_2 (DAP 100 + Urea 6 kg acre^{-1}) and T_3 (DAP 120 + Urea 8 kg acre^{-1}). DAP fertilizer was given as basal dressing at the time of sowing. Foliar applications of nitrogenous fertilizer (urea) remained better regarding productivity and quality of potato. The overall fertilizer efficacy regarding yield and quality was: T_3 were given after 30 of sowing with one week interval in five split doses. Results indicated that $T_3 > T_2 > T_1 > T_0$. However, Vitamin C was found maximum in T_0.

Ahmed *et al.* (2015) conducted two field experiments during the two successive winter seasons of 2010 and 2011 at the experimental station of the Agriculture Research Centre (ARC), Kafr El-Zayat, El-Gharbia Governorate, Egypt to study the response of potato plant (*Solanum tuberosum L.*) cv. Valor to application of farmyard manure as organic nitrogen fertilizer as well as ammonium nitrate (33.5 % N) and urea (46 % N) as inorganic nitrogen fertilizer alone or in combination on vegetative growth, yield and tubers quality of potato plants as well as nutritional content of tubers. The experiment included 18 treatments representing the interaction of farmyard manure at three levels (0, 10 and 20 m^3 fed^{-1}.), ammonium nitrate and urea at three levels (120, 165 and 210 N unit fed^{-1}.). The experimental design used in the two successive winter seasons was split design with three replicates. Results showed that application of farmyard manure had positively influence on vegetative growth characters of potato plants. Whereas, they were improved with increasing of farmyard manure levels up to 20 m^3 fed^{-1}; feddan (fed.) = 4200 m^2 in both seasons. Vegetative growth characters of plants were enhanced by using of inorganic nitrogen fertilizer in the form of ammonium nitrate rather than urea fertilizer. Moreover, vegetative growth characters of potato plants were significantly increased with increasing of inorganic nitrogen fertilizer levels up to 210 N unit fed^{-1}. in both experimental seasons. Application of farmyard manure improved the productivity of potato plants and it was increased with increasing of farmyard manure levels up to 20 m^3 fed^{-1}. in both

seasons. Yield of potato plants was better with using of ammonium nitrate as inorganic nitrogen fertilizer rather than using of urea fertilizer. Furthermore, productivity of potato plants was gradually increased with increasing of inorganic nitrogen fertilizer levels. Tubers quality in response of specific gravity, starch percentage, crude protein percentage and dry matter percentage were enhanced with increasing of farmyard manure levels. On the other hand, specific gravity, starch percentage and dry matter percentage were decreased with increasing of inorganic nitrogen fertilizer levels. Yield of plants, tubers quality and nutritional content of tubers were influenced by the integration treatments between different levels of farmyard manure and different levels and forms of inorganic nitrogen fertilizer. Whereas, the highest values of tubers yield (t fed^{-1}.), tubers number $plant^{-1}$, marketable tubers percentage and crude protein percentage were recorded with using of farmyard manure at the level of 20 m^3 fed^{-1}. combined with inorganic nitrogen fertilizer as ammonium nitrate at the level of 210 N unit fed^{-1}. in both seasons while the highest values of specific gravity, starch percentage and dry matter percentage were observed with application of farmyard manure at the level of 20 m^3 fed^{-1}. along with ammonium nitrate at the level of 120 N unit fed^{-1}. in both seasons.

Husain *et al.* (2018) carried out a field study during winter (*Rabi*) season of 2016-17, at the instructional farm, AKS University, Satna, Sherganj, Madhya Pradesh. An experiment entitled "To work out the interactive use of nitrogen level and tuber size on growth and yield of potato tuber (*Solanum tuberosum* L.) cv. Kufri Badshah*"* . The experiment considered of twelve treatment combinations comprising four levels of nitrogen *i.e.* 0kg, 80kg, 100kg & 120kg N ha^{-1} and three tuber sizes of potato *viz.*, (25g, 35g and 45g). The experiment was laid out in Randomized Block Design with factorial concept with three replications. Growth parameters like plant height, number of leaves/plant, number of branches, number of tuber plant, fresh weight of tuber, stem diameter, dry weight of tuber and number of tuber ha^{-1}. The highest tuber yield (29.54t ha^{-1}) of potato have been obtained from tuber size *viz.,* 45g. The different nitrogen levels caused significant variations in tuber yield of crop. The application of nitrogen up to N_{120} gave significantly higher tuber yield (29.54t ha^{-1}) which was

higher by 7.86 t ha^{-1} over no nitrogen and higher by 2.45 t ha^{-1} over N_{120}. The largest seed tuber size (45 g) resulted in significantly higher tuber yield (27.01 t ha^{-1}) which was higher by 2.42 t ha^{-1} over smallest (25 g) seed tuber size. Such an increase in tuber yield may be ascribed to the maximum increase in yield-attributes (number of tubers $plant^{-1}$ and $plot^{-1}$ and their fresh weight) under the largest tuber size (45 g). Similar results trend has also been observed by many research workers.

Rostami *et al. (*2015) studied the effects of nitrogen fertilizer and plant density on yield characteristics of potatoes (CV. Sante), an experiment was conducted in summer of 2013. The experimental design was factorial based on randomized complete blocks design with four replications. In this experiment, densities were in 80, 100 and 130 thousand plants in ha and nitrogen fertilizer was tested at four levels (Nitroxin, Nytrazhyn, Azotobacter and urea). After harvesting potatoes on number of tubers per plant, tuber weight, tuber yield, harvest index, density and percent nitrogen gland tubers were measured and the results of analysis of variance. The results showed that the density and type of nitrogen fertilizer was significant on all traits. The density of 80 thousand plants per hectare than other treatments were superior in many characteristics between the treatments of different types of nitrogen fertilizer urea fertilizer for most traits were statistically significantly better. Also, in different types of nitrogen fertilizer urea fertilizer was better statistically significantly for most traits. The interaction between plant density and nitrogen fertilizer were statistically significant for most traits. So most of the potato tuber yield (4584.9), the density of the tuber (1.44 cm^3) and harvest index (56.33) was conducted from application of urea and planting 80 thousand plants ha^{-1}. Therefore it is suggested to use density of 80 thousand plants per hectare and application of urea fertilizer in this study had shown the best results. Also yield difference between 80 and 100 thousand plant density was not significant in any of the applied fertilizers.

Chandra *et al.* (2017) undertook an experiment at Vegetable Research Centre of G.B.P.U.A. and T. Pantnagar, Uttarakhand, during Rabi season of 2012-13 and 2013-14. In order to know the marketable yield and nitrogen use efficiency of potato, five nitrogen levels and two potato varieties were replicated thrice in the experiment. It was observed from the study that variety Kufri Surya performs better than Kufri Sadabahar in relation to marketable yield, nitrogen uptake, nitrogen use efficiency and nitrogen apparent recovery. Maximum marketable yield (43.87 t ha^{-1}), nitrogen content in tuber (1.17 %) and total nitrogen uptake (193.94 kg ha^{-1}) were recorded with application of 150 kg N ha^{-1} (N_2), while nitrogen use efficiency (141.60 kg tuber kg^{-1} N) and nitrogen apparent recovery (67 %) were observed maximum with application of 75 kg N ha^{-1} (N_1). Interaction effect of variety Kufri Surya and 150 kg N ha^{-1} (V_2N_2) gave maximum marketable tuber yield (45.75 t ha^{-1}) and total nitrogen uptake (199.05 kg ha^{-1}) among all treatments. The maximum nitrogen use efficiency was recorded (152.80 kg tuber kg^{-1} N) with treatment combination V_2N_1. Based on this experiment, the variety Kufri Surya with application of 150 kg ha^{-1} nitrogen was best among all other treatments for potato production.

Getie *et al.* (2015) conducted a field experiment on the effect of nitrogen fertilizer and planting density on yield and yield components of potato crop (Bubu variety) in Haramaya, Eastern Ethiopia during the rainy season of 2012. The experiment was a 4 x 5 factorial combination and a randomized complete block design with 3 replicates. Treatments included quantity of nitrogen fertilizer (0, 110, 165 and 220 kg N ha^{-1}) and planting density (4.17 plant m^{-2} (75 cm x 30 cm), 5.56 plant m^{-2} (60 cm x 30 cm), 6.67 plant m^{-2} (80 cm x 30 cm), 4.44 plant m^{-2} (60 cm x 25 cm) and 8 plant m^{-2} (50 cm x 25 cm)).Increasing nitrogen level up to 110 kg N ha^{-1} lead to more tuber yield, highest stem number, plant height, total dry biomass, total tuber number, large-sized tuber yield (59.01%) and marketable tuber yield. The highest foliar N concentration was recorded at 170 kg N ha^{-1}. Increasing planting density resulted in higher tubers yield, total tuber number, total dry biomass yield (%), marketable tuber yield and small-sized tuber yield (16.92%). Highest foliar N concentration was found at the

lower planting densities of 4.17 and 4.44plant m^{-2}. Yield of tuber per hectare was significantly and positively correlated with leaf area index, total tuber number, days to physiological maturity and total dry biomass yield. Results of the experiment revealed that 110 kg N ha^{-1} and planting density of 6.67 plant m^{-2} resulted in optimum total (35.50 and 35.66 t ha^{-1}, respectively) and marketable tuber yields of the Bubu variety in Haramaya, Eastern Ethiopia during the rainy season.

Regassa *et al.* (2016) undertook an experiment at Bule hora district, Eastern Guji zone, southern Ethiopia in 2016 to study the effect of different NP rates on the yield and yield components of Irish potato to determine biological and economic optimum NP rate at the area. Adapted and recommended variety of Irish potato variety (Gudane) was used for the experiment under rainfall. The treatment consisted of combination of five levels of N (0, 50, 80, 110 and 140 kg N ha^{-1}) and four levels of P (0, 45, 90 and 135 kg P ha^{-1}). Data were collected on parameters like plant height, number of branch $hill^{-1}$, tuber weight, marketable yield per hectare, unmarketable yield per hectare and total yield per hectare. ANOVA and Partial budget analysis were used to determine biological and economic optimum NP rate. Tuber yield was significantly affected by both P and N levels. There was also a significant N and P interaction effect on tuber yield. The maximum total tuber yield (195.06 qt ha^{-1}) was obtained when 50 kg N ha^{-1} and 135 Kg P ha^{-1} were combined, and it was closely followed by 193.21 qt ha^{-1} obtained at 110-90 kg ha^{-1} NP combinations, resulting in grain yield benefit of 361 and 358% over the control, respectively. Almost all collected parameters were significantly affected by P rate but did not respond to N rate. This could be due to substantial amount of total N in the soil (0.61%) which was in the high range. As to partial budget analysis, treatment 110-90 kg ha^{-1} NP combination had highest net benefit and acceptable marginal rate of return (473.67%). Based on this experiment, 110-90kg ha^{-1} NP combination was found profitable and recommended for Irish potato farmers of Bule hora district and similar areas.

