EFFECT OF TUBER SIZE AND PLANT GROWTH REGULATORS ON GROWTH AND YIELD OF POTATO *(Solanum tuberosum* L.)

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CERTIFICATE

*This is to certify that the thesis entitled, "**Effect of Tuber Size and Plant Growth Regulators on Growth and Yield of Potato (Solanum Tuberosum L.)**" Submitted to the DEPARTMENT OF HORTICULTURE, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE** embodies the result of a piece of bona-fide research work carried out by **MD. ARIF AFJAL, Registration No. 09-03338** under my supervision and guidance. No part of the thesis has been submitted for any other degree.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has been duly acknowledged by him.

Dated: June, 2015
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ABSTRACT

An investigation was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2013 to February 2014 to study the effect of tuber size and plant growth regulators on growth and yield of potato. The experiment consisted of 3 sizes of seed tuber (S_1 = 15 ± 5g, S_2 = 25 ± 5g and S_3 = 35 ± 5g tuber) and 3 levels of PGR (G_0 = Control, G_1 = 100 ppm GA_3 and G_2 = 50 ppm BAP) thus there were 9 treatment combinations. The two factor experiment was laid out in Randomized Complete Block Design with three replications. Significant effect was found for different parameters at different growth stages due to the influence of tuber size and growth regulators. Results revealed that the tallest plant (52.2 and 53.5 cm at 60 and 75 DAS respectively) was observed from S_2G_1 but the highest number of stem hill^{-1} was observed from S_3G_2. Similarly, the highest leaf area (162.9 cm^2 at 60 DAS and 171.4 cm^2 75 DAS), stem diameter (0.95 cm at 60 DAS and 1.04 cm at 75 DAS), number of tuber plant^{-1} (9.53), tuber weight plant^{-1} (544.1 g), tuber weight plot^{-1} (6.69 kg) and tuber yield ha^{-1} (30.97 t) were recorded from S_3G_2. Likewise, the highest net assimilation rate (8.28 at 60 DAS and 10.33 at 75 DAS), highest intercellular CO_2 concentration (421.7 at 60 DAS and 304.7 at 75 DAS), highest photosynthetic active radiation (838.3 at 60 DAS and 1405 at 75 DAS) and highest chlorophyll content (50. 34 at 60 DAS and 50.13 at 75 DAS) were measured from S_3G_2. So, the tuber size (35 ± 5g) with 50 ppm BAP is best for potato production among the treatments.

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BARI	=	Bangladesh Agricultural Research Institute
BCR	=	Benefit Cost Ratio
DAS	=	Days after sowing
et al.	=	and others *(at elli)*
LER	=	Land Equivalent Ratio
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
RCBD	=	Randomized Complete Block Design
TSP	=	Triple Super Phosphate

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the important food crops of the world. It is used as a staple food in many countries of the world, but mainly as a vegetable in Bangladesh (Hussain, 1995). The potato ranks 4^{th} among the important food crops in the world including, wheat, rice and corn. Potato is very nutritious tuber vegetable. Potato is the rich source of starch, vitamin C and B and minerals. It also contains a good amount of essential amino acids like leucine, tryptophan and isoleucine. Potato also contains a variety of phytonutrients that have antioxidant activity.

Potato is commonly used as vegetables in Bangladesh. It alone contributes to about 64% of total annual vegetable production in Bangladesh (BBS, 2011). The varieties of potato introduced to Bangladesh after 1960 is designated as modern variety. However, with the introduction of modern potato varieties from Holland during the early sixties, the area and production of potato in Bangladesh began to increase rapidly and all of the new areas were covered by the modern varieties. In the year 2011- 2012, potato was grown in an area of 43 millions of hectares and the production was 82 millions of metric tons (BBS, 2012).

Tuber size profile is an important quality component of a potato seed lot. Larger seed tubers are usually cut into pieces to minimize the quantity of seed required per unit area and thus to minimize the cost of production through seed. Additionally, larger tubers could be better utilized for direct consumption or processing if small tubers are available for seed purposes. Larger tubers are generally unacceptable for seed because when they are cut some seed pieces may not certain a meristem or eye (blind seed pieces) and subsequently plant population may be reduced (Nielson *et al.*, 1989).

On other side, plant growth regulator (PGR) is also need on growth and development of potato followed by tuberization, bulking and yield (Sami and Roy, 2007). In terms of short duration of potato production season make their morphological as well as physiological change rapidly. Consideration of GA_3 as PGR, promotes the cell elongation at juvenile stage, after case it increases the number and weight of tuber (Alexopoulos *et al.* 2006). Besides Benzylaminopurine (BAP) as another PGR which also enhance cell division and differentiation through their photosynthetic activity and it implicate the enzymatic activity of tuberization. Ultimate effect of these plant hormones increases potato production and size of tuber.

The main role of growth regulator is to change the growth of a plant such as stimulate the growth of the plant or have a selective effect on some parts only (Zhang *et al.*, 2013). Plant growth regulators (PGR) have considerable effects on tuber fertility and it is highly related to hormonal balance (Stuart and Cathey, 1961). By treating the tubers using gibberellic acid, the tubers sprouted faster and produced more number of seed tubers (Rehman *et al.*, 2001).

Considering the above facts, the present work has been undertaken in order to characterize the effect of Tuber Size and Plant Growth Regulators on Growth and Yield of potato with a view to investigating the relationship among the tuber size and plant growth regulators and selecting suitable treatment combination for commercial cultivation under Bangladesh condition. The present experiment was undertaken with the following specific objectives:

1. To determine the effect of tuber size on potato yield
2. To screen out the performance of GA_3 and BAP on potato yield
3. To find out the suitable combination of tuber size and PGR for improving growth and yield of potato.

CHAPTER II

REVIEW OF LITERATURE

Potato is one of the most important vegetable crops in the world. Most of the countries are now playing important role for the development of this crop. Extensive research works have been conducted on potato in different parts of the world. Investigations relevant to this study have been reviewed in this chapter under the following heads and would be used in discussion part of the results of this present study.

2.1 Effect of tuber size

In a field trail Jage *et al.* (2001) observed the effect of seed tuber size and crop duration on yield of potato. Plant height, number of stems per hill, number of tuber per plant and total yields increased with the increase in the size of seedling tubers.

Seed piece size may influence the performance of a potato crop. Emergence, seedling vigor, subsequent plant growth, and final yield are all related to seed piece size. Research shows that larger seed pieces result in more total yield than smaller sizes. However, the benefit of larger-sized seed pieces diminishes as the size of seed pieces increases above approximately 2.5 ounces (Iritani *et al.* 1984).

