EFFECT OF UREA SUPER GRANULE ON THE GROWTH AND YIELD OF POTATO

A Thesis

By

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CERTIFICATE

*This is to certify that the thesis entitled **" EFFECT OF UREA SUPER GRANULE ON THE GROWTH AND YIELD OF POTATO"** submitted to the **DEPARTMENT OF SOIL SCIENCE,** Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in SOIL SCIENCE,** embodies the results of a piece of bonafide research work carried out by **MD. NAJMUL HOSSAIN,** Registration No. **11-04296**, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.*

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

Dated: June, 2017

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The Author

ABSTRACT

A research work was carried out at the Research Farm, Sher-e-Bangla Agricultural University, Dhaka during the period from November 2016 to March 2017 in order to determine the suitable nitrogen source to observe the growth performance with a view to increasing the yield of potato. The experiment consisted of eight treatments. The experiment was laid out with Randomized Complete Block Design with three replications. Experimental results showed that nitrogen sources had significant effect on plant height, number of effective stem hill^{-1}, wt. of tuber (g), yield of tubers (kg plot^{-1}), yield of tubers t ha^{-1}, tuber fleshy dry matter content, specific gravity, grading of tubers (% by number). Potato production increased significantly due to the application of USG. The highest production was observed in T_3 treatment. The application of T_3 treatment showed the highest wt. of tuber hill^{-1} (57.53g), highest tuber yield kg per plot (25.77), highest tuber yield (29.45 t ha^{-1}) than any other sources of nitrogen treatments. The mean apparent recovery of N by tested varieties (Diamont) was obtained with the application of USG in other treatment (except control) but the nitrogen use efficiency was highest in T_3 treatment. Findings revealed that application of USG showed the superiority over other sources of nitrogen to produce highest tuber yield of potato and for all cases lowest results were found in T_1 treatment receiving no fertilizer (control).

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LIST OF ACRONYMS

AEZ	= Agro- Ecological Zone
AIS	= Agricultural Information System
BARC	= Bangladesh Agricultural Research Council
BBS	= Bangladesh Bureau of Statistics
BINA	= Bangladesh Institute of Nuclear Agriculture
BARI	= Bangladesh Agricultural Research Institute
cm	= Centimeter
cv.	= Cultivar
CGR	= Crop growth rate
CAR	= Conventional application rate
DAT	= Days after transplanting
° C	= Degree Centigrade
DF	= Degree of freedom
DAP	= Di-ammonium phosphate
DMA	= Dry matter accumulation
DMRT	= Duncan’s Multiple Range Test
EC	= Emulsifiable Concentrate
et al.	= and others
etc.	= Etcetera
FAO	= Food and Agriculture Organization
FYM	= Farmyard manure
g	= Gram
GDP	= Gross domestic product
HI	= Harvest Index
HYV	= High yielding variety
hr	= hour
Kg	= Kilogram
LV	= Local variety
m	= Meter
m^2	= Meter squares
MV	= Modem variety
MoP	= Muriate of potash
mm	= Millimeter
viz.	= Namely
N	= Nitrogen

NFAA	= Nitrogen fertilizer application amount
NS	= Non significant
%	= Per cent
CV %	= Percentage of Coefficient of Variance
P	= Phosphorus
K	= Potassium
ppm	= Parts per million
PU	= Prilled urea
SAU	= Sher-e- Bangla Agricultural University
S	= Sulphur
SRDI	= Soil Resources and Development Institute
t ha^{-1}	= Tons per hectare
USG	= Urea super granules
UDP	= Urea deep placement
Zn	= Zinc
TSP	= Triple super phosphate
TDM	= Total dry matter
Kg ha^{-1}	= Kilogram per hectare

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the 3rd largest food and vegetable crop in Bangladesh after rice and wheat. It is also a world leading vegetable crop that furnishes appreciable amount of vitamin B and vitamin C as well as minerals. As an industrial crop, potato is a raw material of various foods and confectionaries. It produces more calories and protein per unit land with minimum time and water than most of the major food crops (Upadhya, 1995). Potato can be used in numerous ways, such as, boiled, baked and fried potatoes, dehydrated potatoes, canned potatoes and as starch for culinary purposes (Hoque, 1994). Because of its high yield potential and food value, compared to rice and wheat, potato is considered as a promising candidate crop for feeding the hungry people of the world.

In 2016-17, the area, production and average yield of potato in Bangladesh were 0.43 million hectare, 7.93 million tons and 18.24 tons per hectare, respectively (BBS, 2016). The yield level of this crop in Bangladesh is low compared to other potato growing countries of the world (Anon., 1997). Nitrogen requirement of potato is very high. It is an essential plant nutrient element and is the most limiting due to its high mobility and different types of losses like leaching, volatilization and mobilization (Nuruzzaman *et al*. 1993; Bhuiyan *et al*. 1990; De Dalta and Crasswell, 1982). Farmers of Bangladesh grow potato in different regions through prilled urea with other fertilizers. Nitrogen is the most deficit nutrient element in Bangladesh soil. In general farmers traditionally apply at least nitrogenousfertilizer to their crops for better yield. It is said that urea super granule (USG) is more efficient than that of prilled urea. USG minimizes N leaching and volatilization loss to a greater extent. Where large amount of urea fertilizer application are made, especially if they are not well incorporated, substantial losses (20 to 40%) of added N might be accepted. Application of USG in potato field improve efficiency more than 60% with an increase of about 15-20% potato yield over conventional urea application (Haque, 1998). Now, USG has been considered as a proven technology in potato production (Kumar, et al.1989; Savant and Stangel, 1990). During the last couple of years, farmers are applying USG. Some research report on different crops especially vegetables revealed that by using of USG substantial amount of urea fertilizer can be saved (Anon. 2003). Urea currently consistence more than 70% of the fertilizer being consumed in Bangladesh. Again, to meet thedemand ofurea-N fertilizer in country,often Bangladesh has to import urea fertilizer (Kumar, et al.1989; Savant and Stangel, 1990). USG more efficiently in upland vegetable and fruit crops like brinjal, cabbage, cauliflower, tomato and on quick growing fruits like papaya,banana etc. (Annual Report, 2006-07). USG requirement is less than prilled urea in cabbage, cauliflower, brinjal and tomato. USG also increases yield of these crops. However, there is no recommendation of USG for upland crops and research findings in this regard are very scanty. Again efficiency of USG on upland crops is yet to be ascertained.

Among the various factors responsible for high yield in Bangladesh. There is a vast scope of increasing the yield per hectare through the introduction of high yielding potato and good keeping quality .The local variety are in existence in Bangladesh have become degenerated on account of various reasons and give extremely low yield. On the other hand, the yields of high yielding varietyare much better than the local ones under the identical conditions and cultural practices. Therefore, with a view to stepping up the degeneration gap and getting high yield, Bangladesh has to import seed-tubers of good quality from abroad at the cost of hard earned foreign exchange.

Hence, the present study was undertaken with the following objectives:

- To evaluate the efficiency of USG on the yield of potato
- To find out the optimum dose of USG for maximum potato production.

CHAPTER II

REVIEW OF LITERATURE

High production of any crop depends on manipulation of basic ingredients of agriculture. Growth and yield of potato is greatly influenced by environmental factors like day length or photoperiod, temperature, humidity, variety and agronomic practices such as planting time, spacing and number of tuber hill^{-1}, fertilization and irrigation. Among the factors variety and level of nitrogen fertilizer application are important especially for the production of potato.

Nitrogen is one of the macro-nutrients used in Bangladesh in the form of urea. There is different form of urea. USG is one of them which greatly influences crop yield. Prilled urea is another form of urea. Many experiments were conducted by national and international institutions. A number of studies were conducted in Bangladesh on different forms of urea as the source of nitrogen especially prilled urea dose and dose of USG also an important factor in research farms and farmers filed under different agro-ecological conditions. An attempt has been made in this chapter to review the literatures and research finding on the level of prilled urea and USG application as the source of nitrogen and varietal performance in potato production.

2.1 Effect of N-fertilizer

2.1.1 Plant height

Zohra (2012) set an experiment with 3 different potatovarieties and highest plant height was recorded when 3 pellets of USG applied 4 adjacent hills.

Razib (2010) showed the highest plant height (55 cm) of potato when 120 kg N ha^{-1}was applied.

Mizan (2010) stated that the highest plant height (60cm) was obtained from potato 140 kg N ha^{-1}and 120 kg N ha^{-1}.

Ahammed (2008) stated that leaf area increased with increasing level of nitrogen application from 40 kg N ha^{-1}up to 120 kg N ha^{-1}.

Wiersema, S. G. (1984) observed that effect of depth of placement of USG significantly influenced all growth characters and the yield attributes except plant height.

Salem (2006) showed that the nitrogen levels had a positive and significant effect on growth parameters of potato plants in robi season. Increasing nitrogen levels up to 70 kg ha^{-1}significantly increased leaf area index and plant height. The highest plant height at harvest was recorded about 56 cm when potato plants were fertilized with the highest nitrogen level of 120 kg ha^{-1}. On the contrary, the lowest value of the height was recorded about 40 cm when potato plants received no nitrogen fertilizer.

Meena *et al.* (2003) stated that between two levels of N 100 and 200 kg ha^{-1}, application of 200 kg ha^{-1}significantly increased the plant height (53 cm) of potato and total number of tuber $hill^{-1}$(73).

Ahmed *et al.* (2002) showed that among 5 levels, 80 kg N ha^{-1}gave the highest plant height (48 cm) and the height decreased gradually with decreased levels of nitrogen fertilizer application. Plants receiving no nitrogenous fertilizers were significantly shorter than other treatments. They also stated that nitrogen influences cell division and cell enlargement and ultimately increases plant height.