Powon *et al.* (2006) carried out a field study to enhance growth and yield of potato (*Solanum tuberosum L*.) under different levels of phosphorus and farm yard manure for 2 seasons at NARC – Kitale and on farm Psigirio in 2002 and 2003. The experimental design was Randomized Complete Block (RCB), with three replications. Nine treatments of phosphorus rates (0, 52.2 and 100.4 kg ha^{-1} and farmyard manure 0, 10 and 20t ha^{-1}) either singly or in combination were used. Data were recorded on tuber dry weight; shoot dry weight and total yield of potatoes. Phosphorus and FYM had a significant ($p< 0.05$) influence on tuber dry weight; shoot dry weight and total yield depending on the season and year. A combination of P at 100.4 kg ha^{-1} and FYM at 20t ha^{-1} resulted in an increase of 82% tuber dry weight and 62% of fresh tuber yield compared to the control. Tuber number and shoot dry weight were also affected by the application of P and FYM. Potato yield can therefore be improved through application of phosphorus and farm yard manure.

Maan *et al.* (2018) conducted an experiment on influence of irrigation methods and nitrogen levels on plant growth and tuber yield of potato cultivar Kufri Bahar at Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during *Rabi* season of 2015-16 and 2016-17. The treatments comprising of irrigation methods (drip and furrow) and five doses of nitrogen (60, 80, 100, 120 and 140% of RDN) were laid out in split plot design with three replications. The irrigation methods showed significant differences in all the treatments in both the years. The maximum value for percent plant emergence, number of shoots $^{\text{per hill}}$s, plant height (cm), foliage weight (kg m^{-2}) and total tuber yield (q ha^{-1}) were recorded with 100% of RDN and drip irrigation. Hence, 100% of RDN with drip irrigation condition have shown the best treatment combination for potato production under semiarid conditions of Hisar, Haryana. Based on the experimental results, it was concluded that the irrigation method and nitrogen levels improved the growth and yield of potato crop. Drip irrigation (I1) with 100% of RDN (N_3) was found superior to increase growth significantly and to give maximum total tuber yield of potato, which was comparatively higher than the yield of potato under furrow irrigation

method. In 2015-16 tuber yield was increased 20.22% in drip irrigation than the furrow irrigation, while 10.55% increased tuber yield was noticed in year 2016-17.

Sharma and Arora (2009) undertaken six field experiments, three each during 1982– 3 and 1983–4, were conducted on a sandy loam soil to study the effect of varying levels of nitrogen, phosphorus and potassium, in the absence and presence of farmyard manure (FYM) (30 t ha^{-2}), on the number of tubers and yield of potato in three grades. Increase in nitrogen, phosphorus and potassium application, in the absence or presence of FYM, did not significantly affect the total number of tubers/m^2 but did affect the number of tubers in different grades. An increase in nitrogen and potassium significantly decreased the number of tubers m^{-2} in small (< 25 g) and increased in medium (25–75 g) and large (> 75 g) grades at 45, 60, 75 and 90 days after planting. Increase in the application of phosphorus increased the number of tubers m^{-2} in the small grade and decreased it in the large grade but did not affect the number in the medium grade. Increase in nitrogen and potassium application decreased the tuber yield in the small grade and increased it in the medium and large grades. Applied phosphorus increased the yield in the small and medium grades and decreased it in the large grade. The increase in the yield of tubers with increase in nitrogen and potassium application was found to be caused by an increase in the number of tubers in the medium and large grades at the expense of the small grade; however, with applied phosphorus the increase in yield was due to increase in the weight of individual tubers within the small and medium grades. FYM application decreased the number of tubers in the small grade and increased it in the medium and large grades. The response of potato to nitrogen increased and to phosphorus and potassium decreased with the application of FYM.

Feleafel (2005) carried out two field experiments during the summer seasons of 2000 and 2001, at the Experimental station Farm, Faculty of Agriculture, Alexandria University, at Abies, to investigate the response of potato plants cv. Alpha, to two bio-fertilizer types (Nitrobein and Halex-2) under four varying percentages NPK; 25%, 50%, 75% and 100% from the commercial recommended rates (180-60-96 Kg N-P-K

fed^{-1}).The results indicated that increasing NPK applied rate or inoculation with Halex-2 bio-fertilizer was accompanied with significant increases in plant height, number of branches and leaves, fresh weight and leaf area plant^{-1} . The mineral contents of leaves (N-PK) were positively and significantly responded as a result of increasing NPK application percent. Halex-2 appeared to be more effective than Nitrobein in this respect. Moreover, yield potential; i.e., total yield fed^{-1}, number of tubers plant^{-1} and average tuber weight were increased due to the application of 75% of the recommended NPK or bio-fertilizer inoculation treatments, particularly Halex-2 bio-fertilizer. The treatments enhanced most tuber quality characteristics (percentages of large and medium tuber sized, T.S.S. and total carbohydrates). Application of 75% of the recommended NPK level combined with Halex-2 bio-fertilizer appeared to be the most commercial and efficient treatment combination which gave balanced vegetative growth and higher yield potential with a best tuber quality. This particular treatment significantly produced higher yield (the increment in the total yield fed^{-1} was 19.8%, as average of the two seasons) than that obtained from the application of 180- 60- 96 Kg NPK fed^{-1} without bio-fertilizer, as well as saved 25% from potato plants requirements of NPK fertilizers.

After inspecting the various sources of data regarding the present experiment it was found and decided that the nitrogen and phosphorus levels have the effect of response against different attributes of potato. To inspect the effects on vegetative growth, tuber yield and quality of potato, several levels of nitrogen and phosphorus in combination were taken for the present study.

CHAPTER III

MATERIALS AND METHODS

A brief description about experimental period, study area, experimental material, treatments, experimental design, experimental procedures, intercultural operations, data collection and statistical analysis were presented in this chapter. The details of experimental materials and methods are given below:

3.1 Experimental period

The experiment was carried out at the Agronomy Research Field, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 during the period from November, 2016 to March 2017.

3.2 Study area description

The site was located at $23^0$77'N latitude and $90^0$33'E longitude at an altitude of 8.6 meter above the sea level. The experimental site go with the agro-ecological zone of "Modhupur Track", AEZ-28.This was a region of complex relief and soils developed over the Modhupur Clay. The landscape comprises level up land, closely or broadly dissected terraces associated with either shallow or broad, deep valleys.

3.3 Soil

The soil type of the experimental site was to the general soil type of shallow red brown terrace soils under Tejgaon series. The surface layer of the soil is called Top soil and in cultivated soil it includes the cultivated layer and underlying ploughpan, if present; in uncultivated soils the uppermost soil layer or layer darkened by organic matter. The top soil of Madhupur Tract is usually grey and mixed brown. The soil was also labeled by pH 5.67 and 0.462% organic carbon. The selected plot was above flood level and plenty of sunshine was present during experimental period. The

experimental site was flat enough and having accessible irrigation and drainage system. The plot was medium high land.

3.4 Climate of experimental site

Under sub-tropical cropping zone with remarkable monsoon climate, the experimental location labeled by winter during the months from November, 2016 to March 2017.The experimental area was with maximum and minimum temperature which was vary during the period from November, 2016 to March, 2017.During the study period ,the weather statement of experimental area such as maximum and minimum temperature, total rainfall and relative humidity were shown in (Appendix-II).

3.5 Crop: Potato (*Solanum tuberosum*)

3.5.1 Variety: Courage (BARI Alu-29)

"Courage" variety was developed by Bangladesh Agricultural Research Institute (BARI) and it was released in 2008 by Tuber Crops Research Centre (TCRC) for higher yield and high demand in food industry as those are suitable as raw material for manufacturing various popular food items like potato chips, French fries and crackers. Maximum field duration from 85-90 days and average yield from 20-27 t ha^{-1}.Due to improve the income status of farming communities of potato in Bangladesh, the variety was used.

3.6 Treatments

The experiment was included two different factors as treatments are as follows:

Factor A: Level of Nitrogen: 4

N_0= 0 kg N ha^{-1}

N_1= 150 kg N ha^{-1}

N_2= 160 kg N ha^{-1}

N_3= 170 kg N ha^{-1}

Factor B: Level of Phosphorus: 4

P_0= 0 kg P ha^{-1}

P_1= 45 kg P ha^{-1}

P_2= 50 kg P ha^{-1}

P_3= 55 kg P ha^{-1}

Total sixteen combinations were applied under existing study are as follows:

N_0P_0, N_0P_1, N_0P_2, N_0P_3

N_1P_0, N_1P_1, N_1P_2, N_1P_3

N_2P_0, N_2P_1, N_2P_2, N_2P_3

N_3P_0, N_3P_1, N_3P_2, N_3P_3

3.7: Experimental Design and Layout

The experiment was laid out in a split-plot design in two factors with three replications. Levels of Nitrogen allocated to main plots and levels of Phosphorus to sub plots. The size of unit plot was 2.5 m x 2 m . The spacing between rows and plants was 60 cm and 25 cm, respectively. Total numbers of unit plot were 48.

3.8 Source of seed

The source of seed potato was Tuber Crop Research Centre (TCRC), Bangladesh Agricultural Research Institute (BARI).

3.9 Seed preparation

Whole tuber was planted for seed potato and large tubers were cut into pieces. Each cut tuber contained at least two eyes. Clean knife used to avoid transmitting viral and bacterial diseases.

3.10 Land preparation

Land was prepared on last week of October, 2016. The land was ploughed and cross ploughed 4 times followed by the laddering for getting the expected tilt using power tiller. By using spades the weeds and stubbles from the corner of the experimental area were eradicated. At last, on November 10, 2016 before five days of planting the seed tuber, the land was fully prepared. Drainage system was built surrounding the land for avoiding water logging condition during rainfall in research period. For soil treatment 10 kg/ha Ascend 3Gr was applied to the field.

3.11 Fertilizer management

Fertilizer	Doses (kg ha^{-1})
Urea	350
TSP	200
MoP	250
Gypsum	120
Zinc Sulphate	10
Boric Acid	10

(TCRC, 2018)

At the time of planting, half of the N and total amount of P fertilizer rate was applied and remaining half of the N dose was practiced at the time of first earthing up (35 days after planting) as side dressing.