Garg *et al.* (2000) was conducted in experiments on Kufri, Himachal Pradesh, India during 1996-98 on different planting (19 April, 2 May, and 1 and 17 June) and haulm killing (75, 90, or 105 days after planting) dates, tuber size (10-15, 15-20, 20-40, 40-60 and 60-80 g) and de-sprouting, seed size (10-15, 15-20, 20-40, 40-60 and 60-80 g) and spacing (60×10 and 60 ×15) and dehaulming of potatoes (cv. Kufri and Jyoti) to study the effect of physio-agronomical manipulations on number and yield of seed-sized tubers. Physiological characters like, seed weight loss, emergence, number of sprouts per tuber, number of shoots and number of compound leaves per plant and haulm weight were influenced by use of physiologically older seeds. Once desprouting of different grades of seed tubers also resulted in higher sprout number, shoots/m2, compound leaves per plant and number and yield of seed-sized tubers in all the grades of seeds used over the control. The higher economic yield of seed-sized tubers could be achieved from 15-20 g of seeds at 60×10 cm spacing at 90 days. The seed to production ratio was highest in this case, i.e. 23 q/ha of seed used and 327 q/ha harvested compared to 59 q/ha seed used and 358 q/ha harvested from 40-50 g seed used.

Cotes *et al*. (2000) observed the effects of sowing density and tuber size on the seed yield of Creole potato (*S. phureja*). Sowing tubers with a diameter varying between 1.27 and 2.00 cm recorded the highest seed production compared with the other treatment (tuber size of 4.00 cm).

Divis and Barta (2001) determined the effect of tuber size on potato yield. Tubers of potato cultivars Krasa (early) and Svatava (medium early) at different sizes (25-30, 30-55, 55-75 and 75-85 mm) were used. Increasing seed tuber size produced an increase in emergence percentage. Larger tubers produced higher number of stems per plant compared to small tubers. Large tubers resulted in higher yield compared to small ones.

Kang *et al*. (2001) stated that 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 on 10 August 2000 and grown for 15 days in a glasshouse 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. 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 plug seedlings, the total number of tubers per plant 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 produced 22% more tubers per plant and had 21% higher >80 g tuber yield than the directly planted potatoes.

Malik and Ghosh (2002) conducted a field experiment with the optimum rate of N (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. Differences in plant height and fresh weight of foliage due to seed size and plant spacing were not significant. The number of stems per hill, tuber yield per plant and tuber yield were higher under 60×20 plant spacing and using 60-90 g seeds. The interaction effects of N rate, seed size and plant spacing on plant height, number of stems per hill and tuber yield were significant.

Singh *et al.* (2003) carried out an field experiment 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 intra row spacing (20, 25 and 30 cm) on the yield of potato cv. Kufari Chandramukhi. The total yield, number of tubers per plant and average weight per tuber were greatly affected by seed size and spacing. Tuber yield (305.24 q/ha) and number of tubers per plant (10.40) were significantly highest with big seed size and 25 cm intra row spacing, while average weight per tuber (53.93 g) was highest with large seed size and 30 cm intra row spacing.

Eleven potato varieties (including Da 92062-1, Kexin No. 12, Neishu No. 7 and Gaoyuan No. 7) with different starch contents were grown in 2000. Yields of tubers with different size grades, total tuber yield, content of starch in tuber and starch yield for each variety were investigated and determined by Xie *et al.* (2003). The contents of starch in tubers with different sizes varied with the tested varieties. The contents of starch in tubers with different size grades were consistent for some varieties, but were significantly different for other varieties. The content of starch in tubers might be obtained by the weighted arithmetic mean in the light of contents of starch in the tubers with different size grades, which was more exact than the starch content obtained by random sampling method.

A two year field experiment was conducted by Meitei *et al*. (2005) to investigate the effect of tuber size (30, 40, 50 and 60 g), and transplanting method on the performance of potato cv. Kufri Joyti. Growth characters and tuber yields were unaffected by tuber size. Tuber yield was maximum (274.67 and 258.67 q/ha) with a tuber size of 40 g and whole tuber transplanting, respectively. The highest sprouting was observed in 60-g tubers. Whole tuber transplanting also resulted in the highest tuber sprouting. The highest cost benefit ratio (1:3.91) was obtained with 30 g tubers and whole tuber transplanting.

An experiment was carried out by Chang *et al.* (2005) to investigate the growth patterns of a cultivar, including tuber number, size and quality, under hydroponics, potato tubers were sampled at 60, 70, 80 and 90 days after transplanting (DAT), and were sorted by fresh weight into 6 classes of tuber size: 1-5, 5-10, 10-20, 20-30, 30-50 and >50g. Compared with the conventional harvesting date (90 DAT), the earlier harvests at 70 or 80 DAT increased the number of tubers in the range of 5-30 g. The total number of tubers produced per plant remained similar. However, total tuber weight per plant significantly decreased in earlier harvests. Specific gravity increased with the tuber size up to 10 g, but the difference between 10 and 50 g tubers was not significant. The specific gravity increased over time to 90 DAT. Shoot growth was maximum at the early harvesting date (60 or 70 DAT) and declined thereafter. Except for tubers from 60 DAT, the dormant period of early harvest tubers was not different with that of late harvest tubers of 90 DAT. These results clearly represented an economic advantage of early harvesting of 70 or 80 DAT because of cost education in hydroponics.

Ali and Chattapadhyay (2006) conducted a field experiment to investigate the effect of different physiological parameters of growth on yield and distribution of tubers according to size: big (120-130 g), medium (60-120 g), small (20-60 g) and very small (<20 g). The growth parameters, i.e. leaf area index, chlorophyll content, crop growth rate, relative growth rate and bulking rate, had influence on growth, biomass production and yield of potato tubers. Kufri Ashoka established its superiority and out yielded all other cultivars. The big and medium sized tubers made up the bulk of the tubers (78.71 and 73.05% in the first and second year, respectively) of Kufri Ashoka. A similar result (70.34%) in the case of Kufri Jyoti was observed in the first year. Statistical variations among cultivars were observed with respect to tuber size in both years.

In a field trial Gavrilov and Semenov (2006) observed the effect of seed potato tuber size and fertilizer input method on the yield of potato. Small (25-35 mm) and medium (35-55 mm) fractions of tubers of cv. Alvara and Romano, with localized versus general fertilizer input were studied. The best results (55.8 t/ha) were achieved using small tubers of the cv. Alvara with local fertilizer input. These conditions reduce expenditure on seed material by 50%. Local inputs of fertilizer increases potato yield by 1.8-2.0 t/ha and decreases fertilizer input.

Chang *et al.* (2011) reported on hydroponic potato production, little is known about its field establishment, yield components and efficiency of nitrogen (N) use from small hydroponic tubers (HT) planted in fields. Three sizes of HT (0.7 g, 5 g, and 10 g) and conventional cut seed tubers (CT) of about 40 g of medium-early maturity cultivar 'Superior' were planted at the Highland Agriculture Research Center, Pyeongchang, Korea, on 20 May 2005 and 23 May 2006, and their field performances were compared. Increasing seed size resulted more emergence, faster shoot growth soon after emergence, higher N utilization efficiency (plant dry matter accumulation/plant N accumulation), higher tuber growth rate (TGR) and dry matter production, and higher fresh tuber yields. The first tuber formation and bulking were observed in CT plants followed by HT plants of 5 g and 10 g. The time to tuber formation and tuber bulking in 0.7 g HT plants was the longest and delayed by 6 or 8 days compared to CT plants. Accumulation of tuber dry matter increased linearly from the period of tuber formation to near harvest. During the period, increasing seed size gave a significant increase in dry matter production in tubers. Tuber fresh yield of 0.7 g HT plants was 55% of that of CT plants, while those of larger HT (5 g and 10 g) plants were 75% and 80%, respectively. The results suggested the potential of using HT (5 to 10 g) for direct field planting.