Alam (2002) stated that plant height increased significantly with the increase of level of USG/4 hills. Rahman (2003) also showed that different level of USG did not affect the plant height.

Mishra *et al*. (2000) concluded that the application of 76 kg N ha^{-1}USG at 14 DAT increased plant height, length, N uptake and consequently the tuber yields of potato.

Sahrawat *et al.* (1999) said that nitrogen level significantly influenced plant height of potato. Increasing levels of nitrogen increased the plant height significantly up to 120 kg N ha^{-1}.

Chowdhury *et al.* (1998) reported that the longest plant height of 52 cm was produced by nitrogen application at 100 kg $ha^{-1}$and was followed by 75 kg ha^{-1}due to the excellent vegetative growth of potato.

Thakur (1992) showed that the highest plant height of potato was obtained from 120 kg N $ha^{-1}$and the lowest one from the control.

Rekhi *et al.* (1989) set an experiment on a loamy sand soil with potato cv. PR 106 providing 0, 37.5, 75.0 or 112.5 kg N ha^{-1}as prilled urea (PU) or USG. PU was applied in three equal splits at planting, tuber formation and USG was placed 8-10 cm deep in alternate rows, equidistant from 4 hills. They concluded that PU produced the longest plant, higher number of tuber and higher amount of nitrogen uptake.

Singh and Singh (1986) showed that the plant height increased significantly with the increase in the levels of nitrogen from 27 to 87 kg N ha^{-1}. Deep placement of USG resulted in the highest plant height than pilled urea.

The varieties differing in plant type markedly differ in their response to added nitrogen levels (Evant *et al*, 1960; Tanaka *et al*, 1964). Nitrogen fertilization also influenced the plant height (Talukdar, 1973; Hoque *et al.*, 1977; BRRI, 1989).

2.1.2 Number of stem per $hill^{-1}$

Zohra *et al. (*2012) stated that the number of stem per $hill^{-1}$was varied significantly due to different level of USG.

Ravichandran.G and Sing (2003) reported that there was no appreciable change in stem per $hill^{-1}$due to higher dose of N above 150 kg ha^{-1}. They also showed an appreciable reduction in stem per $hill^{-1}$at 250 kg N ha^{-1}.

Idris and Matin (1990) reported that the length of stem was highly related with the application of increased level of nitrogen. They also stated that tuber formation and elongation was directly related with the contribution of nitrogen.

Salam, M.A Forhad (2004) noted that number of stem m^{-2}were significantly higher with 90 kg N ha^{-1}as deep placed USG than split application of urea.

Singh and Kumar (1998) reported that tuber yield increased consistently with increasing N application up to 87 kg ha^{-1}USG produced the higher tuber yield of than ordinary urea applied in three equal split dressings and other N sources.

Verma (2003) concluded the effects of deep placement of USG or PU on yields of cv. Verma reported that with random transplanting, deep placement of USG increased yield of cv. Jaya and Govind by 25 and 22 t ha^{-1}respectively over yields with broadcast application of PU.

2.1.3 Number of effective tuber hill^{-1}

Azam (2009) set an experiment with 3 varieties and observed, in general, the number of total tuber hill^{-1}was increased as the USG level increased but highest no. of total tuber hill^{-1}was produced when 120 kg N ha^{-1}applied as USG.

Hasan (2007) stated an experiment during the *robi* season of 2006 and recorded the increased number of tuber hill^{-1}with increased nitrogen level used USG.

Singh and Shivay (2003) reported that the effective tuber hill^{-1}was significantly affected by the level of nitrogen and increasing levels of nitrogen significantly increased the number of effective tuber hill^{-1}.

Alam (2002) showed that total tuber hill^{-1}and effective tuber hill^{-1}increased significantly with the increase of level of USG, when USG was applied as one, two, three and four granules/4 hills during the robi season.

Kushwash, V.S and Singh, S.P (2008) reported that increasing levels of N application resulted in more secondary tuber which contributed little number of tuber resulting in low harvest index.

Ahsan (1996) said that tuber is strongly correlated with nitrogen content of the plant.

Kumar *et al* (1995) concluded that an increase in N level from 80 to 120 kg N ha^{-1}significantly increased total tuber hill^{-1}.

Thakur (1993) stated that the yield attributes of potato like number of productive tuber m^{-2}and tuber weightincreased with increasing levels of nitrogen.

Idris and Matin (1990) reported that the maximum number of tuber hill^{-1}was produced with 140 kg N ha^{-1}which was statistically similar to 60, 80, 100 and

120 kg N ha^{-1}. The minimum number of tuber $hill^{-1}$was obtained from the control treatment (0 kg N ha^{-1}).

Mirzeo and Reddy (1989) effort different modified urea materials and levels of N (30, 60 and 90 kg N ha^{-1}). They stated that root zone placement of USG produced the highest number of tuber at 30 or 60 days after planting.

Tuber of potato plant is strongly influenced by nitrogen supply (BINA, 1998; BARI, 2000) and adequate nitrogen is necessary during tubering stage to ensure sufficient number of mature tuber.

Tanaka *et al.* (1998) showed that at a higher N level, potato plants have vigorous growth, high maximum tuber per plant but lower percentage of effective tuber $hill^{-1}$.

2.1.4 Weight of tuber(g)

Azam *et al.* (2009) conductedan experiment during the *robi* season with 3 different potatovarieties by using both USG and prilled urea as a source of N. He reported that source and dose of nitrogen did not show significant effect on tuber weight. The highest tuber weight (50 g) was concluded with USG applied at 120 kg N $ha^{-1}$and the lowest (40 g) tuber weight was reported at 110 kg N ha^{-1}as PU.

Chopra and Chopra (2004) stated that N had significant effects on yield attributes such as plant heightand tuber weight. Cumulative effect of yield attributing and nutrient characters stated that in significant increase in tuber yield at 120 kg N ha^{-1}over 80 kg N $ha^{-1}$and the control.

A field experiment was reported by Maiti *et al.* (2003) during the robi season with the nitrogen fertilizer applied during planting, at the tuber and formation stages.

Russell. (1998) set an experiment with the treatments comprised of 4 N levels (0, 60, 120 and 180 kg N ha^{-1})and results showed that N had significant effects on yield attributes such as plant height, $plant^{-1}$and tuber weight. Cumulative effects of yield attributing characters resulted in significant increase and tuber yield at 120 kg N ha^{-1} over 60 kg N ha^{-1}.

Alam (2002) reported that tuber weight was not influenced by level of USG.

Garcia and Azevedo (2000) set an experiment with 5 doses of nitrogen fertilizer (0, 50, 100, 150 and 200 kg N ha^{-1})and concluded that weight of tuber increased with increase in nitrogen fertilizer up to 150 kg N ha^{-1}.

Naseem *et al.* (1995) reported lower tuber weight in control treatment when the plots received fertilizer nitrogen.

Ali *et al.*(1993) stated that weight of tuber was higher when 100 kg nitrogen $ha^{-1}$was applied in three equal splits at basal 30 days and 60 days after planting.

Rahman *et al.* (2005) reported that there was a little relationship between nitrogen and weight of tuber in potato plant.

Tanaka *et al.* (1998) concluded that increasing rate of N decreased tuber weight in the varieties of potato.

2.1.5 Effect of tuber weight on growth and yield of potato

The size of tuber influences the production of potato. The growth of young plant is directly related to the size of tuber used and generally large tubers exhibit earlier sprout emergence, faster growth and development, more stems as well as tubers, earlier maturity and higher tuber yield than small tuber (Grewal *et al*., 1998). Use of large tuber generally results increased seed rate. However, the net yield is generally higher with seed of medium size (Bayorbor and Gumah, 2007).

Rashid (1987) set an experiment to know the effect of tuber size on emergence and showed increased plant emergence with large tubers than small seeds which ultimately resulted higher shoots per $plant^{-1}$. Similar result was also noteded by (Escribeno, 1992).

An experiments were stated by Garg*et al*. (2000) to know the effect of tuber size (10-15, 15-20, 20-40, 40-60 and 60-80 g) and spacing (60x10cm and 60x15 cm) and dehaulming of potatoes (cv. KufriJyoti) on number and yield of seed- size tubers. They noted that 40-50 g seed tubers planted at 60x10 cm showed the highest seed yield. The higher economic yield of seed-sized tubers could be achieved from 15-20 g of seeds at 60x10 cm spacing.

Gregoriou (2000) reported the effect of tuber size (30, 40, 50 and 65 mm) and row spacings (10, 20, 30 or 40 cm) on yield in potato cv. Cara and noted that seedling emergence was reduced at 10 cm spacing. Tuber yield decreased with increasing spacing. The tubers stem^{-1} and the yield per stem decreased as stem number per unit area increased. The best combination of total and baking (>65 mm) potato yield was estimated to be with a 27-cm planting distance.

Three experiments were stated by Khalafalla (2001) to know the effects of intra-row spacing (15, 25 and 35 cm) and seed size (whole, half-seed and farmer's seed piece) on the growth and yield of potato and noted that yield decreased with decrease in seed size and increase in spacing at all locations. Seed size had significant effect on marketable tubers per plant, marketable tuber weight, and stems plant^{-1}.

Shingrup *et al.* (2003) showed the effect of row spacing (45 and 60 cm) and tuber size (6-25 g and 26-45 g) on growth, yield and yield components of potato cv. KufriJyoti and noted that plant growth and development increased with increased tuber size. The tuber size of 26-45 g recorded significantly higher yield but average weight of tuber was higher in 16-25 g tuber size.