3.12 Planting of seed tuber

The well sprouted and medium size tubers were implanted in the experimental plot on November 15, 2016. Distance between row to row was 60cm and plant to plant was 25cm.

3.13 Intercultural operation

3.13.2 Irrigation

The sufficient soil moisture is needed for satisfactory sprouting. Until the end of the growing period four irrigations were given at different growing stage (vegetative, tuberization, tuber bulking and maturity) of potato. Excess water is very harmful for potato plant.

3.13.3 Earthing up

Earthing up of potatoes is an important part of the growing process. It involves drawing mounds of soil up around the plant to prevent new tubers from growing and turning green and poisonous. Earthing up was done when plants were 15 to 20 cm in height and second earthing up was done after two weeks of the first one (50 days after planting).

3.13.4 Pest management

Every possible phytosanitary measures were taken for maintaining the plant health. Belt 24WG @ 250 gm ha^{-1} and Decis 2.5EC @ 500ml ha^{-1} were spread on the plant 25DAP for controlling the cutworm. Confidor70WG @100 gm ha^{-1} and Admire 200SL @ 500 ml ha^{-1} for controlling aphid and jassid. For controlling the late blight of potato at moist and foggy condition Secure 600WG @ 1kg ha^{-1} was applied at 7 days interval.

3.13.5 Haulm killing

The haulm killing was done about 10days before of harvesting at 8 February, 2017 so that the tuber skin matured and prevented the tubers from getting injured at harvesting and grading. Haulms were pulled manually. The tuber and cut haulm were harvested, collected, bagged and tagged separately for further data collection.

3.14 Data Collection

To measure the effect of N and P rates on growth, yield and quality of potato, data were collected on growth, yield components, yield and quality of potato as follows.

3.14.1 Growth parameters

3.14.1.1 Plant height

Plant height was determined by measuring the height of the plant from the base of the main shoot to the apex at 30DAP, 45DAP, 60DAP and 75DAP.

3.15.1.2 Number of stems hill^{-1}

Number of stems hill^{-1} was recorded as an average count of five hills plot^{-1} at flowering. Only stems arising from the mother tuber were considered as main stems (Zelalem *et al*., 2009).

3.14.2 Yield parameter

3.14.2.1 Total number of tuber hill^{-1}

Mean number of tubers produced from randomly selected five hills of each plot, was enumerated at harvest and expressed as number of tubers hill^{-1}.

3.14.2.2 Average tuber weight (g)

Five hills were randomly selected from each plot .The total tuber was enumerated and weighted from five hills by using an electronic balance. It was recorded by dividing total fresh weight of tubers by the total number of fresh tubers per plot.

3.14.2.3 Marketable tuber number hill^{-1}

Mean number of tubers assembled from five hills of each plot. It was counted at harvest and those tubers are healthy, large sized and greater than 20 g were considered as marketable tuber number.

3.14.2.4 Non-marketable tuber number hill^{-1}

It was recorded by counting average number tubers of five hills, rotten, diseased, insect infected, and green tubers and those with less than 20 g, weight were regarded as non-marketable tuber.

3.14.2.5 Total tuber yield (t ha^{-1})

The sum of both marketable and non-marketable tuber yields was recorded as total tuber yield. Tubers of each plot were collected, weighed, recorded in kilogram and converted to t ha^{-1}.

3.14.2.6 Marketable tuber yield (t ha^{-1})

Mean weight of marketable tubers produced from the randomly selected hills, was recorded at harvest by weighing tubers which are healthy and greater than 20 g. The value were taken in kg plot^{-1} and converted to t ha^{-1}.

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

At harvest, mean weight of non-marketable tubers collected from randomly selected five hills from each plot was recorded and those rotten, turned green and less than 20 g , were considered to determine non-marketable tuber yield, (kg plot^{-1}) and changed into t ha^{-1}.

3.14.3 Tuber quality parameters

3.14.3.1 Tuber dry matter content (%)

Dry matter yield was calculated following the method by taking samples of tuber from each treatment. Sample tubers were washed, peeled off and dried in an oven at 72^{0}C for 72 hours. Dry matter content was expressed in percent.

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

3.14.3.2 Specific gravity (g cm^{-3})

Tuber specific gravity (TSG) was calculated based on the following formula.

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

3.14.3.3 Total soluble solid (TSS)

By using portable hand refractometer (ERMA, Tokyo, Japan) total soluble solid (TSS) were determined. At room temperature, every single tuber was bland and a drop of juice was placed on clean prism of refractometer and the lid was closed to measure (^{0}brix).

3.14.3.4 Starch content

The residue remined after extraction for sugar,was washed for several times with water to ensure that there was no more soluble sugar in the residues. After that using tap water and mark up to 250 ml beaker. Stire well on a magnetic stirrer. Then 0.5 mL solution was taken from the beaker into 3 test tubes. 0.5 mL was taken during the stirring. Then boiling the test tubes for 10 min at 100^{0}C. Amyloglucosidase solution was added and mix well and heat at 50-60^{0}C for 2 hrs in hot water. After cooling, a 0.5 mL Copper solution was added and mix well, heat at 100^{0}C for 10min., cool in tap water again added 0.5 mL Nelson solution, mix well and added 7 mL distilled water, mix well (Final volume= 9.5 mL), and measure the absorbance at 660 nm (Abs4). . Calculate starch content using the glucose standard curve.

3.15 Data analysis

The collected data on different growth, yield and quality parameters were subjected to analysis of variance (ANOVA) by using Statistix 10 computer program. All pair of treatment means was compared using Least Significant Difference (LSD) test at 5% level of significance. The raw data management was completed by using Microsoft excel spread sheet. (Gomez and Gomez, 1984)

CHAPTER IV

RESULTS AND DISCUSSION

The current inquiry was supervised in the research field to estimate the growth, yield and quality of potato as influenced by N and P levels. To present, analyse and compare the data obtained from the present study; different figures, tables, and appendices have been used in this section. The acknowledgement and all possible explanations were given under the following heading:

4.1 Plant height at different DAP

4.1.1 Effect of N levels

At 30 DAP variation was prominent among different N levels to plant height (Table-1 and Appendix III).The upper limit of plant height (22.09 cm) was retained by N_3 and lower limit of plant height (19.92 cm) was retained by N_2 (Table 1). Notable difference was noticed to plant height among distinct N levels at 45 DAP (Table-1).The maximum plant height (60.30 cm) was found by N_3 treatment and the minimum (40.51 cm) was observed by N_0 treatment (Table 1). By different N levels of potato tubers the plant height at 60 DAP was observed outstanding distinction (Table 1).The taller plant (70.12 cm) was observed from N_3 treatment and the smaller (47.72 cm) was in treatment N_0 (Table 1). In respect of plant height at 75 DAP due to different N levels was observed statistically significant (Table 1).The maximum plant height (72.17 cm) was retained in the plant produced from treatment N_3 and the minimum (49.31 cm) was in treatment N_0 (Table 1).

Jamaati-e-Somarin *et al.* (2009) and Yibekal, (1998) have also observed that 200 kg N ha^{-1} gave the highest plant height of potato, as it was observed in the present experiment that application of the highest N (165 kg $ha^{-1)}$ rate gave the highest plant height at 30 DAP (21.92 cm), 45 DAP (60.30 cm), 60 DAP (70.12 cm) , 75 DAP (72.170 cm).

Table 1: Effect of N levels on plant height of potato at different DAP

Nitrogen levels	Plant height at			
	30 DAP (cm)	45 DAP (cm)	60 DAP (cm)	75 DAP (cm)
N_0	20.46 b	40.51 d	47.72d	49.31 d
N_1	20.25 bc	47.87 c	57.48 c	61.88 c
N_2	19.92 c	58.00 b	66.68 b	70.80 b
N_3	22.09 a	60.30 a	70.12a	72.17 a
CV%	2.83	3.28	0.34	1.31
$LSD_{0.05}$	.4169	1.6916	0.2041	0.8338
Level of significance	**	**	**	**

Numbers in columns followed by the same letter are not statistically different at $P_{0.05}$
** = Significant at 1% level of probability
N_0-Control, N_1-150 kg N ha^{-1}, N_2-160 kg N ha^{-1}, N_3-170 kg N ha^{-1}

4.1.2 Effect of P levels

In aspect of plant height at 30 DAP because of different P doses was perceived statistically significant (Table 2 and Appendix III). The upper limit of plant height (20.81 cm) was revealed by P_0, while lower limit (20.52 cm) was revealed by P_3 treatment. Plant height was statistically similar for P_0 and P_1 treatments. Modest difference was recognized by different P doses of plant height at 45 DAP (Table 2). Maximum plant height (150.03 cm) was noticed in treatment P_3 and the

minimum (49.92 cm) was noticed in P_0 treatment which was statistically similar to P_1 and P_2 treatment (Table 2). By different P levels of potato tubers the plant height at 60 DAP different variation was observed (Table 2).The maximum plant height (62.97 cm) was measured for the treatment P_3 and the minimum (58.74 cm) was recorded for the control plot P_0 which was not significantly different from the treatments P_1 and P_2 (Table 2). Variation was noticed to plant height among distinct P rates at 75 DAP (Table-2). Application of P at the rate of 150 kg ha^{-1} (P_3) gave the highest plant height (66.22 cm) while the lowest (61.39 cm) was recorded for control (P_0) (Table 2).

Table 2: Effect of P levels on plant height at different DAP

Phosphorous levels	**Plant height at**			
	30 DAP (cm)	**45 DAP (cm)**	**60 DAP (cm)**	**75 DAP (cm)**
P_0	20.81 a	49.92 b	58.74 b	61.39 c
P_1	20.80 a	50.15 b	59.89 b	62.37 bc
P_2	20.60 ab	51.57 b	60.39 b	64.19 ab
P_3	20.52 b	150.03 a	62.97 a	66.22 a
CV%	0.19	4.30	4.61	4.50
$LSD_{0.05}$	0.2686	1.8719	2.3504	2.4098
Level of significance	**	**	**	**

Numbers in columns followed by the same letter are not statistically different at $P_{0.05}$
** = Significant at 1% level of probability
P_0-Control, P_1-45 kg P ha^{-1}, P_2-50 kg P ha^{-1}, P_3-55 kg P ha^{-1}

Mulubrhan (2004) and Zelalem *et al.* (2009) have also reported that increasing application of phosphorous significantly increased the height of potato plant.