Song *et al.* (2011) investigated that the effects of mini tuber sizes (<=5, 6-10, 11-20, 21-30, and 31-40 g) on elite I class seed production using a dominant potato cv. Weiyu 3 (*Solanum tuberosum*) as plant material. The size of mini tuber planted at the same density had significant effects on the occurrence of potato late blight (caused by *Phytophthora infestans*). When the mini tubers planted were <=5 g, the occurrence rate of late blight was lower than in the other treatments. The high yield of elite I class seed was obtained when the mini-tubers planted were 21 g or more. It is inferred that the larger sized mini-tubers should be selected for the production of elite I class seed.

2.2 Effect of growth regulators

Weiyan (2015) conducted an experiment aimed to explore the effects of new plant growth regulators on the growth and quality of potato. He conducted potato tubers with different concentrations of the regulators and cultivated in the seedling pot, with water as the control treatment. The results showed that sorbic amide (5%), sorbic amide quaternary ammonium salt (5%), Cinnamamide (5%), betaine Cinnamamide (5%), naphthalene dicarboxamide (5%), betaine naphthalene-dicarboxamide (5%) these 6 new regulators have good activity in improving and enhancing the content of chlorophyll, soluble protein, soluble sugar and free amino acids with 400 times dilution and 800 times dilution on potato seedling. At the same time, he compared the changes of the physiological indexes in different periods. As can be seen from the experiment, these 6 compounds have a strong role in promoting growth and improving the quality of the potato so that they can be called plant growth regulators.

Barani *et al*. (2013) performed an experiment to evaluate the effect of gibberellic acid (GA_3) on seed size and sprouting of potato (*Solanum tuberosum* L.). The experiment was laid done in factorial design (3×3) using Agria, Marfona and Draga cultivars and three concentrations of GA_3 (0, 5 and 10 mg/lit). Results showed that application of gibberellic acid at low concentrations (5 and 10 mg/lit) was able to increase general performance and productivity of seed tubers of potatoes. Seed tuber production was increased by application of using gibberellic acid in all cultivars. Total weight of seed tubers produced by application of 5 mg/lit GA_3 was statistically different compared to control ($p \leq 0.05$). Also, results showed that after one week from application of GA_3, starch content decreased and total content of sugar increased in potato tuber. The tubers treated with GA_3 sprouted earlier while in control sprouting was very late and slow. Furthermore, they indicated that sugar content is one of the important parameters determining the sprouting of seed potatoes. Thus the sequence of events can be summarized as: Application of GA_3 → Starch hydrolysis → Decrease of starch content of tubers → Production and increase of total sugar content → Dormancy breaking → Tuber sprouting.

Khadiga *et al.* (2009) conducted the study to investigate the effects of different concentrations and combinations of growth regulators on callus induction and plant regeneration of potato (*Solanum tuberosum* L.) cultivar Diamant. The tuber segments were used as explants and cultured on Murashige and Skoog (MS) medium supplemented with different concentrations of -naphthalene acetic acid (NAA), 2,4-Dichlorophenoxy acetic acid (2,4-D), benzyl adenine (BA) and thidiazeron (TDZ) alone and 2,4-D in combinations with BA for callus induction. The best degree for callus formation (6.0) was obtained on MS medium supplemented with 2,4-D alone at 3.0 mg/l or 2,4-D in combination with BA both at 2.0 mg/l. MS media supplemented with different levels of BA and TDZ were employed for shoot regeneration. MS medium containing 5.0 mg/l TDZ was the best for days to shoot initiation, the highest percentage of callus with shoot (81%) and highest number of shoot per callus (3.4). Callus derived shoots were rooted most effectively in half-strength MS medium containing 0.5 mg/l IBA. The success of plant tissue culture for in vitro culture of potato was encouraged by acclimatization of the plantlets in the greenhouse conditions. Regenerated plants were morphologically uniform with normal leaf shape and growth pattern.

Sillu *et al*. (2012) carried out an investigation with plant growth regulators and methods of application on growth and yield components of potato. Out of 10 treatment combinations comprised of two levels of methods of application viz., M_1 (Seed treatment) and M_2 (Spray treatment) and five levels of plant growth regulators R_1 (control), R_2 (GA_3 25 ppm), R_3 (GA_3 50 ppm), R_4 (IBA 100 ppm) and R_5 (IBA 200 ppm). Spray treatment of IBA 200 ppm was effective in maximum germination percent, growth, number of shoots per plant, days taken for physiological maturity, number of tubers harvested per plant and yield of tuber kg ha^{-1} and application of spray of GA_3 50 ppm was superior for minimum days taken for germination and average weight of tuber.

Kumar *et al*. (1981) studied the effects of some growth regulators on growth, yield and composition of potato (*Solanum tuberosum* L.). GA_3 increased shoot extension, leaf area, number of leaves, stolons and tubers but decreased dry matters of stem, leaf and tuber. IAA and K increased dry matters of stem and leaf but decreased leaf number and leaf area, the number of stolons and tubers either decreased or were not affected. Yield of tuber increased with IAA used alone or in combinations with GA_3. Total sugars increased with GA_3 used alone, and combinations with IAA and K while starch content decreased with GA_3 and increased with IAA and IAA+K treatments. Ascorbic acid content was higher in GA_3 and was not affected significantly with IAA and K. Protein nitrogen decreased only with GA_3 while total nitrogen did not differ significantly with the treatments.

Growth promotors and inhibitors control the plant growth, tuberization and yield in potato. The role of cytokinins in tuber initiation has been reported by Kumar and Baijal (1979). Chemical composition of the potatoes may also be changed by applications of certain growth regulators.

The growth regulators are known to have beneficial effect on tuberization, bulking and hence yield. The GA_3 gave significantly higher number and weight of seed size (20-80 g) tubers than rest of treatments. The increment in yield by number and weight was 22.1% and 18% with GA_3 while it was 12.7% and 10% with NAA over control (Birbal *et al.*, 2005).

CHAPTER III

MATERIALS AND METHODS

An experiment was carried out to study the effect of tuber size and plant growth regulators on growth and yield of potato during the period from November 2014 to February 2015.

3.1 Field location

The research work was carried out at the research field of Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka. The experimental fields were located at 90^0 33′ E longitude and 23^0 71′ N latitude at a height of 9 m above the sea level.

3.2 Weather and climate

The climate of the area was sub-tropical and was characterized by high temperature, heavy rainfall during Kharif-1 season (March-June) and scanty rainfall during Rabi season (October-March) associated with moderately low temperature, monthly average temperature, humidity, rainfall and sunshine hours prevailed at the experimental area during the cropping season are presented in Appendix 1.

3.3 Soil

The land belongs to the Agro-ecological zone “Madhupur tract” (AEZ-28) having the red brown trace soils and acid basin clay of Nodda soil series. The soil of the experimental site were well drained and medium high. The physical and chemical properties of soil of the experimental site sandy loam in texture and having soil p^H varied from 5.45-5.61. Organic matter content ware very low (0.83). The physical composition such as sand, silt, clay content were 40%, 40% and 20% respectively. The physical and chemical characteristics of the experimental field soil are furnished in Appendix 2.