Upadhya and Cabello (2001) said the influence of seed size and density on the performance of direct seedling transplants from hybrid true potato seed and noted that seed size and density strongly suggest a high correlation between seed size and yield.

BongKyoon *et al*. (2001) stated an experiment with tubers of potato (*Solanum tuberosum*) cv. Dejima weighing 10, 20, 30, 40, and 50 g were planted in plug trays with vermiculite-based root medium to determine the effects of mini-tuber size on plug seedling growth and field performance of plug seedlings. For a control, common potato tubers weighing 50 g were also planted. The authors reported that as size of seed tubers planted increased from 10 to 50 g, seedling height decreased from 24.6 to 20.0 cm while shoot number per seedling increased from 2.0 to 3.5, main stem diameter from 4.3 to 6.1 mm, and fresh weight of root + top from 9.3 to 19.4 g/seedling. At 90 days after transplanting, the total tubers plant^{-1} was increased from 3.62 to 4.72, average tuber weight from 62.9 to 72.8 g, and total tuber yield 20.5 to 23.6 t/ha with increase in seed tuber size. Plug seedlings raised from 50 g tubers was produced 22% more tubers per plant and had 21% higher >80 g tuber yield than the directly planted potatoes.

The effect of tuber size (25-30, 30-55, 55-75 and 75-85 mm) on potato growth and yield was observed by Divis and Barta (2001) in Czech Republic in 1998. The authors noted that increasing seed tuber size produced an increase in emergence percentage. Larger tubers produced higher stems plant^{-1}, crop growth rate as compared to small tubers which resulted in higher yield compared to small ones.

A three year field trial was set by Reust (2002) at the Swiss Federal Research Station for Plant Production of Changins [Switzerland] with different seed tuber sizes (25-35, 35-50 and 50-65 mm) to find out the effect of seed tuber size on yield in potato and noted that yields were not different between small graded seed (25-35 mm) and normal seed size (35-50 mm). The author further noted that small seed tubers had a longer dormancy and produced less stems and tubers plant^{-1} than large ones. The author opined that by using small graded seed, farmers might significantly reduce production costs.

The effect of N rate (75, 100, 125 and 150 kg/ha), seed size (30-60 and 61-90 g) and spacing (60 ×15 and 60 × 20 cm) for the newly released potato cv. Kufri Sutlej were observed by Malik et al. (2002) and reported that the number of stemhill^{-1}, tuber yield per plant and tuber yield were higher under 60 x 20 cm spacing and using 60-90 g seeds.

A field experiment was stated by Shingrup *et al.* (2003) on clayey soil during the robi season of 1999-2000 at the farm of the Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India, to study the effect of row spacing, seed tuber size and fertility level on the economics of potato cultivation. The author noted that seed tubers size of 26-45 g recorded significantly higher tuber yield, gross monetary returns, net monetary returns and benefit-cost ratio than seed tubers of 6-25 g size.

Trials were conducted in 2000, 2001 and 2002 in Tamil Nadu, India by BongKyoon *et al.* (2001) to reported suitable agro-techniques for obtaining the maximum number of seed size tubers from potato cultivars Kufri Swarna and

Kufri Jyoti. Treatments included: tuber weights of 10-20, 20-30, 30-40 and 40-50 g; intra-row spacings of 10, 15 and 20 cm; and 2 dates of haulm killing (75 and 90 days after planting). The authors noted that in both cultivars, 30-50 and 20-50 g tubers, might be used at an intra-row spacing of 10 cm, and with haulm killing at 90 days after planting to obtain the maximum number of seed size tubers.

A field experiment was set by Patel *et al.* (2002) during 2000 and 2001 in Kargil, Jammu and Kashmir, India, to investigate the effect of seed size [medium (25-50 g), big (50-75 g) and large (75-100 g) and intrarow spacing (20, 25 and 30 cm) on the yield of potato cv. Kufari Chandramukhi. The authors noted that growth, total yield, tubers plant^{-1} and average weight per tuber were greatly affected by seed size and spacing. Tuber yield (305.24 q/ha) and the number of tuber plant (10.40) were significantly highest with big seed size and 25 cm inter row spacing, while average weight per tuber (53.93 g) was highest with large seed size and 30 cm inter row spacing.

An experiment was conducted by Sonawane and Dhoble (2004) during the winter (robi) seasons of 1996-97 and 1997-98 in Maharashtra, India, to find out suitable and economical combination of inter- and intra-row spacing with seedling tuber size of potato (*Solanum tuberosum*) and noted that the tuber yield increased with the increase in seedling tuber size. Significantly highest tuber yield was recorded by large seedling tuber size of 11-15 g over 1-5 g and 6-10 g sizes. Similarly, 6-10 g seedling tuber weight was significantly superior to 1-5 g size. Benefit: cost ratio decreased as the seedling tuber size increased from 1 to 15 g.

Sonawane and Dhole (2004) set an experiment to find out suitable and economic combination of inter and intra row spacing with seedling tuber size of potato and found that tuber yield increased with increase in seedling tuber size due to increased growth and development of plants. The highest tuber yield was recorded in large seedling tuber size of 11-15 g over 1-5 and 6-10 g sizes. Similarly 6-10 g seedling tuber size was significantly superior to 1-5 g sizes. Benefit cost ratio decreased as the seedling tuber weight increased from 1 to 15 g.

A study was observed by Wadhwa *et al.* (2002) to investigate the effects of four different 'seed' tuber weights and three intra-row spacing on the yield and yield components of 'Frafra' potato. The 'seed' tubers were categorized according to weight: A (>10. 0 g), size B (7.0-9.9 g), size C (3.0-6.9 g) and size D (<3.0 g); three intra-row spacings of 20 cm, 30 cm and 40 cm were also used. The authors reported that leaf area index (LAI) and crop growth rate (CGR) were greater in larger seeds than smaller ones. The authors further noted that yield increased with the use of heavier 'seed' tubers. On the average, yield of plants of category B 'seed' tubers was 52% higher than those obtained from 'seed' tubers of category A and 58% and 59% higher than those of categories C and D, respectively.

The effects of different in-row spacing (20, 25, 30 and 35 cm) and seed size (small, medium and large) treatments on yield components and tuber yield of early potato were observed by Gulluoglu and Aroglu (2009) in *Adana*, *Turkey* noted that planting larger seeds positively affected all growth and yield components. Tuber yield per hectare was increased up to certain stem density and then was started to decline at all seed sizes. However, the optimum stem density for the maximum tuber yield per hectare markedly differed depending on size of seed tubers. The optimum stem density increased with increasing seed size

2.1.6Yield of tuber (tonha^{-1})

Sarker *et al.* (2001) stated the nitrogen response of a cardinal and and hera variety with different nitrogen levels viz. 0, 40, 80 and 120 kg N ha^{-1}. They observed that application of nitrogen increased tuber yields significantly

Dwivedi (1997) reported that application of nitrogen significantly increased the growth yield and yield components tuber yield, plant yield as well as 150 kg N ha^{-1}.

Mishra *et al.* (1999) noted that apparent N recovery in potato also increased from 21% for PU to 40% for USG. Here potato showed a greater response to N upon USG placement than split application of PU.

Gaudin (2012) set an experiment on the kinetics of ammonia disappearance from deep-placed urea supergranules (USG) in planted potato: the effects of deep placement USG application and PU fertilizer. He found that ammonia disappearance from the placement site is faster for the second application, and it appears that the roots took up ammonia at a higher concentration: 20 mM for the second application versus 10 mM for the first application.

Iqbal (2011) showed an experiment on determination of the effects of five fertilizer application rates on vertical leaching from 30 cm and 60 cm soil layers and) found that during tuber growth, nitrogen losses from different nitrogen treatments varied 2.82-5.07% application of the urea compared to USG.

2.2. Effect of variety

Variety has shown effect on different plant characters. The genetic make-up of a variety and environment mainly influence the varietal performance of a crop. Response of potato to nitrogenous fertilizer is largely influenced by variety (BARI, 1988); soil fertility (BARI, 1989); environmental factors and management practices. Tuber yield increase generally with nitrogen, addition up to a certain level. Research findings indicated the positive response of potato to nitrogen fertilization (Islam, 1961, 1964; Pandey and Sinha, 1971; BARI, 1980).

2.2.1 Effect on crop characters

Hasan (2007) has noted that plant height, effective tuber hill^{-1}differed significantly among the varieties. Islam (1995) reported that among the four modern potato varieties (viz., BARI ALU 10, BARI ALU 11, BARI ALU 22 and BARI ALU 23), the highest and the lowest number of non-bearing tuber hill^{-1}.

Bisne *et al.* (2006) showed an experiment with eight promising varieties using four lines of potato and showed that plant height differed significantly among the varieties and cardinal gave the highest plant height in each line.

Rahman (2006) noted that number of effective and non-effective tuber hill^{-1}to show any significant difference in BARI ALU 28 and BARI ALU29.

BARl (2006) reported yield performance of three high yielding varieties namely BARI ALU 70, BARI ALU 7l, BARI ALU 76 in *robi* season and revealed that effective tuber hill^{-1}of the above mentioned varieties were 7, 8 and 8, respectively.

Myung (2005) experimented with four different types of potato varieties and reported that the primary rachis branches (PRBs) stem^{-1}and tuber were more on Sindongjinbyeo and Iksan 67 varieties, but secondary rachis branches (SRBs) were fewer than in Dongjin and Saegyehwa varieties.

Rahman (2003) found that plant height, effective tuber hill^{-1}, stem length and tuberdiffered significantly between the varieties.

Suman *et al.* (2003) set an experiment with the new potato cv. P-73-1-1, P-711 and the local variety and showed that the traditional cv. Raton was the shortest among the varieties.