4.1.3 Effect of N and P combination

In case of plant height at 30 DAP because of different N and P levels was appeared statistically significant (Table 3 and Appendix III). The maximum plant height (23.27 cm) was recorded at combination of 170 kg N ha^{-1} and 0 kg P ha^{-1} (N_3P_0) treatment combination and minimum plant height (18.33 cm) was measured for the combination of 160 kg N ha^{-1} and 55 kg P ha^{-1} (N_2P_3) treatment which was not significantly different from the treatment that received 0 kg N and 0 kg P ha^{-1} (N_0P_0) combination. Plant height at 45 DAP was significantly influenced by combination of nitrogen and phosphorus levels (Table 3). The highest plant height (61.87 cm) was recorded from the combination of 170 kg N ha^{-1} and 55 kg P ha^{-1} (N_3P_3) while the lowest (37.31 cm) value was obtained from the control treatment combination of (N_0P_0) which was not significantly different from N_0P_1 and N_0P_2 treatment. Among different combination of nitrogen and phosphorus levels, the plant height at 60 DAP was remarked statistically non-significant (Table 3). But, numerically, the taller plant (71.17 cm) was seen from N_3P_3 treatment and smaller plant (44.98 cm) was exhibited by N_0P_0 treatment (Table 3). Remarkable difference was observed among different nitrogen and phosphorus levels on plant height at 75 DAP (Table 3). The maximum plant height (74.13 cm) was retained by N_3P_3 treatment, while the minimum plant height (46.53 cm) was recorded for control plot (N_0P_0). Similar trend was also observed for N_0P_1 and N_0P_2 treatment. A good supply of nitrogen stimulates root growth and development as well as the uptake of other nutrients. Jamaati-e-Somarin *et al*. (2009) and Yibekal, (1998) have also reported that, the highest rate of 200 kg N h-1 gave the highest plant height of potato, as it was obtained in the current experiment that application of the maximum nitrogen and phosphorus rate gave the highest plant height (74.13 cm).

Table 3: Effect of combination of N and P levels on plant height at different DAP

Combination	Plant height			
	30 DAP (cm)	45 DAP (cm)	60 DAP (cm)	75 DAP (cm)
N_0P_0	18.51 f	37.31 g	44.98	46.53 g
N_0P_1	19.76 e	38.52 g	46.29	47.09 g
N_0P_2	21.63 b	40.97 fg	48.58	50.54 fg
N_0P_3	21.97 b	45.25 de	51.05	53.11 ef
N_1P_0	20.93 c	43.77 ef	54.03	57.21 de
N_1P_1	20.47 cd	44.28 ef	55.81	58.62 cd
N_1P_2	19.98 de	48.22 d	56.49	63.04 c
N_1P_3	19.63 e	55.21 c	63.59	68.66 b
N_2P_0	20.54 cd	59.12 ab	67.46	71.91 ab
N_2P_1	20.77 c	57.70 bc	66.69	71.27 ab
N_2P_2	20.07 de	57.40 bc	66.49	71.07 ab
N_2P_3	18.33 f	57.80 bc	66.09	68.98 b
N_3P_0	23.27 a	59.50 ab	68.51	69.91 ab
N_3P_1	22.22 b	60.12 ab	70.80	72.50 ab
N_3P_2	20.74 c	59.71 ab	70.01	72.14 ab
N_3P_3	21.16 b	61.87 a	71.16	74.13 a
CV%	0.19	4.30	4.61	4.50
$LSD_{0.05}$	0.6225	3.6490		4.2544
Level of significance	**	**	NS	*

Numbers in columns followed by the same letter are not statistically different at $P_{0.05}$

** and *=Significant at 1% and 5% level of probability, respectively

NS=Non-significant

N_0-Control, N_1-150 kg N ha^{-1}, N_2-160 kg N ha^{-1}, N_3-170 kg N ha^{-1}

P_0-Control, P_1-45 kg P ha^{-1}, P_2-50 kg P ha^{-1}, P_3-55 kg P ha^{-1}

4.2 Number of stems hill^{-1}

4.2.1 Effect of nitrogen

Profound variation was found among different levels of nitrogen on numbers of stem hill^{-1}. Increasing application nitrogen from 0 to 170 kg ha^{-1} increased main stem number hill^{-1} from 3.87 to 5.29. The maximum stem number (5.29) hill^{-1} was recorded at 170 kg N ha^{-1} and the minimum stem number (3.87) hill^{-1} was obtained from the control (Fig.1). Individual treatment was statistically different from each other. An increase in nitrogen level up to 170 kg N ha^{-1} brought about an increase in stem number hill^{-1}. This might be related to the fact that main stem number is mostly dependent on the number of sprout per tuber.

In agreement with the present finding, Nizamudin *et al.* (2003), Hassanpanah *et al.* (2009) and Alam *et al.* (2007) have reported that the lowest stem number of potato was obtained from unfertilized control. Shakh *et al.* (2001) have also reported that increased in stem number with an increased in nitrogen application (180 kg N ha^{-1}). Similarly, Jamaati-e-Somarin *et al.* (2009) reported that increasing nitrogen level up to 110 kg N ha^{-1} increased the stem number; but further increases in nitrogen fertilizer level did not affect it any more.

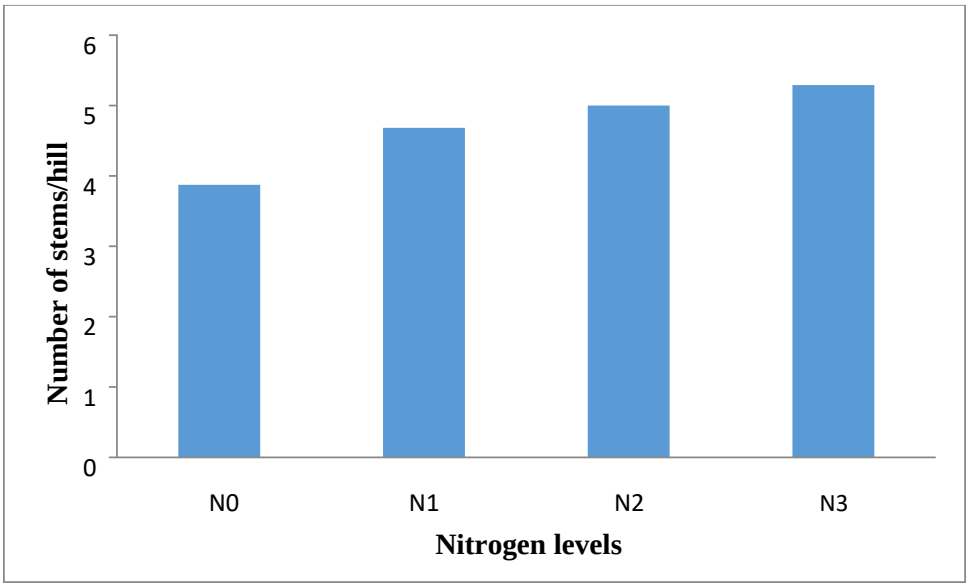

Figure 1: Number of stems hill^{-1} as influenced by nitrogen rates ($LSD_{(0.05)}$=4.0078)

N_0=0 kg N ha^{-1}, N_1=150 kg N ha^{-1}, N_2=160 kg N ha^{-1}, N_3=170 kg N ha^{-1}

4.2.2 Effect of phosphorus

Similar to nitrogen, increasing the level of phosphorus significantly increased main stem number hill^{-1} of potato (Fig.2). Increasing application of phosphorus from 0 to 55 kg ha^{-1} increased main stem number hill^{-1} from 4.40 to 4.94 .The maximum stem number (4.94) hill^{-1} was recorded at 55 kg P ha^{-1} and the minimum stem number (4.40) hill^{-1} was obtained from the control (Fig.2). Stem number hill^{-1} at 50 kg P ha^{-1} (4.88) was not statistically different from that at 55 kg ha^{-1} (4.94).

Similar result have been reported by Rosen and Bierman (2008), who showed that phosphorus applications increased the number of stems hill^{-1} compared with the zero phosphorus levels (control). Maier *et al.* (2002) have also reported a significant increase in stem number plant^{-1} with phosphorus fertilization in a greenhouse study which might be related to the fact that adequate amount of phosphorus forms good root system, strong stem and good growth.

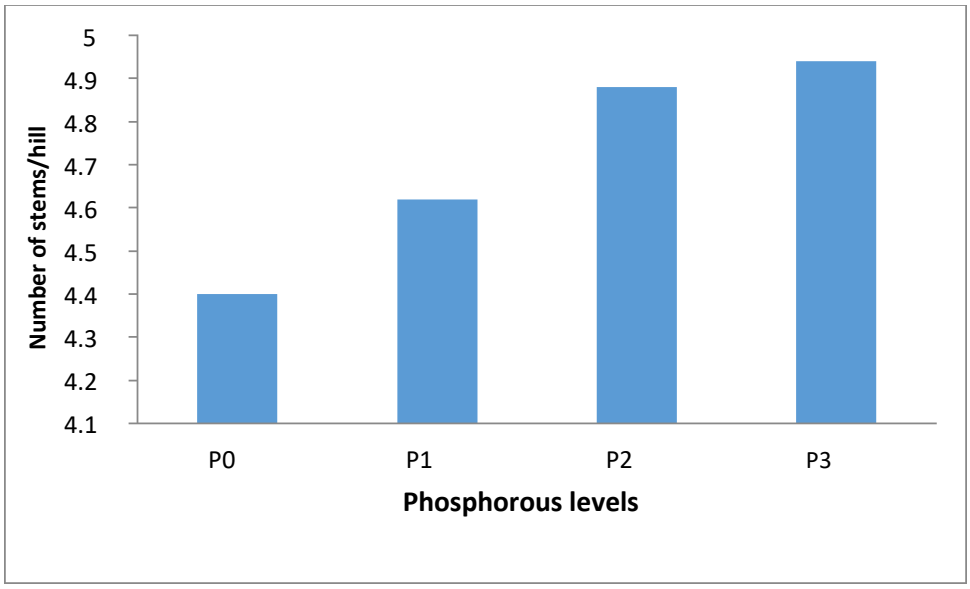

Figure 2: Number of stems hill^{-1}as influenced by phosphorus rates (LSD $_{0.05}$ =0.1795)

P_0-Control, P_1-45 kg P ha^{-1}, P_2-50 kg P ha^{-1}, P_3-55 kg P ha^{-1}

4.2.3 Combined effect of nitrogen and phosphorous

Profound contrast was found among different levels of combinations of stem hill^{-1}. Increasing application nitrogen and phosphorus combination rates from 0 kg N ha^{-1} and 0 kg P ha^{-1} (N_0P_0) to 170 kg N ha^{-1} and 50 kg P ha^{-1} (N_3P_2) combination increased main stem number hill^{-1} from 3.41 to 5.65. The maximum stem number (5.65) hill^{-1} was recorded at N_3P_2 treatment. The minimum stem number (3.41) hill^{-1} was obtained from the control (Fig.3).