3.4 Planting Materials

The planting materials comprised the seed tubers of high yielding variety Diamant. The experimental potato accessions were collected from Bangladesh Agricultural Development Corporation (BADC).

3.5 Design and layout of the experiment

The two factor experiment was laid out in Randomized Complete Block Design with three replications. As the experiment was replicated thrice, the total number of plots was 27. The size of unit plot was 1.8m × 1.2m. A spacing of 0.5 m was provided between the plots and 1 m spacing was provided between two blocks and followed plant spacing was 60cm × 30cm.

3.6 Seed tuber preparation

Pre-heating and fanning of seed tuber was done in cold storage premises. Then, they were kept in well ventilated place where defused light available for sprout initiation of tubers. The well sprouted tubers were cut into three different sizes (small cut tuber: 15 ± 5g, medium cut tuber: 25 ± 5g and large cut tuber 35 ± 5g).

3.7 Land preparation

The land of the experimental plot was first opened on 5 November, 2013 with a power tiller and it was exposed to the sun for few days prior to next ploughing. It was then thoroughly prepared by ploughing and cross ploughing with a power tiller followed by laddering to obtain a good tilth. The subsequent operations were done with harrow, spade, hammer, basket etc. The clods were broken into fine soil particles and the surface was leveled until the desired tilth was obtained. The weeds and stubbles were removed and the plots were prepared after applying the basal dose of manure and fertilizers. Irrigation and drainage channels were prepared around the plot. The soil was treated with insecticides (Furadan 5G @ 10 kg/ha) at the time of final land preparation to protect young plants from the attack of soil insects such as cutworm and mole cricket.

3.8 Manures and fertilizers

Manures and fertilizers applied to the plot as per recommendation of BARI for the potato production farm practices have been stated below:

Manures and fertilizers: Doses/hectare

Cow dung	:	10 t/ha
Urea	:	300 kg/ha
TSP	:	140 kg/ha
MoP	:	320 kg/ha

The entire amount of Cowdung was applied during final land preparation. Half of urea and full doses of TSP and MoP were applied in furrows made on both sides of the seed rows and mixed properly with soil at planting. The remaining half of urea was applied after 35 days of planting as side dressing and mixed well with soil followed by flood irrigation (Rashid, 2003).

3.9 Treatments of the experiment

The experiment consisted of two factors namely, size of cut seed tubers and application of different growth regulators. There were three levels of seed tuber size and three levels of PGR application were as follows:

3.9.1 Factor A: Tuber size

T_1 = Small tuber (15 ± 5g)

T_2 = Medium tuber (25 ± 5g)

T_3 = Large tuber (35 ± 5g)

3.9.2 Factor B: Plant growth regulators

G_0 = Control

G_1 = 100ppm GA_3

G_2 = 50ppm BAP

3.10 Planting of seed tubers

The seed tubers were planted in the experimental plots on 14 November 2014 at a depth of 5 cm. A spacing of 60 cm × 30 cm was used. Each plot accommodated 12 cut seed tubers in 3 rows, containing 4 seed tubers per row. The soil along the rows of seed tubers were ridged up immediately after planting

3.11 Intercultural operations

3.11.1 Weeding and mulching

Manual weeding was done as and when necessary to keep the plots free from weeds. The soil was mulched by breaking the crust of the soil for easy aeration and to conserve soil moisture as and when needed. Mulching also helped to disturb the emergence of Bathua plants (*Chenopodium album*) and other weeds. These two operations were done carefully without hampering the luxurious crop health.

3.11.2 Earthing up

The soil along the rows of seed tubers were ridged up immediately after planting. The earthing up was done at 35 days of the planting which was preceded by top dressing of the remaining half of urea and also it was treated as a final earthing-up.

3.11.3 Irrigation

Three irrigations were provided throughout the growing period. The first irrigation was given at 35 days after planting followed by two irrigations at 20 days interval after the first application.

3.11.4 Plant protection

Except cutworm, no other insects were found harmful for potato in growing season. To protect the soil borne insects Furadan 5G was applied @10kg ha-1 during the final land preparation. Dursban was applied @2ml L-1 after 20 DAP to control the cutworm. Dithane M-45 was applied @2g L-1 at 10 days interval as a preventive measure against late blight (*Phytophthora infestans*) of potato. Poison bait was used in some plots for protecting the tuber from the rat.

3.12 Haulm cutting

Haulm cutting was done at maturity level on 15 February, 2015. After haulm cutting the tubers were kept under the soil for skin hardening.

3.13 Harvesting

The maturity of the crop was determined by the appearance of the yellowish color of the leaves, falling of the stems on the ground and finally drying of leaves. Five sample plants were harvested at first from each plot and then the whole plot was harvested with the help of spade. Care was taken to avoid injury of potatoes during harvesting. Harvesting was done on 27 February, 2014.

3.14 Collection of data

Data were recorded on different morphological, yield components and yield from 5 randomly selected sample plants. Data on different parameters were recorded as per the following parameters:

3.14.1 Growth related

1. Plant height
2. No. of stems/hill
3. Leaf area
4. Stem diameter

3.14.2 Yield related

1. No. of tuber/plant
2. Tuber weight/plant
3. Tuber yield/plot
4. Yield of tuber/hectare

3.14.3 Physiological related

1. Net assimilation rate (g cm^{-2} d^{-1})
2. Intercellular CO_2 concentration (ppm)
3. Cu-leaf (Photosynthetic active radiation) (w/m^2)
4. Chlorophyll content (%)

3.15 Procedure of recording data

3.15.1 Plant height

The height of the 5 sample plants (From those plants data were collected) was measured in centimeter from the ground level to the tip of the longest shoot at 45, 60 and 75 days after planting.

3.15.2 Number of main stems per hill

The number of stem per hill was calculated from the average of 5 plants selected randomly from each unit plot and mean was calculated out.

3.15.3 Leaf area

Leaf area was calculated from the average of 5 plants selected randomly from each unit plot and mean was calculated out.

3.15.4 Average diameter of stem

Average diameter of stem was determined from randomly selected 5 plants from each unit plot at 60 and 75 days after sowing and was expressed in centimeter.

3.15.5 Number of tubers per hill

The number of tubers per hill was determined from the average of 5 selected plants randomly from each unit plot at harvest.

3.15.6 Yield of tubers per hill

The weight of tubers per hill was calculated from the average of 5 selected plants randomly from each unit plot at harvest and was expressed in gram.

3.15.7 Yield of tubers per plot

Yield of tubers per plot was recorded from total tubers weight of all the plants from each unit plot at harvest and was expressed in kilogram.

3.15.8 Total yield/hectare

The yield obtained from each unit plot was converted into per hectare yield and expressed in t/ha.

3.15.9 Physiological factors

Net assimilation rate, Intercellular CO_2 concentration, Cu-leaf (Photosynthetic active radiation) in plant body or cell were measured by using LC-Pro+ machine and Chlorophyll content was measured by using S-Pad machine.