Bokyeong *et al.* (2003) noted that applied with same nitrogen dose hera and Dera of potato varieties gave high primary rachis branches Dera varieties.

Khisha (2002) reported that the plant height was significantly influenced by variety. He found the highest plant height (56.94 cm) in BINA potato 13, which was significantly higher than BARI potato29.

Hasan *et al.* (2002) showed that BARI ALU 34 produced the highest number of tuberproduced. And highest number of tuber were produced by cultivar BARI ALU 11 and BARI ALU 10, respectively.

Niu *et al.* (2001) set an experiment with three potato varieties viz. BARI 45, 48, 56. Results revealed that tuber was 186.2, 139.2 and 205.7, respectively.

Nuruzzaman *et al.* (2000) showed that tuber number varied widely among the varieties and the number of plant^{-1}at the maximum stage ranged between 14.3 and 39.5 in 1995 and 12.2 and 34.6 in 1996. Among all the varieties,BARI 36 followed by Suweon 258 produced the highest tuber number and Dawn produced the lowest value.

Cities, T.J.M Nustez (2000) showed with two hybrids and two high yielding potato varieties and found that first varieties produced more number of productive tuber and filledtuber than any other variety, whereasBARI ALU 36 gave the highest tuber weight, number of stem $m^{-2}$and filled stemof any two varieties.

BARI (1998) noted that tuber weight was 24, 22, 25, 20, 23, 18 and 17 and one high yielding variety BARI 25, respectively. The average plant height of BARI 30, BARI 22,and Rustom were 50 cm, 45 cm, and 55 cm, respectively (BARI, 1995).

MoA (2009) reported a field trial during the robi season of 2008-09. It was found that the hybrid potato gave higher number of tuber hill^{-1}and effective tuber hill^{-1}than the modern varietycardinal.

Mia (1993) noted that plant height different significantly among BARI 63, BARI 61, BARI 52 varieties in *robi* season.

BARI (1995) showed out the performance of BARI 14 and Tulshimala. Tulshimala produced the highest and BARI 14 produced the lowest number of tuber. They concluded that the finer the tuber size, the higher was the number of plant.

Gosh (2002) stated an experiment with four varieties/advance lines and noted significant variation in plant height, number of non-bearing tuber hill^{-1}, stem length and tuber. They also reported that tuber yield did not differ significantly among the varieties.

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CHAPTER III

MATERIALS AND METHODS

This chapter deals with a brief description on experimental period, experimental site description, soil and climatic condition of the experimental area, crop or planting materials, treatments, experimental design and layout, crop growing procedure, intercultural operations, data collection and statistical analysis.Details of materials and methodologies followed in conducting the experiment are presented below:

3.1 Experimental period

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the Robi season of November 2016 to March 2017.

3.2 Description of the experimental site:

3.2.1 Geographical location

The present research work was conducted in the farm area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level.

3.2.1.1 Agro-Ecological Region

The experimental field belongs to the Agro-ecological zone (AEZ) of “The Modhupur Tract”, AEZ-28 (Anon., 1988). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain. For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in **Appendix II**.

3.2.2 Climate characteristics

The experimental site under the sub-tropical climate that is characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and scanty rainfall associated with moderately low temperature during Robi season (November-March). The weather data during the study period at the experimental site are shown in **Appendix I**.

3.2.3 Soil characteristics

The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.4-5.6. The landwas above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from the experimental field. The physicochemical properties of the soil are presented in Tables 1 and 2.

Table 1: Physical characteristics of the experimental field

Physical characteristics	Analytical Result
Agroecological Zone	Madhupur Tract
Textural class	Clay loam
Sand (%)	25
Silt (%)	47
Clay (%)	28

Table 2: Chemical composition of soil of the experimental plot

Soil Characteristics	Analytical results
pH	5.4
Organic matter(%)	1.28
Organic carbon(%)	0.743
Total N (%)	0.05(Very low)
Available phosphorous (ppm)	20
Exchangeable K (meq / 100 g soil)	0.15
Total S (microgram/g soil)	16

3.3 Treatments

The experiment comprised ofeight treatments:

T_1 = Control;
T_2 = Recommended fertilizer dose (N_{150} P_{30} K_{140} S_{15} Zn_3) Kg/ha
T_3 = 2.7 g size USG (2 granule at both side) with P_{30} K_{140} S_{15} Zn_3 Kg/ha
T_4 = 1.8 g size USG (2 granule at both side) with P_{30} K_{140} S_{15} Zn_3 Kg/ha
T_5 = 1 USG (2.7g) + 1 USG (1.8g) with P_{30} K_{140} S_{15} Zn_3 Kg/ha
T_6 = 1 USG (2.7g) + 2 USG (1.8g) with P_{30} K_{140} S_{15} Zn_3 Kg/ha
T_7 = 1 USG (2.7g) + 1 time top dress 1/4th dose of N (tuber bulk stage) with P_{30} K_{140} S_{15} Zn_3 Kg/ha
T_8 = 1 USG (1.8g) + 1 time top dress 1/4th dose of N (tuber bulk stage) with P_{30} K_{140} S_{15} Zn_3 Kg/ha.

The description of the source of nitrogen treatments is given below:

3.3.1 Planting material

Diamont (BARI ALU -7) variety was the test crop collected from Bangladesh Agricultural Development Corporation, Nalitabari, Sherpur.

3.3.2 Land preparation

The land of the experimental site was first opened in the 2^{nd} week of November 2016 with power tiller. Later on, the land was ploughed and cross-ploughed four times followed by laddering to obtain the desirable tilth. The corners of the land were spaded. Weeds and stubbles were removed from the field. The land was finally prepared on 23 November 2016. Seeds were planting after three days. In order to avoid water logging due to rainfall during the study period, drainage channels were made around the land. The soil was treated with Furadan 5G @ 15 kg ha^{-1}at final land preparation to protect the young seedlings from the attack of cut worm.

3.4 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The size of the unit plot was 5 m ×1.75m. Distances between block to block and plot to plot were 1.0 m and 0.50 m, respectively. Treatments were randomly distributed within the blocks. The plots were raised up to 10 cm. There were 8 treatments andthree replications. So, the number of total plots were 24.For better understanding about the experimental layout has been given in **APPENDIX XI**.

3.5 Manure and fertilizer application

The crop was fertilized as per recommendation of BARC (2012). Urea, Triple super phosphate (TSP), Muriate of potash (MoP), Gypsum, Zinc oxide were used as sources of nitrogen, phosphorus, potassium, sulphur, zinc respectively. The doses of fertilizers were N 150 kg ha^{-1}.P 30 kg ha^{-1}, K 140 kg ha^{-1}, S 15 kg ha^{-1}, Zn 3 kg ha^{-1} respectively. Total amount of TSP, Gypsum, ZnO and 50 % MoP were applied as basal doses during final land preparation. The remaining 50% MoP were side dressed in two equal splits at 25 and 45 days after planting (DAP) during first and second earthing up.

3.5.1 Seed preparation and sowing

The tubers were taken out of the cold store about three weeks before planting. The tubers were graded according to the size of 40 g, 10 g and kept under diffuse light conditions to have healthy and good sprouts.After sprouting 40gm sized were cut by sharp knife into two pieces with good sprouting. Cut pieces were kept on ash to protect it's from fungus. Planting was done on November 26, 2016. The well sprouted tubers were planted at a depth of 5-7 cm in furrow made 60 cm apart. Hill to hill distance was 75 cm. After planting, the seed tubers were covered with soil.

3.5.1.1 Intercultural operations

3.5.1.2 Weeding

First weeding was done 19 December 2016. Another weeding was done after urea super granule application.

3.5.2Earthing up

Earthing up was done twice during growing period. The first earthing up was done at 25 days after planting and second earthing up was done after 20 days of first earthing up.

3.5.3 Irrigation

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

3.5.4 Plant protection

Furadan 5G @ 10 kg $ha^{-1}$was applied in soil at the time of final land preparation to control cut worm. Dithane M-45 was sprayed in 2 installment at an interval of 15 days from 50 DAP as preventive measure against late blight disease.

3.5.5 General observation

The field was frequently observed to notice any changes in plants, pest and disease attack and necessary action was taken for normal plant growth.

3.5.5.1 Haulm Cutting

Haulm cutting was done at 19 February 2017 when 40-50% plants showed senescence and the tops started drying.After haulm cutting the tubers were kept under the soil for 7 days for skin hardening.

3.5.6 Harvesting

Harvesting of potato was done at 26 February 2017 at 7 days after haulmcutting.The potatoes of each treatment were separately harvested, bagged, tagged and brought to the laboratory. Harvesting was done manually by hand.

3.5.7 Recording of data

The following parameters were recorded and their mean values were calculated from the sample plants.

A. Crop growth characters

i. Plant height at haulm cutting (cm)

ii. Number of stem $hill^{-1}$

B. Yield and yield components

iii. Number of tubers $hill^{-1}$

iv. Average Weight of tubers $hill^{-1}$(g)

v. Yield of tubers kg $plot^{-1}$

vi. Yield of tubers t ha^{-1}

C. Quality characters

vii.Tuber flesh dry matter content

viii. Specific gravity

ix. Grading of tubers (% by number)

A. Crop growth characters

i. Plant height at haulm cutting (cm): Plant height was taken to be the length between the bases of the plant to the tip during haulm cutting.

ii. Number of stems $hill^{-1}$

Number of stems $hill^{-1}$was counted at the time of haulm cutting. Stem numbers $hill^{-1}$was recorded by counting all stem from each plot. Total number of stems of 5 sample plants were counted and made it average.