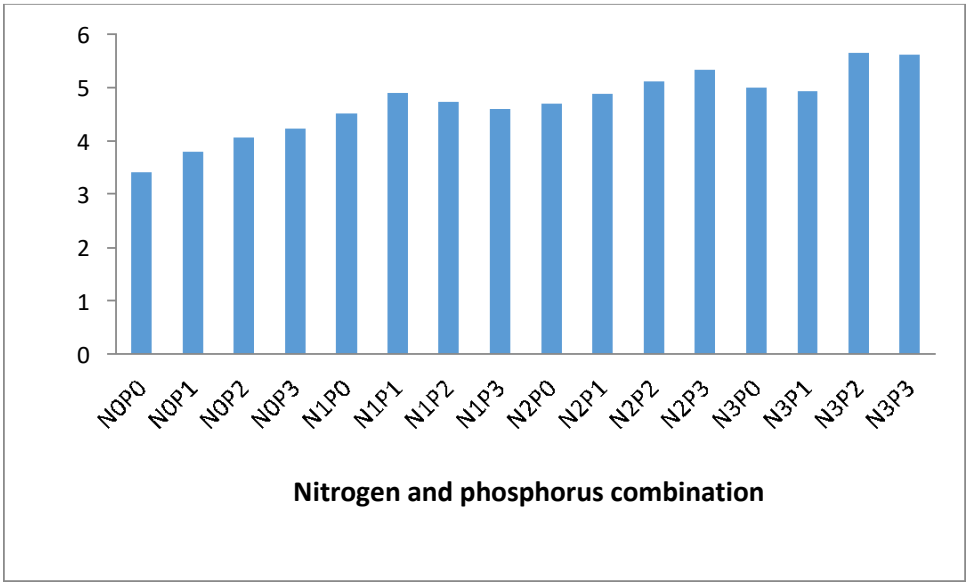

Figure3: Number of stems hill^{-1}as influenced by nitrogen and phosphorus combination rates ($LSD_{0.05}$= 0.3109)

N_0-Control, N_1=150 kg N ha^{-1}, N_2=160 kg N ha^{-1}, N_3=170 kg N ha^{-1} P_0-Control, P_1-45 kg P ha^{-1}, P_2-50 kg P ha^{-1}, P_3-55 kg P ha^{-1}

4.3 Effect of N on yield and yield contributing characters of potato

4.3.1 Total number of tubers hill^{-1}

Significant variation was noted because of different nitrogen levels to number of tuber hill^{-1} (Table 4 and Appendix IV). The higher total tuber number (13.61 hill^{-1}) was recorded for the N_3 treatment and lower total tuber number (9.7 hill^{-1}) was obtained from the control treatment N_0 (Table 4).

4.3.2 Average tuber weight

Average tuber weight was significantly regulated by different nitrogen levels (Table 4). The highest average tuber weight (54.20g) was attained from N_3 treatment and lowest average tuber weight (40.26g) was attained from N_1 treatment which is statistically similar to N_0 treatment (Table 4).

4.3.3 Marketable tubers number hill^{-1}

By different N levels of potato tubers the marketable tuber number was observed outstanding distinction (Table 4). Application of nitrogen at the rate of 170 kg ha^{-1} (N_3) gave the highest marketable tuber numbers hill^{-1} (10.02). The minimum value (5.71) was observed from N_0 treatment (Table 4).

4.3.4 Non-marketable tubers number hill^{-1}

Notable difference was noticed to non-marketable tuber number among distinct N levels (Table-4). The maximum (4.23) non-marketable tuber number was found by N_1 treatment and the minimum (3.52) was observed by N_2 treatment (Table 4).

Nitrogen application to potatoes before tuber initiation increases the number of tubers plant^{-1} and mean fresh tuber weight (Kanzikwera *et al.,* 2001). In agreement with the present finding, Mulubrhan (2004); Guler (2009); Jamaati-e-Somarin *et al*. (2010) have reported a significant increase in average tuber weight in response to nitrogen application. Jamaati-e-Somarin *et al*. (2010) have also shown that variation in tuber yield due to nitrogen treatments was related to the tuber weight increment. Zelalem *etal*. (2009) also reported that nitrogen application beyond 138 kg ha^{-1}not bringsignificant yield advantage. According to Wilcox and Hoff (1970), the positive effect of nitrogen fertilizer on potato growth and yield was noted in its impact on promoting the number of tubers produced plant^{-1}, the average weight of tubers, and establishment of optimum leaf area index and leaf area duration.

Table 4: Effect of N level on yield and yield contributing characters of potato variety cv. Courage

Nitrogen levels	**Total tuber hill^{-1} (no.)**	**Average tuber weight (g)**	**Marketable tuber hill^{-1} (no.)**	**Non-marketable tuber hill^{-1} (no.)**
N_0	9.70 d	40.48 c	5.71 d	3.98 b
N_1	12.13 c	40.26 c	7.94 c	4.23 a
N_2	13.08 b	42.94 b	9.56 b	3.52 d
N_3	13.61 a	54.20 a	10.02 a	3.58 c
CV%	0.36	2.56	2.40	0.78
$LSD_{0.05}$	0.0440	1.1376	0.1990	0.0299
Level of significance	**	**	**	**

Numbers in columns followed by the same letter are not statistically different at $P_{0.05}$
**=Significant at 1% level of probability
N_0-Control, N_1=150 kg N ha^{-1}, N_2=160 kg N ha^{-1}, N_3=170 kg N ha^{-1}

4.4 Effect of P on yield and yield contributing characters of potato

4.4.1 Total number of tubers hill^{-1}

Total tuber number was significantly affected by P levels (Table 5 and Appendix IV). Increasing the rate of phosphorus consistently increased total tuber number hill^{-1} from 11.02 to 13.08. The maximum total tuber number (13.08) was noted against P_3 treatment and minimum total tuber number (11.02) was noted against P_0 treatment (Table 5).

4.4.2 Average tuber weight (g)

By different nitrogen levels of potato tubers the average tuber weight was significantly influenced (Table 5). The higher average tuber weight (47.99 g) was observed from P_3 treatment and lower average tuber weight (41.85 g) was obtained from P_1 treatment and statistically similar result of average tuber weight was recorded at control plot (P_0) (Table 5)'

4.4.3 Marketable number of tubers hill^{-1}

By different P levels of potato tubers the marketable tuber number was observed outstanding distinction (Table 5). Application of phosphorus at the rate of 55 kg ha^{-1} (P_3) gave the highest marketable tubers number hill^{-1} (9.57) .The minimum value (6.77) was observed from P_0 treatment (Table 5).

4.4.4 Non-marketable number of tubers hill^{-1}

Significant difference was remarked to non-marketable tuber number among distinct P levels. (Table-5).The maximum (4.24) non-marketable tuber number was found by P_0 treatment and the minimum (3.51) was observed by P_3 treatment (Table 5).

Rosen and Bierman (2008) have reported that phosphorus fertilizer treatments significantly increased total number of tubers hill^{-1}. Sanderson *et al*. (2002) have also noted that application of phosphorus increased the number of tubers set unit^{-1} area. Similarly, Mulubrhan (2004) have published that average tuber weight increased in response to the application of phosphorus.

Table 5: Effect of P level on yield and yield contributing characters of potato variety cv. Courage

Phosphorous levels	Total tuber no. hill^{-1}	Average tuber weight (g)	Marketable tuber no. hill^{-1}	Non-marketable tuber no. hill^{-1}
P_0	11.02 d	42.14 c	6.77 d	4.24 a
P_1	11.90 c	41.85 c	8.17 c	3.72 b
P_2	12.51 b	45.90 b	8.70 b	3.85 b
P_3	13.08 a	47.99 a	9.57 a	3.51 c
CV%	5.41	4.39	5.61	5.25
$LSD_{0.05}$	0.15032	1.6459	0.3931	0.1696
Level of significance	**	**	**	**

Numbers in columns followed by the same letter are not statistically different at $P_{0.05}$
** and *= Significant at 1% and 5% level of probability, respectively
P_0-Control, P_1-45 kg P ha^{-1}, P_2-50 kg P ha^{-1}, P_3-55 kg P ha^{-1}

4.5 Combined effect of N and P on yield and yield contributing characters of potato

4.5.1 Total tuber number hill^{-1}

The total number of tuber hill^{-1} was found to be significantly affected by nitrogen and phosphorus fertilizer, however, the interaction of nitrogen and phosphorus was not significant (Table 6 and Appendix IV). But, numerically, the highest (14.9) total tuber number hill^{-1} was exhibited by N_3P_3 and the lowest (9.03) was exhibited by N_0P_0 (Table 6).

4.5.2 Average tuber weight

By the interaction of nitrogen and phosphorus levels the average weight of tuber was significantly affected (Table 6). The highest average tuber weight (59.89 g) was recorded for the plot that received a combination of 170 kg N ha^{-1} and 50 kg P ha^{-1} (N_3P_2), while the lowest (26.33 g) value was obtained from the control combination (N_0P_0).

4.5.3 Marketable tuber number $hill^{-1}$

In case of marketable tubers number $hill^{-1}$ due to different N and P levels was shown statistically significant (Table 6). The maximum marketable tubers number (11.54) was recorded at combination of 170 kg N ha^{-1} and 55 kg P ha^{-1} (N_3P_3) treatment and minimum marketable tubers number (3.00) was measured for the combination of 0 kg N ha^{-1} and 0 kg P ha^{-1} (N_0P_0) treatment.

4.5.4 Non-marketable tuber number $hill^{-1}$

Combinedly, a significant dissimilarity was found among the treatment against non-marketable tuber numbers of potato (Table 6). The interaction effects show that the least non-marketable tuber numbers (2.72) $hill^{-1}$ recorded for the application of 0 kg N ha^{-1} when combined with 45 kg P ha^{-1} (N_0P_1) and the most non-marketable tuber number (6.03) was recorded for plot that received the control (N_0P_0) treatment.