3.16 Statistical analysis

The data obtained for yield contributing characters and yield were statistically analyzed to find out the significance of the differences among the treatments. The collected data from the experimental plot on morphology yield and yield contributing characters are compiled and analyzed using the Statistical, Mathematical Calculation and Data Management (MSTAT-C) package program. Morphological variation and yield performance among the treatments were studied by Analysis of Variance (ANOVA) by F-test. The significance of the difference between pairs of treatment means was evaluated by least significant difference (LSD) test at 5% and 1% level of probability (Gomez and Gomez, 1984).

3.17 Economic analysis

The cost of production was analyzed with a view to find out the most profitable combination of the treatments. All the non-material and material input costs and interests on running capital were considered for computing the cost of production. Benefit cost ratio was calculated by the following formula:

$$\text{Benefit cost ratio} = \frac{\text{Gross return (Tk/ha)}}{\text{Total cost of production (Tk/ha)}}$$

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the effect of tuber size and plant growth regulators on growth and yield of potato. The results of the present study on the yield and yield contributing characters have been presented and discussed in this chapter.

4.1 Growth parameters

4.1.1 Plant height

4.1.1.1 Effect of tuber size

Plant height was recorded at different days after sowing (DAS) and it was observed that different tuber size showed significant variation in plant height at all the DAS (Appendix 4). The longest plant (36.71, 48.98 and 50.58 cm at 45, 60 and 75 DAS respectively) was achieved with S_2 (Medium tuber; 25 ± 5g) which was statistically identical with S_3 (Large tuber; 35 ± 5g). The shortest plant (34.36, 45.29 and 47.36 cm at 45, 60 and 75 DAS respectively) was obtained from S_1 (Small tuber; 15 ± 5g) (Table 1). The results from the present study were not conformity with findings of Malik and Ghosh (2002) and they observed that a difference in plant height due to seed was not significant.

4.1.1.2 Effect of growth regulators

Different growth regulators had also significant effect on plant height at different days after sowing (Appendix 4). At 45 DAS there was no plant height data by the application of growth regulators because growth regulator was applied at 45 DAS. Results revealed that the tallest plant (48.31 and 51.18 cm at 60 and 75 DAS respectively) was achieved from G_1 (100ppm GA_3) where the shortest plant (46.58 and 48.24 cm at 60 and 75 DAS respectively) was found from G_0 (Control) which was closely followed by G_2 (50ppm BAP) (Table 1). Sillu *et al*. (2012) observed that spray treatment of IBA 200 ppm was effective in maximum growth where GA_3 50 ppm was superior to other than plant height.

4.1.1.3 Combined effect of tuber size and growth regulators

Significant effect was found for plant height at different growth stages in case of combined effect of tuber size and growth regulators (Appendix 4). Results showed that the tallest plant (52.20 and 53.53 cm at 60 and 75 DAS respectively) was observed from S_2G_1 followed by S_3G_2 and S_2G_2. Again, the shortest (43.47 and 48.80 cm at 60 and 75 DAS respectively) was found from S_1G_0 followed by S_1G_1, S_3G_0 and S_2G_0 (Table 1). The results obtained from the combined effect of S_1G_2 and S_2G_2 gave mid-level plant height at all growth stages compared to the highest and the lowest plant height but significantly different from all other treatments (Table 1). At 45 DAS the highest and lowest plant height (40.13 and 32.27 cm respectively) was found in $S_2G_1$and S_1G_0 respectively. Here, growth regulators were not in consideration and only tuber size influenced plant height at 45 DAS.

Table 1: Effect of tuber size and plant growth regulators on plant height at different days after sowing

Treatment	Plant height (cm)		
	45 DAS	60 DAS	75 DAS
Effect of tuber size			
S_1	34.36	45.29	47.36
S_2	36.71	48.98	50.58
S_3	36.02	47.53	50.49
$LSD_{0.05}$	1.367	1.666	1.618
Effect of plant growth regulator			
G_0	--	46.58	48.24
G_1	--	48.31	51.18
G_2	--	46.91	49.00
$LSD_{0.05}$	--	1.334	1.618
Combined effect of tuber size and plant growth regulator			
S_1G_0	32.27	43.47	48.80
S_1G_1	32.93	44.67	47.67
S_1G_2	35.67	47.73	45.13
S_2G_0	32.53	46.33	48.93
S_2G_1	40.13	52.20	53.53
S_2G_2	37.47	48.40	49.27
S_3G_0	34.47	45.67	49.27
S_3G_1	35.87	48.07	52.33
S_3G_2	39.93	48.87	50.33
$LSD_{0.05}$	2.368	2.451	2.637
CV (%)	11.84	10.74	10.62

S_1 = Small tuber (15 ± 5g)
S_2 = Medium tuber (25 ± 5g)
S_3 = Large tuber (35 ± 5g)

G_0 = Control
G_1 = GA_3 (100ppm)
G_2 = BAP (50ppm)

4.1.2 Number of stems hill^{-1}

4.1.2.1 Effect of tuber size

Number of stems hill^{-1} was recorded at different days after sowing (DAS) and it was observed that different tuber size showed significant variation on number of stem hill^{-1} at all the crop duration (Appendix 5). The highest number of stem hill^{-1} (2.40, 2.44 and 2.44 at 45, 60 and 75 DAS respectively) was counted from S_3 (Large tuber; 35 ± 5g). The lowest number of stem hill^{-1} (2.09, 2.10 and 2.10 at 45, 60 and 75 DAS respectively) was obtained from S_1 (Small tuber; 15 ± 5g). The results obtained from S_2 (Medium tuber; 25 ± 5g) gave significantly same result compared to lowest number of stems hill^{-1} at all growth stages (Table 2). The results obtained from the present study were similar with findings of Divis *et al*. (2001). They observed that larger tubers produced higher number of stems per plant compared to small tubers.

4.1.2.2 Effect of growth regulators

Different growth regulators had significant effect on number of stem hill^{-1} at different days after sowing (Appendix 5). Results revealed that the highest number of stems hill^{-1} (3.09 and 3.09 at 60 and 75 DAS, respectively) was achieved from G_2 (BAP; 50ppm) where the lowest number of stems hill^{-1} (1.66 and 1.63 at 60 and 75 DAS, respectively) was found from G_0 (Control). The growth regulator effect of G_1 (GA_3; 100ppm) gave intermediate result in case of number of stems hill^{-1} at all growth stages of cropping season (Table 2). Sillu *et al*. (2012) observed that spray treatment of IBA 200 ppm was effective in maximum number of shoots per plant than GA_3 50 ppm.

4.1.2.3 Combined effect of tuber size and growth regulators

Significant variation was found for number of stems hill^{-1} at different growth stages in case of combined effect of tuber size and growth regulators (Appendix 5). Results showed that the highest number of stems hill^{-1} (3.40 and 3.40 at 60 and 75 DAS respectively) was observed from S_3G_2 which was statistically identical with S_2G_2 at all growth stages. Again, the lowest number of stems hill^{-1} (1.39 and 1.39 at 60 and 75 DAS respectively) was found from S_1G_0 followed by S_2G_0 and S_2G_1 (Table 2). The results obtained from the combined effect of S_1G_1, S_1G_2, S_3G_0 and S_3G_1 gave mid value of number of stems hill^{-1} at all growth stages compared to highest and lowest number of stem hill^{-1} but significantly different from all other treatments (Table 2). At 45 DAS the highest and lowest number of stems hill^{-1} (3.27 and 1.40 respectively) was found in S_3G_2 and S_1G_0 respectively. Here, growth regulators were not in consideration and only tuber size influenced plant height at 45 DAS (Table 2).