B. **Yield and yield components**

iii. Number of tubers $hill^{-1}$

Number of tubers $hill^{-1}$was counted at harvest. Tuber numbers $hill^{-1}$was recorded by counting all tubers from sample plant and made it average.

iv.Average weight of tubers (g $hill^{-1}$)

Average weight of tubers $hill^{-1}$was measure at harvest. Tuber weight $hill^{-1}$was recorded by measuring all tubers from sample plant and made it average.

v. Yield of tuber (kg $plot^{-1}$)

Tuber yield was recorded on the basis of total harvested tuber $plot^{-1}$.

vi. Yield of tubers t ha^{-1}

Tuber yield was recorded on the basis of total harvested tuber $plot^{-1}$and was expressed in terms of t ha^{-1}.

C. Qualitycharacters

vii. Tuber dry matter content (%)

The samples of tuber were collected from each treatment. After peel off the tubers the samples were dried in oven at 72 degree centigrade for 72 hours. From which the weights of tuber flesh dry matter content % were recorded. From which the dry matter percentage of tuber was calculated with the following formula

Dry matter content (%) = Dry weight /Fresh weight × 100

viii. Specific Gravity

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

Specific gravity = Weight of tuber in air/ weight of tuber in water at 4 degree centigrade.

ix. Grading of tuber (% by number)

Tubers harvested from each treatment were graded by number on the basis of diameter into the greater 55 mm, 45-55 mm, 28-55 mm, less 28 mm, greater 20 g, less 20 g and converted to percentages (Hussain, 1995). A special type of frame (potato riddle) was used to grading of tuber.

3.6.7 Post harvest soil sampling

After harvest of crop, soil samples were collected from each plot at a depth of 0 to 15 cm. Soil samples of each plot was air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

3.5.7.2 Analyses of soil samples

Soil samples were analyzed for both physical and chemical properties such as texture, pH, organic carbon, total nitrogen, available P and exchangeable K. These results have been presented in **Appendix I**

3.5.7.3 Textural class

Particle size analysis of soil was done by hydrometer method and the textural class was determined by plotting of values for %sand, %silt and %clay to the Marshall's Triangular Coordinate following the USDA system.

3.5.7.4 Soil pH

Soil pH was measured with the help of a glass electrode pH meter using soil: water ratio of 1: 2.5 as described by Jackson (1962).

3.5.8 Organic matter content

Organic carbon was determined by wet oxidation method as outlined by Black (1965). The oxidization of organic C was done with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and the excess $K_2Cr_2O_7$ solution was titrated with 1N $FeSO_4$. To obtain the organic matter content, the value of organic carbon was multiplied by Van Bammelen factor(1.73) and the results were expressed in percentage.

3.5.8.1 Available phosphorus

Available phosphorus was extracted from the soil samples by shaking with 0.5 M $NaHCO_3$ solution at pH 8.5 following Olsen method (Olsen *et al.*, 1954). The extracted phosphorus was determined by developing blue color by $SnCl_2$ reduction of phosphormolybdate complex and measuring the intensity of color colorimetrically at 660 nm wavelength and the readings were calibrated to the standard P curve.

3.5.8.2 Exchangeable potassium

Exchangeable potassium was extracted from the soil samples with 1.0 N NH_4OAc (pH 7) and K was determined from the extract by flame photometer and calibrated with a standard curve (Black, 1965).

3.5.8.3Statistical analysis of the data

The analysis of variance for different crop characters as well as for different nutrient concentrations of the treatments were made and the mean differences were judged at 5% level of probability by using Duncan's Multiple Range Test (DMRT) with a computer operated program named MSTAT-C.

CHAPTER IV
RESULTS AND DISCUSSION

The experiment was conducted to study the indicative performance of urea super granules while used in potato cultivation. Data on different crop growth characters, yield contributing characters and yield of potato were recorded and found significant differences among the recorded characters. The analyses of variance (ANOVA) of the data on different parameters are presented in **Appendix (III- X).** The results have been discussed with the help of table and graphs and possible interpretations given under the following headings.

4.1 Plant height at haulm cutting (cm)

Plant height due to application of different levels of urea super granules was significantly influenced at haulm cutting. The maximum plant height (65 cm) was recorded from T_3 treatment whereas the minimum (39 cm) was recorded from control treatment (T_1). But T_2 and T_4 treatments are statistically similar in recording in plant height as show in Table 3. Plant height was increased due to application of different levels of urea super granules. Zohra (2012) set an experiment with 3 different potatovarieties and highest plant height was recorded when 3 pellets of USG applied in 4 adjacent hills. Razib (2010) showed the highest plant height (55 cm) of potato when 120 kg N $ha^{-1}$was applied. Nitrogen level significantly influenced plant height of potato. Increasing levels of nitrogen increased the plant height significantly up to 150 kg N ha^{-1}. Plants receiving no nitrogenous fertilizer as significantly shorter than other treatments. They also stated that nitrogen influences cell division and cell enlargement and ultimately increases plant height.

Table 3. Effect of Urea super granule on plant height at haulm cutting (cm)

Treatment	**Plant height (cm)**
T_1	39 g
T_2	51 d
T_3	65 a
T_4	52 d
T_5	55 c
T_6	48 e
T_7	58 b
T_8	44 f
CV(%)	2.33
LSD	2.099

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

4.1.1 Number of stem hill^{-1}

The number of stems per hill significantly varied due to application of the different levels of urea super granules. The maximum numbersof stem hill^{-1}(7) was obtained from T_3 treatment and minimum (4) was obtained from control treatment. The study referred that USG produced maximum number of stem hill^{-1}in Table 4. But T_2, T_4, T_6 and T_8 treatments are statistically similar stem shows in Table 4. Zohra *et al. (*2012) stated that the number of stem hill^{-1}was varied significantly due to different level of USG. Rajarathinam and Balasubramaniyan (1999) reported that there was no appreciable change in stemhill^{-1}due to higher dose of N above 150 kg ha^{-1}. They also showed an appreciable reduction in stemhill^{-1}at 250 kg N ha^{-1}. Length of stem was highly related with the application of increased level of nitrogen. Tuber formation and elongation was directly related with the contribution of nitrogen.

Table 4. Effect of urea super granule on number of stem per hill

Treatment	Number of stem per hill
T_1	4 d
T_2	5 c
T_3	7 a
T_4	5 c
T_5	4 d
T_6	5 c
T_7	6 b
T_8	5 c
CV(%)	9.34
LSD	0.838

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

4.1.2 Number of tuber hill^{-1}

Number of tubers per hill significantly influenced by application of different treatment. The maximum number of tubers hill^{-1}(8) was recorded from T_3 treatment which statistically similar to T_5 and T_7 whereas the minimum (5) number of tubers hill^{-1} was recorded from T_1 (control) treatment which very close with T_2, $T_{4,}$ T_6 and T_8 treatments Table 5.Hasan (2007) stated an experiment during the robi season of 2006 and recorded the increased number of tuber hill^{-1} with increased nitrogen level used USG. Effective tuber hill^{-1}was significantly affected by the level of nitrogen and increasing levels of nitrogen significantly increased the number of effective tuber hill^{-1}. Idris and Matin (1990) reported that the maximum number of tuber hill^{-1}was produced with 140 kg N ha^{-1}and the minimum number of tuber hill^{-1}was obtained from the control treatment (0 kg N ha^{-1}).

Table 5. Effect of urea super granule on number of tuber per hill

Treatment	Number of tuber per hill
T_1	5 c
T_2	6 bc
T_3	8 a
T_4	6 bc
T_5	7 ab
T_6	6 bc
T_7	7 ab
T_8	6 bc
CV(%)	10.62
LSD	1.185

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

4.2 Average weight of tuber per g hill^{-1}

The variation in weight of tuber per hill due to application of different fertilizer management practices was observed in statistically significant. The maximum tuber average weight g hill^{-1} (57.533g) was recorded T_3 treatment which was statistically similar to T_7 and the minimum (40.667g) average weight of tubers g hill^{-1} was recorded from T_1 (control) treatment. T_5 and T_6 treatments were statistically similar in recordingaverage weight of tuber g hill^{-1} and very close in T_2, T_8 treatments Table 6. Garcia and Azevedo (2000) conducted an experiment with 5 doses of nitrogen fertilizer (0, 50, 100, 150 and 200 kg Nha^{-1}) and concluded that weight of tuber increased with increase in nitrogen fertilizer up to 150 kg N ha^{-1}. Naseem *et al.* (1995) reported lower tuber weight in control treatment when the plots received lownitrogen fertilizer.

Table 6. Effect of urea super granule on average weight of tuber g hill^{-1}

Treatment	Average weight of tuber g hill^{-1}
T_1	40.667 e
T_2	51.233 d
T_3	57.533 a
T_4	52.367 cd
T_5	54.200 bc
T_6	54.320 bc
T_7	55.900 ab
T_8	51.333 d
CV(%)	2.17
LSD	1.980

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

4.2.1 Yield of tuber (kg plot^{-1})

Application of urea super granule had significant effect on the yield of tuber kg plot^{-1}. The highest tuber yield (25.77) kg plot^{-1}was obtained from T_3 treatment and the lowest tuber yield (13.8)kg plot^{-1}was obtained from T_1 (control) treatment. T_5, T_6 treatment were statistically similar and very close to T_2, T_7 treatments (fig 1). Dwivedi (1997) reported that application of nitrogen significantly increased the components of tuber yield and plant yield as well as 150 kg N ha^{-1}.