Table 6: Effect of combination of N and P levels on yield and yield contributing character of potato

Combination	Total tuber no. hill^{-1}	Average tuber weight (g)	Marketable tuber no. hill^{-1}	Non-marketable tuber no. hill^{-1}
N_0P_0	9.03	26.33 j	3.00 i	6.03 a
N_0P_1	9.23	41.31 gh	6.50 gh	2.72 i
N_0P_2	9.87	46.07 de	6.21 h	3.66 ef
N_0P_3	10.67	48.21 cd	7.13 fg	3.54 e-g
N_1P_0	11.28	50.72 c	6.89 gh	4.39 bc
N_1P_1	11.88	32.80 i	7.71 ef	4.16 cd
N_1P_2	12.58	35.09 i	8.21 de	4.57 b
N_1P_3	12.78	42.43 fg	8.95 d	3.83 de
N_2P_0	11.76	44.95 ef	8.61 d	3.15 h
N_2P_1	13.07	39.20 h	8.81 d	4.26 c
N_2P_2	13.50	42.150 fg	10.13 bc	3.36 gh
N_2P_3	14.00	45.07 ef	10.69 b	3.31 gh
N_3P_0	12.03	46.56 de	8.61 d	3.41 f-h
N_3P_1	13.43	54.10 b	9.68 c	3.75 e
N_3P_2	14.10	59.89 a	10.27 bc	3.83 e
N_3P_3	14.90	56.28 b	11.54 a	3.36 gh
CV%	5.41	4.39	5.61	5.25
$LSD_{0.05}$	----	3.0648	0.7087	0.2952
Level of significance	NS	**	**	**

Numbers in columns followed by the same letter are not statistically different at $P_{0.05}$

** =Significant at 1% level of probability

NS=Non-significant

N_0-Control, N_1=150 kg N ha^{-1}, N_2=160 kg N ha^{-1}, N_3=170 kg N ha^{-1}

P_0-Control, P_1-45 kg P ha^{-1}, P_2-50 kg P ha^{-1}, P_3-55 kg P ha^{-1}

4.6 Effect of N on yield and the marketable grading of potato

4.6.1 Total tuber yield

Nitrogen application was significantly influenced the total tuber yield (Table 7 and Appendix V). Increasing application of nitrogen from 0 to 110 kg ha^{-1} increased total tuber yield ha^{-1} from 13.98t ha^{-1} to 21.7t ha^{-1}. The maximum yield (21.7t ha^{-1}) was recorded at N_2 treatment and statistically similar result of total tuber yield was recorded at N_2 and N_3 treatment. The lowest value (13.98t ha^{-1}) was obtained from the control (Table 7).

4.6.2 Marketable tuber yield

Marketable tuber yield (t ha^{-1}) was significantly affected by different nitrogen application (Table 7). Increasing application of nitrogen from 0 to 160 kg ha^{-1} increased marketable tuber yield ha^{-1} from 10.78 t to 17.66 t. The maximum marketable yield (17.66t ha^{-1}) was recorded at N_2 treatment. The lowest value (10.78t ha^{-1}) was obtained from the control (Table 7).

4.6.3 Non-marketable tuber yield

Significant difference was remarked to non-marketable tuber yield among distinct N levels. (Table 7).The maximum non-marketable tuber yield (4.62t ha^{-1}) was found by N_3 treatment and the minimum (3.20t ha^{-1}) was observed by N_0 treatment (Table 7).

Zelalem *et al.* (2009) reported that nitrogen application beyond 138 kg ha^{-1} did not bring significant yield advantage.

Table 7: Effect of N levels on yield and grading of yield for marketing of potato variety cv. Courage

Nitrogen levels	Yield (t ha^{-1})	Marketable tuber yield (t ha^{-1})	Non-marketable tuber yield (t ha^{-1})
N_0	13.98 c	10.78 d	3.20 d
N_1	18.04 b	14.34 c	3.76 c
N_2	21.70 a	17.66 a	4.04 b
N_3	21.60 a	16.97 b	4.62 a
CV%	0.58	0.26	1.85
$LSD_{0.05}$	0.1093	0.0387	0.0723
Level of significance	**	**	**

Numbers in columns followed by the same letter are not statistically different at $P_{0.05}$
**=Significant at 1% level of probability
N_0-Control, N_1=150 kg N ha^{-1}, N_2=160 kg N ha^{-1}, N_3=170 kg N ha^{-1}

4.7 Effect of P on yield, marketable yield and non-marketable yield of potato

4.7.1 Total tuber yield

Total tuber yield was significantly regulated by different phosphorus levels (Table 8 and Appendix V). The highest total tuber yield (25.08 t ha^{-1}) was attained from P_3 treatment and lowest total tuber yield (10.47 t ha^{-1}) was attained from P_0 treatment (Table 8).

4.7.2 Marketable tuber yield

By different P levels of potato tubers the marketable tuber yield was observed outstanding distinction (Table 8). Application of phosphorus at the rate of 55 kg ha^{-1} (P_3) gave the highest marketable tuber yield (20.91 t ha^{-1}). The minimum value (6.76 t ha^{-1}) was observed from P_0 treatment.

4.7.3 Non-marketable tuber yield

Modest difference was recognized by different P doses to non-marketable tuber yield (Table 8). Maximum non-marketable tuber yield (4.17 t ha^{-1}) was noticed in treatment P_3 and minimum (3.75 t ha^{-1}) was noticed in P_1 treatment which was statistically similar to P_0 and P_2 treatment. Mulubrhan (2004) and Israel (2012) have reported that increasing phosphorus application increased total tuber yield.

Table 8: Effect of P levels on yield ,marketable yield and non-marketable yield of potato

Phosphorous levels	**Yield (t ha^{-1})**	**Marketable tuber yield (t ha^{-1})**	**Non-marketable tuber yield (t ha^{-1})**
P_0	10.47 d	6.76 d	3.79 b
P_1	18.06 c	14.31 c	3.75 b
P_2	21.69 b	17.77 b	3.92 b
P_3	25.08 a	20.91 a	4.17 a
CV%	6.15	6.32	5.67
$LSD_{0.05}$	0.9758	0.7953	0.1869
Level of significance	**	**	**

Numbers in columns followed by the same letter are not statistically different at $P_{0.05}$
**=Significant at 1% level of probability
P_0-Control, P_1-45 kg P ha^{-1}, P_2-50 kg P ha^{-1}, P_3-55 kg P ha^{-1}

4.8 Combined effect of N and P on yield, marketable yield and non-marketable yield of potato

4.8.1 Total tuber yield

Data presented on yield parameters in Table 9 revealed that the treatment effect was found to be significantly different for total tuber yield. Significantly maximum tuber yield (30.27 t ha^{-1}) was found on application of 170 kg N, 55 kg phosphorus ha^{-1} (N_3P_3) which was having statistically equal effect with N_2P_3 treatment. The minimum tuber yield (7.90 t ha^{-1}) was counted in the treatment 0 kg N ha^{-1}, 0 kg P ha^{-1} (N_0P_0).

4.8.2 Marketable tuber yield

Data presented on yield parameters in Table 9 revealed that the treatment effect was found to be significantly different for marketable tuber yield. On the perusal of yield attributing data presented in Table 9, it is evident that the maximum marketable tuber yield (24.13 t ha^{-1}) was recorded under the treatment (N_3P_3) 170:55 kg NP ha^{-1} which was having statistically equal effect with N_2P_3 treatment. The minimum marketable tuber yield (1.69 t ha^{-1}) was counted in the treatment 0 kg N ha^{-1}, 0 kg P ha^{-1} (N_0P_0).

4.8.3 Non-marketable tuber yield

Combinedly, a significant dissimilarity was found among the treatment against non-marketable tuber yield of potato (Table 9 and Appendix V). Highest non-marketable tuber yield (6.21 kg ha^{-1}) was recorded with 0, 0 kg NP ha^{-1} (N_0P_0) which was observed to have at par effect with 0,55 kg NP ha^{-1} (N_0P_3) treatment. No significant difference was observed between the treatments N_0P_0 and N_3P_3.

Table 9: Effect of combination of N and P levels on yield, marketable yield and non-marketable yield of potato

Combination	Yield (t ha^{-1})	Marketable tuber yield (t ha^{-1})	Non-marketable tuber yield (t ha^{-1})
N_0P_0	7.90 i	1.69 i	6.21 a
N_0P_1	13.68 g	10.66 g	3.02 f
N_0P_2	16.27 f	14.17 f	2.10 g
N_0P_3	18.10 ef	16.60 de	1.50 h
N_1P_0	12.10 gh	8.70 h	3.70 e
N_1P_1	17.30 f	14.09 f	3.21 f
N_1P_2	19.86 d	15.45 ef	4.41 d
N_1P_3	22.90 c	19.15 c	3.75 e
N_2P_0	10.85 h	8.75 h	2.10 g
N_2P_1	21.92 c	17.40 d	4.52 d
N_2P_2	24.96 b	20.72 b	4.24 d
N_2P_3	29.07 a	23.77 a	5.30 b
N_3P_0	11.06 h	7.91 h	3.15 f
N_3P_1	19.37 de	15.12 f	4.25 d
N_3P_2	25.70 b	20.74 b	4.96 c
N_3P_3	30.27 a	24.13 a	6.13 a
CV%	6.15	6.32	5.67
$LSD_{0.05}$	1.6935	1.3779	0.3315
Level of significance	**	**	**

Numbers in columns followed by the same letter are not statistically different at $P_{0.05}$
**= Significant at 1% level of probability

N_0-Control, N_1=150 kg N ha^{-1}, N_2=160 kg N ha^{-1}, N_3=170 kg N ha^{-}

[1] P_0-Control, P_1-45 kg P ha^{-1}, P_2-50 kg P ha^{-1}, P_3-55 kg P ha^{-1}

4.9 Effect of N on quality parameters of potato

4.9.1 Dry matter (%)

Data presented on quality parameters in Table 10 revealed that the treatment effect was found to be significant for dry matter. The maximum dry matter (20.56%) was recorded under the treatments (N_1) and (N_2). The minimum dry matter (19.61%) was counted in the treatment (N_3).

4.9.2 Specific gravity

By different N levels of potato tubers the specific gravity was observed variation (Table 10 and Appendix VI). Application of nitrogen at the rate of 0 kg ha^{-1} (N_0) gave the highest specific gravity (1.069). The minimum value (1.046) was observed from N_2 treatment which provided 110 kg N $ha^{-1.}$ (Table10).

4.9.3 Total Soluble Solid (TSS°)

Total Soluble Solid (TSS°) for different nitrogen levels differed significantly (Table 10). Among different nitrogen levels, the highest total soluble solid (TSS°) (7.63) was noticed at N_3 treatment and the lowest value (5.54) was obtained from N_0 treatment or control plot.

4.9.4 Starch content

In aspect of starch content of tuber due to different nitrogen levels was found statistically significant (Appendix VI). The largest amount of starch (14.30%) was exhibited by N_2 treatment and statistically similar results of starch content was recorded at N_1 treatments, while the smallest amount of starch (13.08%) was observed for N_3 treatment (Table 10).