Table 2: Effect of tuber size and plant growth regulators on number of stem hill^{-1} at different days after sowing

Treatment	Number of stems hill^{-1}		
	45 DAS	60 DAS	75 DAS
Effect of tuber size			
S_1	2.09	2.10	2.10
S_2	2.09	2.18	2.17
S_3	2.40	2.44	2.44
$LSD_{0.05}$	0.208	0.227	0.248
Effect of plant growth regulator			
G_0	--	1.66	1.63
G_1	--	1.98	1.98
G_2	--	3.09	3.09
$LSD_{0.05}$	--	0.2096	0.2257
Combined effect of tuber size and plant growth regulator			
S_1G_0	1.40	1.39	1.39
S_1G_1	2.07	2.07	2.07
S_1G_2	2.53	2.53	2.53
S_2G_0	1.67	1.67	1.67
S_2G_1	1.80	1.80	1.80
S_2G_2	3.07	3.33	3.33
S_3G_0	1.87	1.87	1.87
S_3G_1	2.07	2.07	2.07
S_3G_2	3.27	3.40	3.40
$LSD_{0.05}$	0.3505	0.3752	0.4132
CV (%)	9.99	12.11	10.11

S_1 = Small tuber (15 ± 5g)
S_2 = Medium tuber (25 ± 5g)
S_3 = Large tuber (35 ± 5g)

G_0 = Control
G_1 = GA_3 (100ppm)
G_2 = BAP (50ppm)

4.1.3 Leaf area (cm^2)

4.1.3.1 Effect of tuber size

Statistically significant variation was observed by different tuber size on leaf area at all the crop duration (Appendix 6). The highest leaf area (155.8 and 167.3 cm^2 at 60 and 75 DAS, respectively) was achieved with S_3 (Large tuber; 35 ± 5g) where the lowest leaf area (140.0 and 157.1 cm^2 at 60 and 75 DAS, respectively) was obtained from S_1 (Small tuber; 15 ± 5g). The results obtained from S_2 (Medium tuber; 25 ± 5g) at 75 DAS gave significantly same result compared to lowest leaf area (Table 3). The findings obtained from the present study might be due to cause of more stems per hill from larger tuber and that was supported by Divis *et al*. (2001).

4.1.3.2 Effect of growth regulators

Different growth regulators had significant difference on leaf area at different days after sowing (Appendix 6). Results revealed that the highest leaf area (154.2 and 169.8 cm^2 at 60 and 75 DAS, respectively) was found from G_2 (50ppm BAP) where the lowest leaf area (140.6 and 155.3 cm^2 at 60 and 75 DAS, respectively) was found from G_0 (Control). The growth regulator effect of G_1 (100ppm GA_3) gave intermediate result in case of leaf area at all growth stages of cropping season (Table 3). Kumar *et al*. (1981) observed leaf area with GA_3 and IAA application in where GA_3 increased shoot extension, leaf area but IAA decreased leaf number and leaf area.

4.1.3.3 Combined effect of tuber size and growth regulators

Significant effect was found for leaf area at different growth stages due to combined effect of tuber size and growth regulators (Appendix 6). Results showed that the highest leaf area (162.9 and 171.4 cm^2 at 60 and 75 DAS, respectively) was observed in S_3G_2 which was statistically identical with S_2G_2 at all growth stages. Again, the lowest leaf area (126.1 and 143.0 cm^2 at 60 and 75 DAS, respectively) was found from S_1G_0 followed by S_1G_1 which was second lowest at 75 DAS (Table 3).

Table 3: Effect of tuber size and plant growth regulators on leaf area (cm^2) at different days after sowing

Treatment	Leaf area (cm^2)	
	60 DAS	75 DAS
Effect of tuber size		
S_1	140.0	157.1
S_2	149.3	158.8
S_3	155.8	167.3
$LSD_{0.05}$	2.244	2.729
Effect of plant growth regulator		
G_0	140.6	155.3
G_1	150.3	158.1
G_2	154.2	169.8
$LSD_{0.05}$	2.266	2.655
Combined effect of tuber size and plant growth regulator		
S_1G_0	126.1	143.0
S_1G_1	146.8	152.6
S_1G_2	157.4	167.8
S_2G_0	143.6	156.8
S_2G_1	148.8	156.1
S_2G_2	162.4	170.3
S_3G_0	131.1	161.4
S_3G_1	156.2	170.3
S_3G_2	162.9	171.4
$LSD_{0.05}$	3.872	4.582
CV (%)	12.52	9.57

S_1 = Small tuber (15 ± 5g)
S_2 = Medium tuber (25 ± 5g)
S_3 = Large tuber (35 ± 5g)

G_0 = Control
G_1 = GA_3 (100ppm)
G_2 = BAP (50ppm)

4.2 Yield and yield contributing parameters

4.2.1 Stem diameter (cm)

4.2.1.1 Effect of tuber size

Diameter of tuber was recorded as significant at different days after sowing (DAS) (Table 4 and Appendix 7). The highest stem diameter (0.93 and 1.01 cm at 60 and 75 DAS, respectively) was achieved with S_3 (Large stem; 35 ± 5g) which was statistically identical with S_2 (Medium stem; 25 ± 5g) at 60 DAS where the lowest stem diameter (0.86 and 0.94 cm at 60 and 75 DAS, respectively) was obtained from S_1 (Small stem; 15 ± 5g) which was statistically identical with S_2 (Medium stem; 25 ± 5g) at 75 DAS (Table 4).

4.2.1.2 Effect of growth regulators

Different growth regulators had significant effect on stem diameter at different days after sowing (Table 4 and Appendix 7). Results revealed that the highest stem diameter (0.92 and 1.01 cm at 60 and 75 DAS, respectively) was achieved from G_2 (50ppm BAP) which was statistically identical with G_1 (100ppm GA_3) where the lowest stem diameter (0.86 and 0.93 cm at 60 and 75 DAS, respectively) was found from G_0 (Control) (Table 4).

4.2.1.3 Combined effect of tuber size and growth regulators

Significant effect was found on stem diameter at different growth stages due to combined effect of stem size and growth regulators (Table 4 and Appendix 7). Results showed that the highest stem diameter (0.95 and 1.04 cm at 60 and 75 DAS, respectively) was observed from S_3G_2 at all growth stages. At 60 DAS S_2G_2 showed significantly same result with S_3G_2 which was closely followed by S_1G_2, S_2G_1 and S_3G_1 but at 75 DAS the treatment combination of S_1G_2, S_2G_2 and S_3G_1 showed statistically similar result with S_3G_2.

Again, the lowest stem diameter (0.83 and 0.90 cm at 60 and 75 DAS, respectively) was found from S_1G_0 followed by S_2G_0 (Table 4).