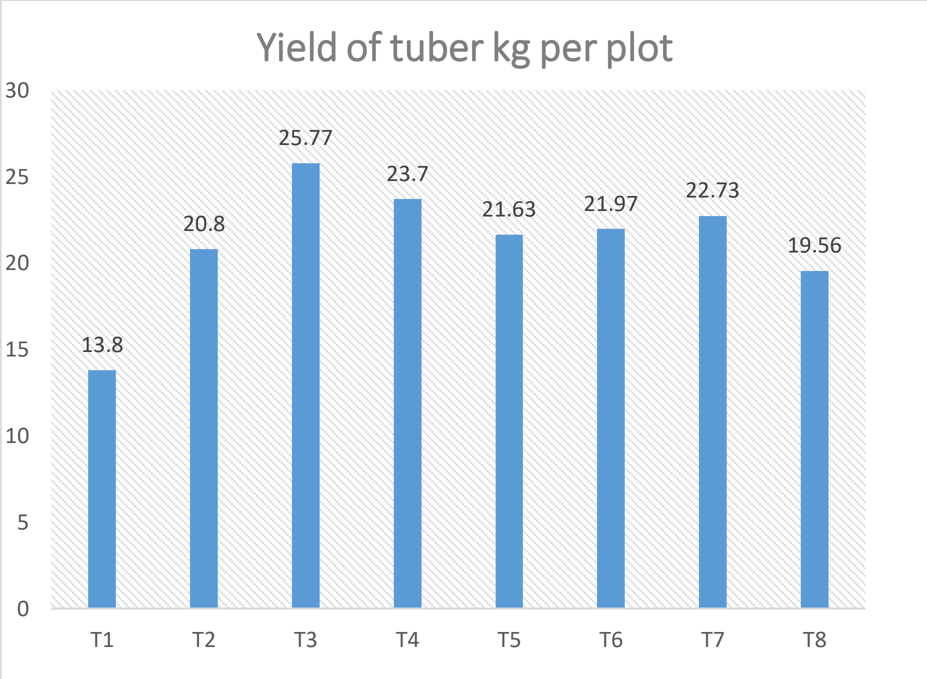

Figure 1. Effect of urea super granule on yield of tuber (kg plot^{-1})

T_1 = Control; T_2 = Recommended fertilizer dose (N_{150} P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_3 = 2.7 g size USG (2 granule at both side) withP_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_4 = 1.8 g size USG (2 granule at both side) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_5 = 1 sized (2.7g) + 1 sized (1.8g) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_6 = 1 sized (2.7g) + 2 sized (1.8g) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_7 = 1 sized (2.7g) + 1 time top dress 1/4th dose of N (tuber bulk stage) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ;T_8 = 1 sized (1.8g)+ 1 time top dress 1/4th dose of N (tuber bulk stage) with P_{30} K_{140} S_{15} Zn_3 Kg/ha.

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

Application of urea super granules had significant effect on the yield of tuber (t ha^{-1}). The highest tuber yield 29.45 (t ha^{-1}) was obtained from T_3 treatment and t ha^{-1}and the lowest tuber yield 15.77(t ha^{-1}) was obtained from T_1 (control) treatment.T_6, T_7 treatment are statistically similar and very close to T_2, T_5 treatments.

Table 7. Effect of urea super granule on Yield of tuber kg plot^{-1}and on yield of tuber t ha^{-1}

Treatment	Yield of tuber (kg plot^{-1})	Yield of tuber(tha^{-1})
T_1	13.80 f	15.77 f
T_2	20.80 de	23.76 de
T_3	25.77 a	29.45 a
T_4	23.70 b	27.08 b
T_5	21.63 cd	24.72 cd
T_6	21.97 cd	25.10 bcd
T_7	22.73 bc	26.40 bc
T_8	19.56 e	22.35 e
CV(%)	3.86	4.75
LSD	1.438	2.026

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

4.2.3 Dry matter content (%)

Above ground stem dry matter content significantly influenced different levels of urea super granules application. Higher stem dry matter content (23.10 %) in T_3 treatment whereas, the minimum (15.95 %) was recorded from the control (T_1) treatment. $T_{6,}$ T_8treatment are statistically similar and very close to T_2, T_5 treatments (Figure 2).

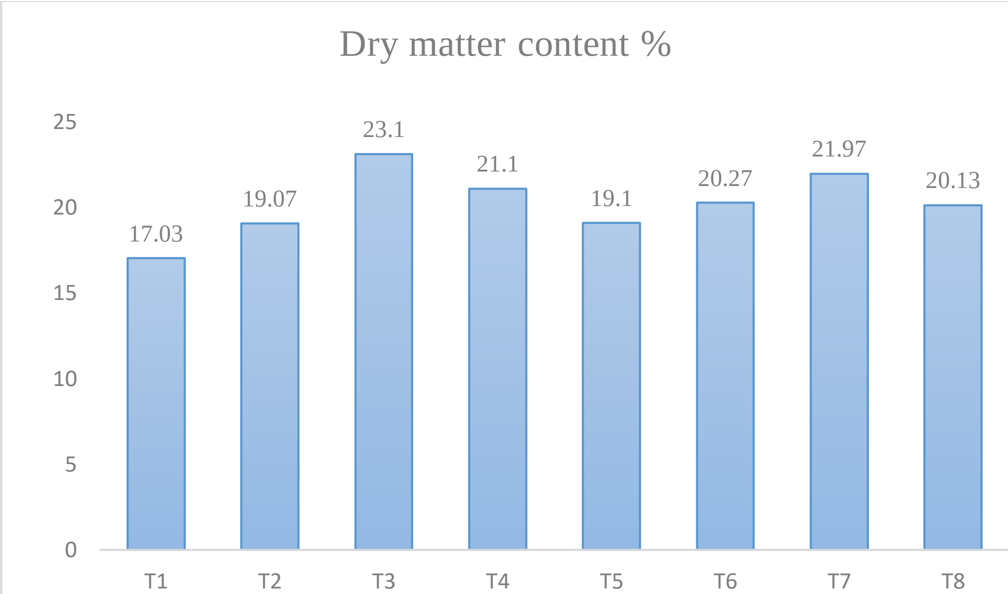

Figure 2. Effect of urea super granule on dry matter content (%)

T_1 = Control; T_2 = Recommended fertilizer dose (N_{150} P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_3 = 2.7 g size USG (2 granule at both side) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_4 = 1.8 g size USG (2 granule at both side) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_5 = 1 sized (2.7g) + 1 sized (1.8g) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_6 = 1 sized (2.7g) + 2 sized (1.8g) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_7 = 1 sized (2.7g) + 1 time top dress 1/4th dose of N (tuber bulk stage) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ;T_8 = 1 sized (1.8g)+ 1 time top dress $1/4^{th}$ dose of N (tuber bulk stage) with P_{30} K_{140} S_{15} Zn_3 Kg/ha.

4.2.4 Specific gravity of tuber

Specific gravity of tuber varied significantly with different urea super granules application. The highest specific gravity of tuber was recorded (1.076) while the minimum was found from control (1.034) .Treatments T_3, T_2, T_6 and T_7were statistically similar (Figure 3)

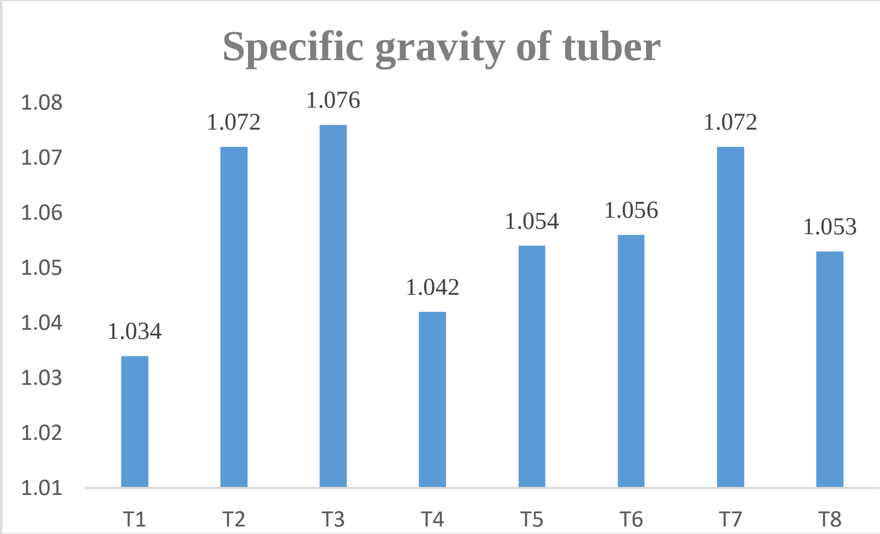

Figure 3. Effect of urea super granule on specific gravity of tuber

T_1 = Control; T_2 = Recommended fertilizer dose (N_{150} P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_3 = 2.7 g size USG (2 granule at both side) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_4 = 1.8 g size USG (2 granule at both side) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_5 = 1 sized (2.7g) + 1 sized (1.8g) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_6 = 1 sized (2.7g) + 2 sized (1.8g) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_7 = 1 sized (2.7g) + 1 time top dress 1/4th dose of N (tuber bulk stage) with P30 K140 S15 Zn3 Kg/ha ;T8 = 1 sized (1.8g)+ 1 time top dress 1/4th dose of N (tuber bulk stage) with P30 K140 S15 Zn3 Kg/ha.