Robert and Cheng (1988) and Simret *et al.* (2010) have noted a non-significant difference in specific gravity of tubers due to nitrogen treatment.

Table 10: Effect of N on quality parameters of potato variety cv. Courage

Nitrogen levels	Dry matter (%)	Specific gravity	TSS	Starch (%)
N_0	20.05 b	1.069	5.54 d	13.72 a
N_1	20.56 a	1.061	5.97 c	14.08 b
N_2	20.56 a	1.046	6.98 b	14.30 a
N_3	19.61 c	1.059	7.63 a	12.97 c
CV%	0.41	1.47	0.13	1.95
$LSD_{0.05}$	0.0833	------	8.0046	0.2688
Level of significance	**	NS	**	**

Numbers in columns followed by the same letter are not statistically different at $P_{0.05}$
**= Significant at 1% level of probability
NS= Non-significant
N_0-Control, N_1=150 kg N ha^{-1}, N_2=160 kg N ha^{-1}, N_3=170 kg N ha^{-1}

4.10 Effect of P on quality parameters of potato

4.10.1 Dry matter

In Table 11 data presented on quality parameters reports that the treatment effect was found to be significant for dry matter because of different N levels. The maximum dry matter (21.12 %) was recorded under the treatment (P_2) and the minimum dry matter (19.57 %) was counted in the treatment (P_1) which was not significantly distinct from P_3 treatment (Table 11).

4.10.2 Specific gravity

By different P levels of potato tubers the specific gravity was observed significant variation (Table 11and Appendix VI). Application of P at the rate of 0 kg ha^{-1} (P_0) gave the highest specific gravity (1.069) which was not significantly different from P_3 And P_2 treatment. The minimum value (1.047) was observed from P_1 treatment (Table 11).

4.10.3 Total Soluble Solid (TSSº)

For different phosphorus levels, Total Soluble Solid (TSSº) differed significantly. Among different P levels, the highest total soluble solid (TSSº) (6.82) was noticed at P_3 treatment and the lowest value (6.36) was obtained from P_0 treatment or control plot which was not significantly different from P_1 and P_2 treatments (Table 11).

4.10.4 Starch content

In aspect of starch content of tuber due to different phosphorus levels was found statistically significant (Table 11). The highest amount of starch (14.79%) was exhibited by P_2 treatment, while the lowest amount of starch (12.57%) was observed for P_1 treatment.'

Table 11: Effect of P on quality parameters of potato variety cv. Courage

Phosphorous levels	Dry matter (%)	Specific gravity	TSS	Starch (%)
P_0	20.39 ab	1.069 a	6.36 b	14.04 b
P_1	19.57 b	1.047 b	6.45 b	12.57 d
P_2	21.12 a	1.056 ab	6.49 b	14.79 a
P_3	19.69 b	1.064 a	6.82 a	13.66 c
CV%	5.34	1.47	4.58	1.51
$LSD_{0.05}$	0.9086	0.0131	0.2523	0.17150
Level of significance	**	**	**	**

Numbers in columns followed by the same letter are not statistically different at $P_{0.05}$
**= Significant at 1% level of probability
P_0-Control, P_1-45 kg P ha^{-1}, P_2-50 kg P ha^{-1}, P_3-55 kg P ha^{-1}

4.11 Combined effect of N and P on quality parameters of potato

4.11.1 Dry matter

The interaction effect of nitrogen and phosphorus rates significantly influenced dry matter content of tuber (Table 12 and Appendix VI). The highest dry matter (23.27%) content of tuber was produced in the treatment combination (N_2P_2) of N rate 160 kg ha^{-1} with P 50 kg ha^{-1}. The lowest (18.17%) were at 170 kg N ha^{-1} with 0 kg P ha^{-1} combination (N_3P_0) which was having statistically equal effect with N_0P_2, N_2P_1, N_3P_1 treatments.

4.11.2 Specific gravity

Specific gravity was significantly influenced by combination of nitrogen and phosphorus levels (Table 12). The highest specific gravity (1.091) was recorded for the plot that received N_3P_3 treatment. While the lowest (1.021) value was obtained from N_2P_3 treatment.

4.11.3 Total Soluble Solid (TSSº)

For combined effect of nitrogen and phosphorus rates, Total Soluble Solid (TSSº) differed significantly (Table 12). Among different combination, the highest total soluble solid (TSSº) (8.2) was noticed at N_3P_3 treatment and the lowest value (5.13) was obtained from N_0P_0 treatment or control plot.

4.11.4 Starch content

Among different nitrogen and phosphorus levels on starch content was remarked statistically significant. The maximum starch (17.41%) was seen from N_2P_2 treatment and minimum starch (10.99%) was exhibited by N_3P_0 treatment which was statistically similar with N_0P_2 treatment (Table 12).

Table 12: Effect of combination of N and P levels on Quality parameter of potato variety cv. Courage

Combination	Dry matter (g)	Specific gravity	TSS	Starch (%)
N_0P_0	20.58 cd	1.061 b-e	5.13 h	14.40 ef
N_0P_1	22.03 a-c	1.072 a-c	5.37 gh	15.98 c
N_0P_2	18.25 f	1.079 ab	5.45 gh	11.00 j
N_0P_3	19.34 d-f	1.067 a-c	6.21 e	13.50 g
N_1P_0	21.92 a-c	1.079 ab	6.38 e	15.92 c
N_1P_1	18.96 ef	1.033 ef	6.17 ef	11.54 i
N_1P_2	20.53 c-e	1.057 b-e	5.75 fg	14.24 f
N_1P_3	20.85 cd	1.077 a-c	5.60 g	14.65 de
N_2P_0	20.91 b-d	1.071 a-c	6.54 de	14.87 d
N_2P_1	18.83 f	1.037 d-f	7.04 cd	11.48 i
N_2P_2	23.27 a	1.0150 b-e	7.08 c	17.41 a
N_2P_3	19.25 d-f	1.021 f	7.29 bc	13.44 gh
N_3P_0	18.17 f	1.065 b-d	7.40 bc	10.99 j
N_3P_1	18.47 f	1.048 c-f	7.25 bc	11.30 ij
N_3P_2	22.46 ab	1.033 ef	7.70 ab	16.51 b
N_3P_3	19.35 d-f	1.091 a	8.20a	13.07 h
CV%	5.34	1.47	4.58	1.51
$LSD_{0.05}$	1.5759	0.0292	0.4370	0.4043
Level of significance	**	**	**	**

Numbers in columns followed by the same letter are not statistically different at $P_{0.05}$

**= Significant at 1% level of probability

N_0-Control, N_1=150 kg N ha^{-1}, N_2=160 kg N ha^{-1}, N_3=170 kg N ha^{-}

[1] P_0-Control, P_1-45 kg P ha^{-1}, P_2-50 kg P ha^{-1}, P_3-55 kg P ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy Research Field, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 during the period from November, 2016 to March 2017.The site was located at $23^0$77'N latitude and $90^0$33'E longitude at an altitude of 8.6 meter above the sea level. The experimental site go with the agro-ecological zone of "Modhupur Track", AEZ-28. This was a region of complex relief and soils developed over the Modhupur Clay. The soil type of the experimental site was to the general soil type of shallow red brown terrace soils under Tejgaon series. The soil was also labeled by pH 5.67 and 0.462% organic carbon. The plot was medium high land. The experimental area was with maximum and minimum temperature which was vary during the period from November, 2017 to March,2018."Courage" was used as planting material under current experiment. The experiment was laid out in a split-plot design with three replications. The current experiment contained two factors. The treatment comprised of the combinations of four levels of N (0, 150, 160, and 170 kg ha^{-1}) and four levels of P (0, 45, 50, and 55 kg ha^{-1}) under irrigation. The result of the study showed that the interaction effects of N and P as well as their main effect had considerable influence on growth, yield component and quality parameters of potato.

In case of plant height at 30 DAP, the maximum plant height (23.27 cm) was recorded at combination of 170 kg N ha^{-1} and 0 kg P ha^{-1} (N_3P_0) treatment and minimum plant height (18.33 cm) was measured for the combination of 160 kg N ha^{-1} and 55 kg P ha^{-1} (N_2P_3) treatment. At 45 DAP, the highest plant height (61.87 cm) was recorded for the plot that received a combination of 170 kg N ha^{-1} and 55 kg P ha^{-1} (N_3P_3) while the lowest (37.31 cm) value was obtained from the control treatment (N_0P_0). Among different nitrogen and phosphorus levels on plant height at 60 DAP was remarked statistically non-significant. The maximum plant height (74.13 cm) was retained by N_3P_3 treatment at 75 DAP, while the minimum plant height (46.53cm) was recorded for control (N_0P_0). Similar trend was also observed for N_0P_1 treatment.

Increasing application N from 0 to 170 kg ha^{-1} increased stem number $hill^{-1}$ from 3.87 to 5.29. The maximum stem number (5.29) $hill^{-1}$ was recorded at 170 kg N ha^{-1} and the minimum stem number (3.87) was obtained from the control. Similar to nitrogen, increasing application phosphorus from 0 to 55 kg ha^{-1} increased stem number $hill^{-1}$ from 4.40 to 4.94 .The maximum stem number (4.94) $hill^{-1}$ was recorded at 55 kg P ha^{-1} and the minimum stem number (4.40) $hill^{-1}$ was obtained from the control. The total number of tuber $hill^{-1}$ was found to be significantly affected by nitrogen and phosphorus fertilizer, however, the interaction of nitrogen and phosphorus was not significant. The highest average tuber weight (59.89 g) was recorded for the plot that received a combination of 170 kg N ha^{-1} and 50 kg P ha^{-1} (N_3P_2), while the lowest (26.33 g) value was obtained from the control combination (N_0P_0). The maximum marketable tubers number (11.54) was recorded at combination of 170 kg N ha^{-1} and 55 kg P ha^{-1} (N_3P_3) treatment and minimum marketable tubers number (3.00) was measured for the combination of 0 kg N ha^{-1} and 0 kg P ha^{-1} (N_0P_0) treatment. The interaction effects show that the least non-marketable tuber numbers (2.72) $hill^{-1}$ recorded for the application of 0 kg N ha^{-1} when combined with 45 kg P ha^{-1} (N_0P_1) and the most non-marketable tuber number (6.03) was recorded for plot that received the control (N_0P_0) treatment.