Table 4: Effect of tuber size and plant growth regulators on stem diameter (cm) at different days after sowing

Treatment	Stem diameter (cm)	
	60 DAS	75 DAS
Effect of tuber size		
S_1	0.86	0.94
S_2	0.90	0.95
S_3	0.93	1.01
$LSD_{0.05}$	0.032	0.045
Effect of plant growth regulator		
G_0	0.86	0.93
G_1	0.91	0.98
G_2	0.92	1.01
$LSD_{0.05}$	0.043	0.045
Combined effect of tuber size and plant growth regulator		
S_1G_0	0.83	0.90
S_1G_1	0.88	0.97
S_1G_2	0.93	0.99
S_2G_0	0.85	0.91
S_2G_1	0.91	0.97
S_2G_2	0.95	1.02
S_3G_0	0.87	0.93
S_3G_1	0.93	0.99
S_3G_2	0.95	1.04
$LSD_{0.05}$	0.0551	0.0547
CV (%)	11.55	11.06

S_1 = Small tuber (15 ± 5g)
S_2 = Medium tuber (25 ± 5g)
S_3 = Large tuber (35 ± 5g)

G_0 = Control
G_1 = GA_3 (100ppm)
G_2 = BAP (50ppm)

4.2.2 Number of tubers plant^{-1}

4.2.2.1 Effect of tuber size

Number of tubers plant^{-1} was significantly influenced by different tuber size (Appendix 8). The highest number of tubers plant^{-1} (7.38) was achieved from S_3 (Large tuber; 35 ± 5g) which was statistically identical with S_2 (Medium tuber; 25 ± 5g) where the lowest number of tubers plant^{-1} (6.20) was obtained from S_1 (Small tuber; 15 ± 5g) (Table 5). The result obtained from the present study was in agreement with the findings of Kang *et al*. (2001) and they observed that at 90 days after transplanting plug seedlings, the total number of tubers plant^{-1} increased from 3.62 to 4.72 with increase in seed tuber size. Singh *et al*. (2003) also observed that the number of tubers per plant were greatly affected by seed size and tuber yield (305.24 q/ha) and number of tubers per plant (10.40) were significantly highest with big seed size.

4.2.2.2 Effect of growth regulators

Different growth regulators had also significant effect on number of tubers plant^{-1} (Appendix 8). Results revealed that the highest number of tubers plant^{-1} (7.87) was achieved from G_2 (50 ppm BAP) but the lowest number of tuber plant^{-1} (6.40) was found from G_0 (Control) which was statistically identical with G_1 (100ppm GA_3) (Table 5). Kumar *et al*. (1981) observed GA_3 increased number of tubers but IAA decreased either number of tubers or was not affected. Sillu *et al*. (2012) observed that spray of GA_3 50 ppm was superior to spray treatment of IBA 200 ppm for number of tubers harvested per plant.

4.2.2.3 Combined effect of tuber size and growth regulators

Combined effect of tuber size and growth regulators had significant effect on number of tubers plant^{-1} (Appendix 8). Results showed that the highest number of tubers plant^{-1} (9.53) was observed from S_3G_2 where the second highest number of tubers plant^{-1} was obtained from S_2G_2. Again, the lowest number of tubers plant^{-1} (5.73) was found from S_1G_0 which was statistically identical with S_2G_0 but closely followed by S_1G_1, S_2G_1 and S_3G_0 (Table 5).

4.2.3 Tuber weight plant^{-1}

4.2.3.1 Effect of tuber size

Tuber weight plant^{-1} was significantly influenced by different tuber size that was planted in field (Appendix 8). The highest tuber weight plant^{-1} (519.50 g) was achieved from S_3 (Large tuber; 35 ± 5g) where the lowest tuber weight plant^{-1} (500.40 g) was obtained from S_1 (Small tuber; 15 ± 5g) (Table 5). The results obtained from S_2 (Medium tuber; 25 ± 5g) gave intermediate results compared to other results. Similar result was found with the findings of Malik and Ghosh (2002) and they found that tuber yield per plant were higher under large size (60-90 g) seeds. Singh *et al*. (2003) also found that average weight per tuber was greatly affected by seed size and significantly highest with big seed size.

4.2.3.2 Effect of growth regulators

Different growth regulators had also significant effect on tuber weight plant^{-1} (Appendix 8). Results revealed that the highest tuber weight plant^{-1} (529.80 g) was achieved from G_2 (50ppm BAP) where the lowest tuber weight plant^{-1} (472.30 g) was found from G_0 (Control). The result obtained from G_1 (100ppm GA_3) gave intermediate result (Table 5).

4.2.3.3 Combined effect of tuber size and growth regulators

Combined effect of tuber size and growth regulators had significant effect on tuber weight plant^{-1} (Appendix 8). Results showed that the highest tuber weight plant^{-1} (544.10 g) was observed from S_3G_2 which was statistically identical with S_2G_2. Again, the lowest tuber weight plant^{-1} (441.50 g) was found in S_1G_0 second and third lowest tuber weight plant^{-1} was found from S_2G_0 and S_3G_0 respectively (Table 5).

4.2.4 Tuber weight plot^{-1}

4.2.4.1 Effect of tuber size

Tuber weight plot^{-1} was significantly influenced by different tuber size that was planted in the field (Appendix 8). The highest tuber weight plot^{-1} (6.09 kg) was achieved from S_3 (Large tuber; 35 ± 5g) where the lowest tuber weight plot^{-1} (5.97 kg) was obtained from S_1 (Small tuber; 15 ± 5g) (Table 5). The results obtained from S_2 (Medium tuber; 25 ± 5g) gave intermediate results compared to other results. This finding was supported with the findings of Kang *et al*. (2001), Singh *et al*. (2003) and Malik and Ghosh (2002).

4.2.4.2 Effect of growth regulators

Different growth regulators had also significant effect on tuber weight plot^{-1} (Appendix 8). Results revealed that the highest tuber weight plot^{-1} (6.47 kg) was obtained from G_2 (50ppm BAP) where the lowest tuber weight plot^{-1} (5.60 kg) was found from G_0 (Control). The result obtained from G_1 (100ppm GA_3) gave intermediate result (Table 5).

4.2.4.3 Combined effect of tuber size and growth regulators

Combined effect of tuber size and growth regulators had significant effect on tuber weight plot^{-1} (Appendix 8). Results showed that the highest tuber weight plot^{-1} (6.69 kg) was observed from S_3G_2 which was statistically identical with S_2G_2. Again, the lowest tuber weight plot^{-1} (5.20 kg) was found in S_1G_0 which was significantly different from all other treatments. The second and third lowest tuber weight plot^{-1} was found from S_2G_0 and S_3G_0 respectively (Table 5).

4.2.5 Tuber yield ha^{-1}

4.2.5.1 Effect of tuber size

Tuber yield ha^{-1} was significantly influenced by different tuber size that was planted in the field (Appendix 8). The highest tuber yield ha^{-1} (28.20 t) was recorded from S_3 (Large tuber; 35 ± 5g) where the lowest tuber yield ha^{-1} (27.64 t) was obtained from S_1 (Small tuber; 15 ± 5g) (Table 5). The results obtained from S_2 (Medium tuber; 25 ± 5g) gave intermediate results compared to other results. The result obtained from the present study was similar with the findings of Sharma and Sarjeet (2009) and they stated that increasing size of the seed tuber from 20 to 60 g resulted in a significant increase in the tuber number and yield.