4.2.5 Grading

On the basis of weight tubers have been graded into marketable tuber greater 20g and non-marketable tuber less 20 g. The results indicate that there was significant difference in the varietal effect in respect of production of different grades of tubers. Among USG application from 2.7 g sized 2 USG in both side produced the maximum (67.32%) marketable tuber greater 20 g while the minimum (32.68%) in non -marketable tuber less 20 g (Table 8). On the basis of size in diameter tubers have been graded into seed tuber greater 55 mm, non-seed tuber less 28 mm, tuber yield for chips 45-55 mm and tuber yield for french fry greater 75 mm. The results indicate that there was significant difference in the varietal effect in respect of production of different grades of tubers. 2.7 g sized 2 USG in both side produced the highest percentage of seed tuber, non-seed tuber, tuber yield for chips and tuber yield for french fry grades that was 19.95%, 16.96%,23.33% and 12% respectively. While the lowest percentage was found in control for seed tuber, non-seed tuber, tuber yield for chips and tuber yield for french fry that was 12.78%, 9.96%, 13.667%, 5% respectively (Table 8).

Table 8. Effect of urea super granule on grading of potato tuber

Treatment	X_1	X_2	X_3	X_4	X_5	X_6
T_1	32.68 c	52.54 b	9.96 c	12.78 b	13.667 c	5 b
T_2	35.79 c	64.21 ab	9.99 c	17.92 a	20.667 ab	7 ab
T_3	47.46 a	67.32 a	16.96 a	19.95 a	23.33 a	12 a
T_4	37.36 ab	62.64 ab	14.04 ab	18.47 a	21.33 ab	10 a
T_5	40.83 abc	59.17 b	13.35 ab	16.23 ab	17.33 abc	6 ab
T_6	46.57 a	53.43 b	12.21 bc	16.76 ab	22.333 a	7 ab
T_7	41.41 abc	58.59 b	11.56 bc	16.80 ab	16.333 bc	9 ab
T_8	36.25 bc	63.75 ab	10.64 bc	16.42 ab	17.33 abc	8 ab
CV(%)	8.80	12.30	16.78	13.65	16.68	13.45
LSD	6.31	6.52	3.62	6.52	3.52	6.02

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

[X_1 : % no. of non-marketable tuber < 20 g, X_2 : % no. of marketable tuber >20 g, X_3 : % no. of non-seed tuber <28 mm ,X_4 : % no. of seed tuber >55 mm , X_5 : % no. of Tuber yield for chips 45-55 mm , X_6 : % no. of Tuber yield for French fry >75 mm.]

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out at the Research Farm, Sher-e-Bangla Agricultural University, Dhaka during the period November 2016 to March 2017 in order to determine the suitable nitrogen source to observe the growth performance with a view to increasing the yield of potato the experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of Treatment : T_1 = Control; T_2 = Recommended fertilizer dose (N_{150} P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_3 = 2.7 g size USG (2 granule at both side) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_4 = 1.8 g size USG (2 granule at both side) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_5 = 1 sized (2.7g) + 1 sized (1.8g) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_6 = 1 sized (2.7g) + 2 sized (1.8g) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ; T_7 = 1 sized (2.7g) + 1 time top dress 1/4th dose of N (tuber bulk stage) with P_{30} K_{140} S_{15} Zn_3 Kg/ha ;T_8 = 1 sized (1.8g)+ 1 time top dress $1/4^{th}$ dose of N (tuber bulk stage) with P_{30} K_{140} S_{15} Zn_3 Kg/ha.

The experiment was laid out in randomized complete block design factorial with three replications where plot was for variety and subplot was for treatment. There was 8 treatment combinations. The total numbers of unit plots was 24. The size of unit plot was 8.75 m^2(5 m × 1.75 m). Triple super phosphate (TSP), Muriate of potash (MoP), Gypsum was applied at the rate of P_{30} K_{140} S_{15} Zn_3 Kg/ha as basal dose at final land preparation of individual plots.

Results revealed that nitrogen sources, variety had significant effect on plant height at different days after planting. The tallest (65 cm) plant was recorded from T_3treatment compared to the lower levels of nitrogen at harvest. At harvest, the tallest plant (65 cm) was observed in diamont variety. The tallest plant (65cm) was found in the T_3treatment and the shortest plant (39 cm) was found in T_1treatment at harvest.

The highest number of stemhill^{-1}(7) was found in T_3treatment at harvest. The highest and lowest number of stemhill^{-1}(7) and (4) were recorded from diamont respectively. The number of stemhill^{-1}was varied significantly due to different level of USG. There was no appreciable change in stemhill^{-1}due to higher dose of N above 150 kg ha^{-1}. They also showed an appreciable reduction in stem per hill^{-1}at 250 kg N ha^{-1}. Length of stem was highly related with the application of increased level of nitrogen. Tuber formation and elongation was directly related with the contribution of nitrogen.

Number of tubers per hill significantly influenced by application of different treatment. The maximum number of tubers per hill (8) was recorded from T_3 treatment whereas the minimum (5) number of tubers per hill was recorded from T_1 (control) treatment which very close with T_2, T_4, T_6 and T_8 treatment.The increased number of tuber hill $^{-1}$ with increased nitrogen level used USG. Effective tuber hill $^{-1}$ was significantly affected by the level of nitrogen and increasing levels of nitrogen significantly increased the number of effective tuber hill^{-1}. The maximum number of tuber hill $^{-1}$ was produced with 150 kg N ha^{-1} and the minimum number of tuber hill^{-1} was obtained from the control treatment (0 kg N ha^{-1}).

The variation in weight of tuber per hill due to application of different fertilizer management practices was observed to be statistically significant. The maximum tuber average weight per hill (57.533gm) was recorded T_3 treatment which statistically similar with T_7 whereas the minimum (40.667gm) average weight of tubers per hill was recorded from T_1 (control) treatment. The weight of tuber increased with increase in nitrogen fertilizer up to 150 kg N ha^{-1}and the lower tuber weight in control treatment when the plots received low fertilizer nitrogen.

Tuber yield varied significantly due to nitrogen sources. The highest tuber yield (29.45 t ha^{-1}) was obtained T_3treatment and the lowest tuber yield (15.77 t ha^{-1}) was obtained no nitrogen. The maximum tuber yield (28 t ha^{-1}) was found in diamont and the lowest tuber yield (25 t ha^{-1}) was found in others. The

T_3treatment produced the highest (29.45 t ha^{-1}) tuber yield and the T_1treatment produced the lowest tuber yield (15.77 t ha^{-1}).

Above ground stem dry matter content (%) significantly influenced different levels of urea super granules application. Higher stem dry matter content (23.10 %) in T_3 treatment whereas, the minimum (15.95 %) was recorded from the control (T_1) treatment. T_6 , T_8 treatment are statistically similar and very close to T_2, T_5 treatments.

Specific gravity of tuber varied significantly with different urea super granules application. The highest specific gravity of tuber was recorded (1.076) while the minimum was found from control (1.034) .T_3, T_2, T_6 and T_7 statistically similar with and others are close relation.

The maximum values of tuber yield, total N uptake and apparent N recovery were obtained with the application of T_3treatment (150 Kg N ha^{-1}as USG)

Nitrogen use efficiency represents the response of potato plant in terms of tuber yield to N fertilizer. Reviewing above the results of the present study, it might be concluded that

- 150 Kg N ha^{-1}as USG showed the superiority over other sources and application methods of nitrogen to produce higher tuber yield of potato.
- Sources and application methods of nitrogen as USG showed the superiority over prilled urea.

This is a single year and single location trial so more research is needed in different agro–ecological zones (AEZ) of Bangladesh for regional adaptability and other performances. There was observed in treatment T_3 (150 Kg N ha^{-1} as USG) and the lowest value was found in T_1.

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APPENDICES

AppendixI. Monthly average of air temperature, relative humidity and total rainfall of the experimental site during the period from November, 2016 to February, 2017.

Months	**Air temperature (0C)**		**Relative humidity (%)**	**Total rainfall (mm)**
	Maximum	**Minimum**		
November	29.74	19.15	67.21	66
December	23.92	14.50	75.58	5
January	24.55	12.20	64.39	12
February	28.60	17.5	48.16	30