Significantly maximum tuber yield (30.27 t ha^{-1}) was found on application of 170 kg N, 55 kg phosphorus ha^{-1} (N_3P_3) which was having statistically equal effect with N_2P_3 treatment. The minimum tuber yield (7.90 t ha^{-1}) was counted in the treatment 0 kg N ha^{-1}, 0 kg P ha^{-1} (N_0P_0). The maximum marketable tuber yield (24.13 t ha^{-1}) was recorded under the treatment (N_3P_3) 170:55 kg NP ha^{-1} which was having statistically equal effect with N_2P_3 treatment. The minimum marketable tuber yield (1.69 t ha^{-1}) was counted in the treatment 0 kg N ha^{-1}, 0 kg P ha^{-1} (N_0P_0). Highest non-marketable tuber yield (6.21 kg ha^{-1}) was recorded with 0, 0 kg NP ha^{-1} (N_0P_0) which was observed to have at par effect with 0, 55 kg NP ha^{-1} (N_0P_3) treatment. No significant difference was observed between the treatments N_0P_0 and N_3P_3. Due to nitrogen application, the treatment effect was found to be significant for dry matter. The

maximum dry matter (21.12%) was recorded under the treatment (P_2) and the minimum dry matter (19.57%) was counted in the treatment (P_1). The interaction effect of nitrogen and phosphorus rates significantly influenced dry matter content of tuber. The highest dry matter (23.27%) content of tuber was produced in the treatment combination (N_2P_2) of N rate 160 kg ha^{-1} with P 50 kg ha^{-1}. The lowest (18.17%) were at 170 kg N ha^{-1} with 0 kg P ha^{-1} combination (N_3P_0) which was having statistically equal effect with N_0P_2, N_2P_1, N_3P_1 treatments. Application of N at the rate of 0 kg ha^{-1} (N_0) gave the highest specific gravity (1.069). The minimum value (1.046) was observed from N_2 treatment which provide 160 kg N ha^{-1}. Specific gravity was significantly influenced by combination of N and P levels. Application of P at the rate of 0 kg ha^{-1} (P_0) gave the highest specific gravity (1.069). The minimum value (1.046) was observed from P_1 treatment. The highest specific gravity (1.091) was recorded for the plot that received N_3P_3 treatment, while the lowest (1.021) value was obtained from N_2P_3 treatment. Among different P levels, the highest total soluble solid (TSS^o) (6.82) was noticed at P_3 treatment and the lowest value (6.36) was obtained from P_0 treatment or control plot. Among different combination, the highest total soluble solid (TSS^o) (8.2) was noticed at N_3P_3 treatment and the lowest value (5.13) was obtained from N_0P_0 treatment or control plot. The maximum amount of starch (14.30%) was exhibited by N_2 treatment and statistically similar results of starch content was recorded at N_0 and N_1 treatments, while the minimum amount of starch (13.08%) was observed for N_3 treatment. The maximum amount of starch (14.79 %) was exhibited by P_2 treatment, while the minimum amount of starch (12.57 %) was observed for P_1 treatment. The maximum starch (17.41%) was seen from N_2P_2 treatment and minimum starch (10.99%) was exhibited by N_3P_0 treatment which was statistically similar with N_0P_2, treatment.

In conclusion the result of this study show that different nitrogen and phosphorus rates and their interaction have a sound and promising impact on growth, yield and quality of potato. Therefore, on the basis of the results of the present study farmers can used 170 kg ha^{-1} nitrogen in combination with 55 kg phosphorus for producing maximum yield with good quality.

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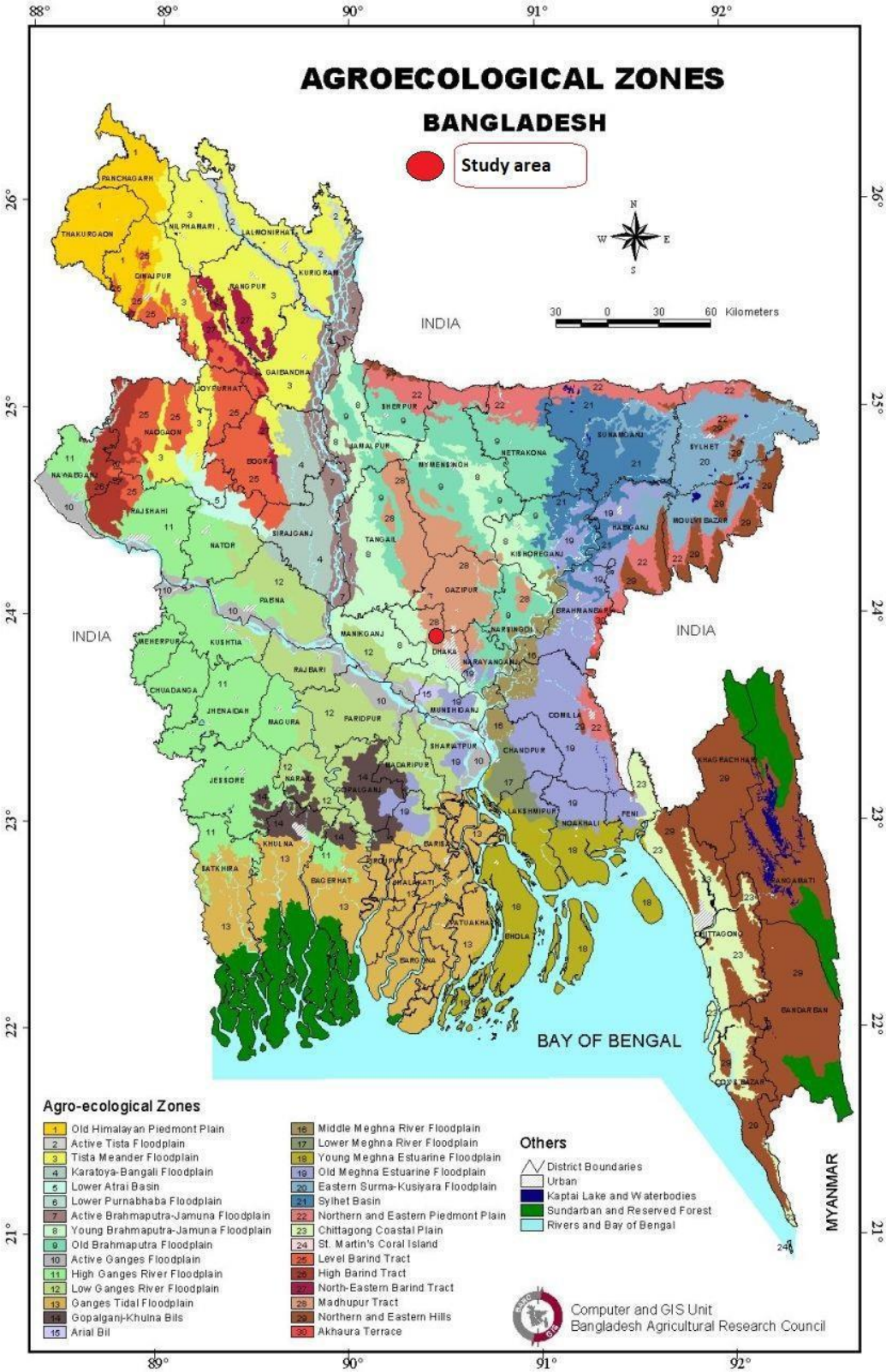
APPENDICES

Appendix I: Map showing the site used for current experiment.



Appendix II: Monthly meteorological information during the period from November'2016 to April'2017

Year	Month	Air temperature(^{0}C)		Relative humidity	Total rainfall
		Maximum	Minimum		
2016-2017	November	34	19	71	2629.20
	December	34	19	68	67.50
	January	29	14	59	26.14
	February	32.00	15.00	51	68.80
	March	32.00	17.00	64	4824.19
	April	36.00	20.00	72	11521.25

Source: Meteorological Centre (Climate Division), Agargaon, Dhaka

Appendix III: Mean square values of the data for plant height at different DAP of potato

Source of variation	df	Plant height at			
		30 DAP	**45 DAP**	**60 DAP**	**75 DAP**
Replication	2	8.4681	1.27	0.03	1.72
Nitrogen	3	9.30538 **	1014.16**	1212.40**	1329.29**
Error	6	0.34174	2.87	0.04	0.70
Phosphorus	3	0.58094 **	66.62**	38.30**	54.42**
Combination	9	5.17069 **	19.73**	13.74 NS	22.61**
Error	24	0.00157	4.94	7.78	8.18
Total	47				

**, indicates significant at 1% level of probability, *, indicates significant at 5% level of probability, NS, Non-significant

Appendix IV: Mean square values of the data for growth and yield contributing characters of potato

Source of variation	df	No. of stems hill^{-1}	Average tuber weight	Total tuber no. hill^{-1}	Marketable tuber no. hill^{-1}	Non-marketable tuber no. hill^{-1}
Replication	2	0.00006	0.079	0.1186	0.0056	0.00167
Nitrogen	3	4.53662**	523.163**	36.0695**	45.6201**	1.38488**
Error	6	0.00002	1.297	0.0019	0.0397	0.00090
Phosphorus	3	0.75022**	107.025**	9.3435**	16.5224**	1.14574**
Combination	9	0.13227**	166.374**	0.3014^{NS}	1.1702**	2.05057**
Error	24	0.04537	3.816	0.4311	0.2176	0.04049
Total	47					

**, indicates significant at 1% level of probability, *, indicates significant at 5% level of probability, NS, Non-significant

Appendix V: Mean square values of the data for yield contributing characters of potato

Source of variation	df	Yield	Marketable yield	Non-marketable
Replication	2	0.687	0.542	0.00814
Nitrogen	3	159.935**	116.797**	4.16346**
Error	6	0.012	0.002	0.00523
Phosphorus	3	470.773**	443.791**	0.43528**
Combination	9	14.008**	5.878**	7.94056**
Error	24	1.341	0.891	0.04919
Total	47			

**, indicates significant at 1% level of probability, *, indicates significant at 5% level of probability, NS, Non-significant

Appendix VI: Mean square values of the data for quality parameters of potato

Source of variation	df	Dry matter	Specific gravity	TSS	Starch
Replication	2	0.0869	0.018150	0.0002	3.0863
Nitrogen	3	2.5364**	0.00118^{NS}	10.8959**	4.0984**
Error	6	0.0070	0.00034	0.0001	0.0724
Phosphorus	3	6.1781**	0.00104*	0.4858**	10.2187**
Combination	9	10.0002**	0.00125**	0.4637**	16.9756**
Error	24	1.1629	0.00024	0.0896	0.0434
Total	47				

**, indicates significant at 1% level of probability, *, indicates significant at 5% level of probability, NS, Non-significant