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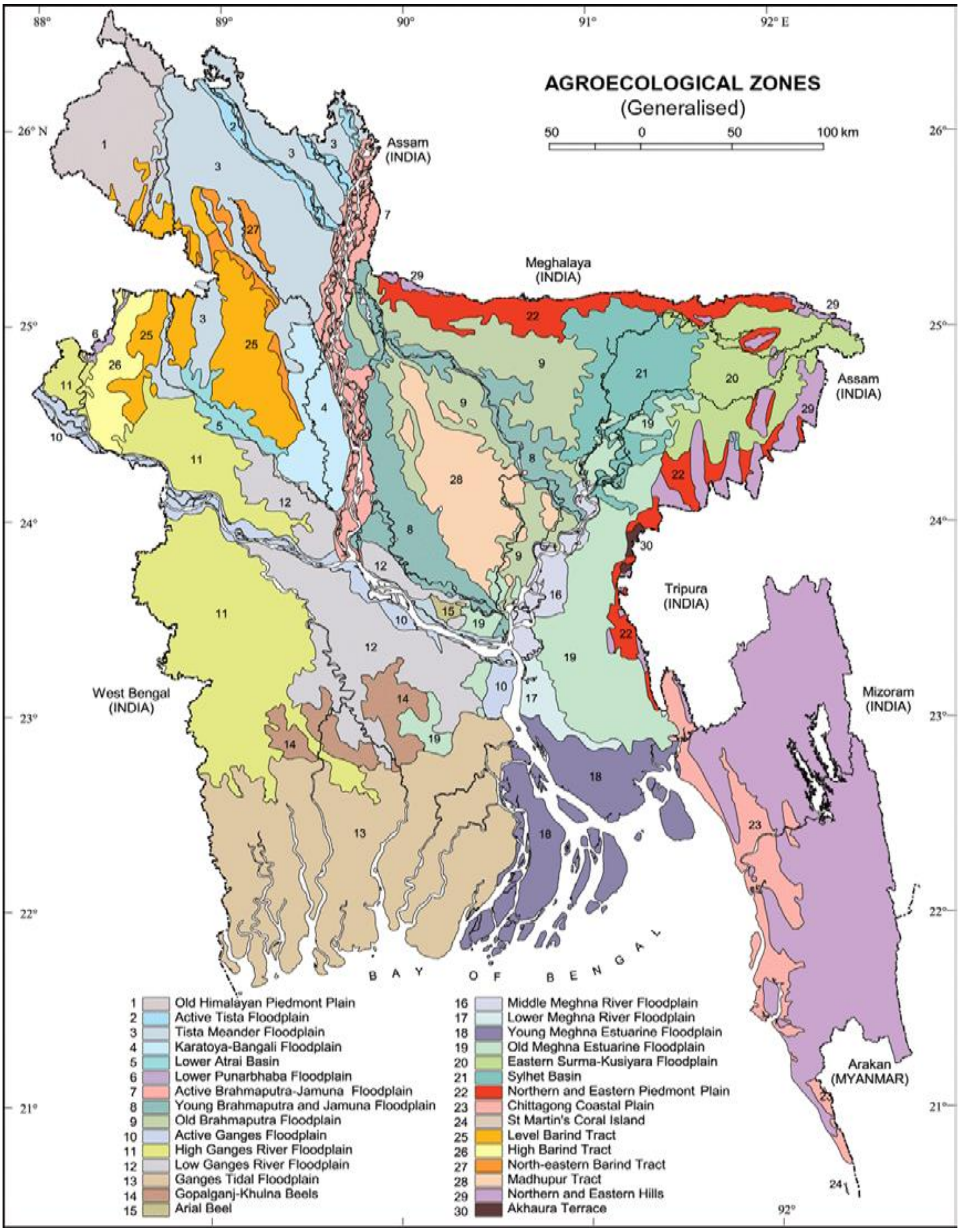
Source: Bangladesh Meteorological Dept. (Climate & weather division) Agargoan, Dhaka – 1207

Appendix II: Experimental location on the map of Agro-ecological Zones of Bangladesh



APPENDIX III: Randomized Complete Block ANOVA Table for Effect of Urea Super Granule Plant height at haulm cutting (cm)

Source	DF	SS	MS	F	P
Replication	2	5.070	2.525	1.7648	
Treatment	7	1386.00	198.00	198.000	137.849
Error	14	20.110	1.436		
Total	23	1411.180			
Grand Mean	51.500				
CV %	2.33 %				

- significant at 0.05 level ofprobability

APPENDIX IV: Randomized Complete Block ANOVA Table for Effect of Urea Super Granule Stem Per Hill

Source	DF	SS	MS	F	P
Replication	2	1.290	0.645	2.8131	
Treatment	7	20.625	2.946	12.8505	137.849
Error	14	3.210	0.229		
Total	23	25.125			
Grand Mean	5.125				
CV %	9.34 %				

APPENDIX V: Randomized Complete Block ANOVA Table for Effect of Urea Super Granule TuberPer Hill

Source	DF	SS	MS	F
Replication	2	1.383	0.691	1.5080
Treatment	7	17.625	2.518	5.4928
Error	14	6.417	0.458	
Total	23	25.425		
Grand Mean	6.375			
CV %	10.62 %			

- significant at 0.05 level ofprobability

APPENDIX VI: Randomized Complete Block ANOVA Table for Effect of Urea Super Granule Av. Wt. Tuber Per Hill

Source	DF	SS	MS	F
Replication	2	2.916	1.458	1.1404
Treatment	7	554.586	79.227	61.9736
Error	14	17.898	1.278	
Total	23	575.400		
Grand Mean	52.179			
CV %	2.17 %			

- significant at 0.05 level ofprobability

APPENDIX VII: Randomized Complete Block ANOVA Table for Effect of Urea Super Granule YieldPer Plot

Source	DF	SS	MS	F
Replication	2	2.714	1.357	2.0141
Treatment	7	263.474	37.639	55.8682
Error	14	9.432	0.674	
Total	23	275.619		
Grand Mean	21.245			
CV %	3.86 %			

- significant at 0.05 level ofprobability

APPENDIX VIII: Randomized Complete Block ANOVA Table for Effect of Urea Super Granule YieldPer Ha

Source	DF	SS	MS	F
Replication	2	0.133	0.066	0.0496
Treatment	7	348.826	49.832	37.2533
Error	14	18.727	1.338	
Total	23	367.686		
Grand Mean	24.330			
CV %	4.75 %			

- significant at 0.05 level ofprobability

APPENDIX IX: Randomized Complete Block ANOVA Table for Effect of Urea Super Granule Dry Matter Content

Source	DF	SS	MS	F
Replication	2	5.211	2.605	56.7718
Treatment	7	74.606	10.658	232.2379
Error	14	0.642	0.046	
Total	23	80.460		
Grand Mean	20.221			
CV %	1.06 %			

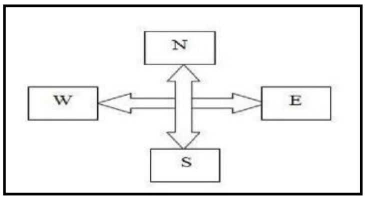
- significant at 0.05 level ofprobability

APPENDIX X: Randomized Complete Block ANOVA Table for Effect of Urea Super Granule Specific Gravity

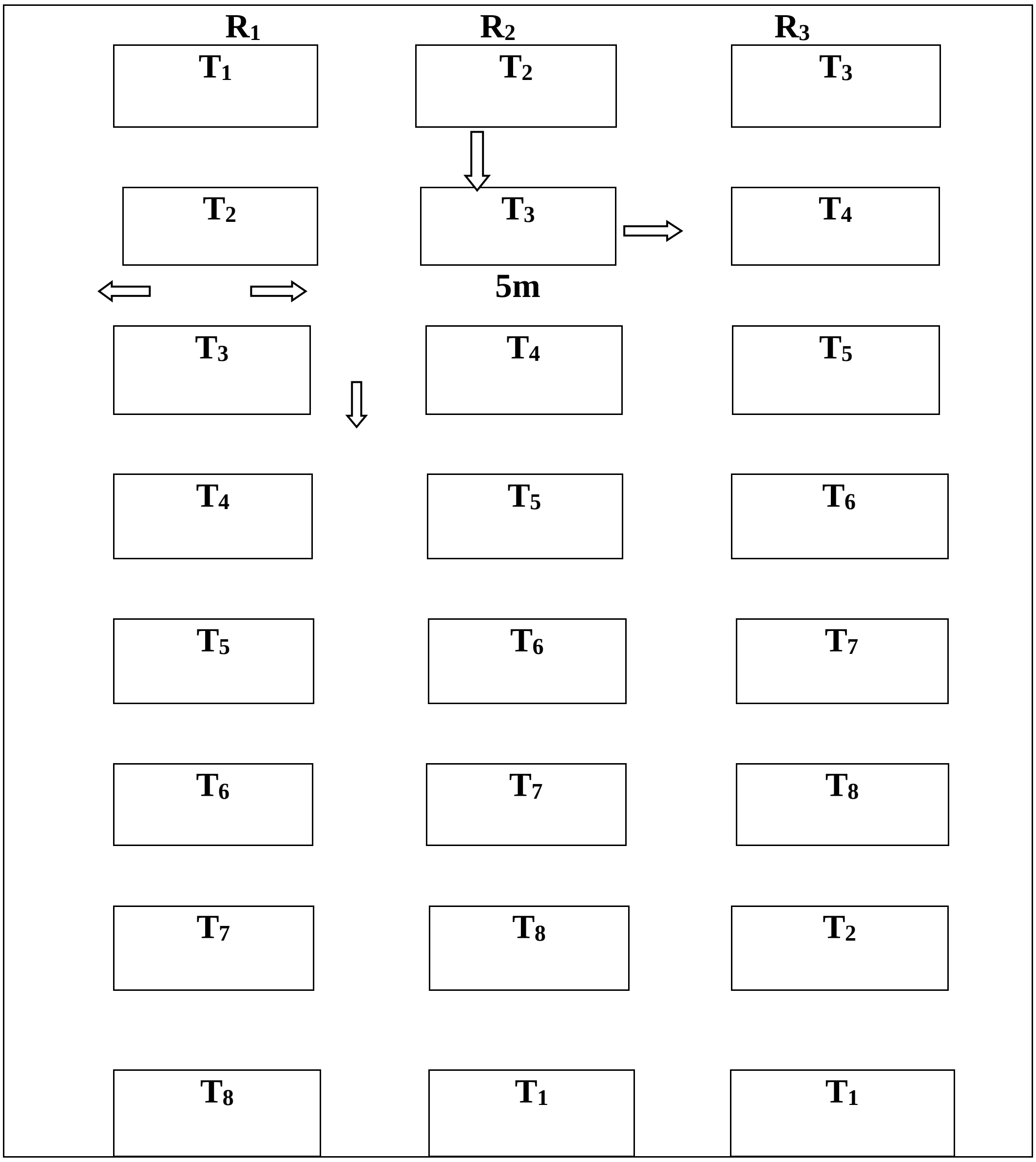
Source	DF	SS	MS	F
Replication	2	0.000	0.000	0.1225
Treatment	7	0.005	0.001	3.6740
Error	14	0.003	0.000	
Total	23	0.007		
Grand Mean	1.057			
CV %	1.28 %			

- significant at 0.05 level ofprobability

APPENDIX XI: Layout of the experimental plot



Plot size: 5 m × 1.75 m (8.75 m^2)
Plot to plot distance: 0.5 m
Block to block distance: 1.0 m



Layout of the experimental plot