4.2.5.2 Effect of growth regulators

Different growth regulators had also significant effect on Tuber yield ha^{-1} (Appendix 8). Results revealed that the highest tuber yield ha^{-1} (29.94 t) was achieved from G_2 (50ppm BAP) where the lowest tuber yield ha^{-1} (25.91 t) was found from G_0 (Control). The result obtained from G_1 (100ppm GA_3) gave intermediate result (Table 5). Kumar *et al*. (1981) observed yield of tuber increased with IAA used alone or in combinations with GA_3. Sillu *et al*. (2012) observed that spray treatment of IBA 200 ppm was effective in maximum yield of tuber and application of spray of GA_3 50 ppm was superior for average weight of tuber. Again, the GA_3 gave significantly higher number and weight of seed size

(20-80 g) tubers. The increment in yield by number and weight was 22.1% and 18% with GA_3 while it was 12.7% and 10% with NAA over control (Birbal *et al.*, 2005)

4.2.5.3 Combined effect of tuber size and growth regulators

Combined effect of tuber size and growth regulators had significant effect on Tuber yield ha^{-1} (Appendix 8). Results showed that the highest tuber yield ha^{-1} (30.97 t) was observed from S_3G_2 and second highest (30.45 t) and third highest (29.57 t) tuber yield ha^{-1} was found in S_2G_2 and S_3G_1 respectively. The lowest tuber yield ha^{-1} (24.06 t) was found in S_1G_0 and second lowest (25.43 t) and third lowest (26.27 t) tuber yield ha^{-1} was obtained from S_2G_0 and S_3G_0 respectively (Table 5).

Table 5: Effect of tuber size and plant growth regulators on yield and yield contributing parameters at the time of harvest

Treatment	Yield and yield contributing parameters			
	Number of tubers $plant^{-1}$	Tuber weight $plant^{-1}$ (g)	Tuber weight $plot^{-1}$ (kg)	Tuber yield ha^{-1} (t)
Effect of tuber size				
S_1	6.20	500.40	5.97	27.64
S_2	7.18	507.10	6.03	27.93
S_3	7.38	519.50	6.09	28.20
$LSD_{0.05}$	0.372	1.502	0.044	0.1303
Effect of plant growth regulator				
G_0	6.40	472.30	5.60	25.91
G_1	6.49	524.80	6.03	27.91
G_2	7.87	529.80	6.47	29.94
$LSD_{0.05}$	0.197	1.502	0.095	0.1224
Combined effect of tuber size and plant growth regulator				
S_1G_0	5.73	441.50	5.20	24.06
S_1G_1	6.27	507.70	6.03	27.90
S_1G_2	6.87	516.50	6.14	28.42
S_2G_0	6.13	478.30	5.49	25.43
S_2G_1	6.33	515.50	6.10	28.24
S_2G_2	7.93	542.50	6.58	30.45
S_3G_0	6.20	497.10	5.67	26.27
S_3G_1	7.27	537.70	6.39	29.57
S_3G_2	9.53	544.10	6.69	30.97
$LSD_{0.05}$	0.631	2.481	0.145	0.1815
CV (%)	8.03	9.50	12.75	12.74

S_1 = Small tuber (15 ± 5g)
S_2 = Medium tuber (25 ± 5g)
S_3 = Large tuber (35 ± 5g)

G_0 = Control
G_1 = GA_3 (100ppm)
G_2 = BAP (50ppm)

4.3 Physiological factors

4.3.1 Net assimilation rate

4.3.1.1 Effect of tuber size

Net assimilation rate was significantly influenced by different tuber size that was planted in field (Appendix 9). The highest net assimilation rate (7.39 and 9.33 at 60 and 75 DAS, respectively) was achieved from S_3 (Large tuber; 35 ± 5g) which was statistically identical with S_2 (Medium tuber; 25 ± 5g) at 60 DAS. The lowest net assimilation rate (5.96 and 8.50 at 60 and 75 DAS, respectively) was obtained from S_1 (Small tuber; 15 ± 5g) (Table 6) which was statistically identical with S_2 (Medium tuber; 25 ± 5g) at 75 DAS.

4.3.1.2 Effect of growth regulators

Different growth regulators had also significant effect on net assimilation rate (Appendix 9). Results revealed that the highest net assimilation rate (7.31 and 9.53 at 60 and 75 DAS, respectively) was achieved from G_2 (50ppm BAP) where the lowest net assimilation rate (6.46 and 8.54 at 60 and 75 DAS, respectively) was found from G_0 (Control) which was statistically identical with G_1 (100ppm GA_3) (Table 6).

4.3.1.3 Combined effect of tuber size and growth regulators

Combined effect of tuber size and growth regulators had significant effect on net assimilation rate (Appendix 9). Results showed that the highest net assimilation rate (8.28 and 10.33 at 60 and 75 DAS, respectively) was observed from S_3G_2 which was statistically identical with S_3G_1 at 75 DAS. Again, the lowest net assimilation rate (5.53 and 7.11 at 60 and 75 DAS, respectively) was found in S_1G_0 which was significantly different from all other treatment combinations but comparatively lower net assimilation rate was also found from S_2G_0 and S_3G_0 (Table 6).

Table 6: Effect of tuber size and plant growth regulators on net assimilation rate

Treatment	Net assimilation rate (g $cm^{-2}d^{-1}$)	
	60 DAS	75 DAS
Effect of tuber size		
S_1	5.96	8.50
S_2	7.12	8.80
S_3	7.39	9.33
$LSD_{0.05}$	0.5434	0.3300
Effect of plant growth regulator		
G_0	6.46	8.54
G_1	6.70	8.56
G_2	7.31	9.53
$LSD_{0.05}$	0.5443	0.1253
Combined effect of tuber size and plant growth regulator		
S_1G_0	5.53	7.11
S_1G_1	6.64	8.51
S_1G_2	6.84	9.16
S_2G_0	5.71	8.25
S_2G_1	7.02	8.79
S_2G_2	7.21	9.35
S_3G_0	6.26	8.31
S_3G_1	7.94	10.10
S_3G_2	8.28	10.33
$LSD_{0.05}$	0.3020	0.2365
CV (%)	4.70	5.19

S_1 = Small tuber (15 ± 5g)
S_2 = Medium tuber (25 ± 5g)
S_3 = Large tuber (35 ± 5g)

G_0 = Control
G_1 = GA_3 (100ppm)
G_2 = BAP (50ppm)

4.3.2 Intercellular CO_2 concentration

4.3.2.1 Effect of tuber size

Intercellular CO_2 concentration was significantly influenced by different tuber size in the crop field (Appendix 10). The highest Intercellular CO_2 concentration (394.6 and 285.6 at 60 and 75 DAS, respectively) was achieved from S_3 (Large tuber; 35 ± 5g). The lowest Intercellular CO_2 concentration (343.3 and 261.3 at 60 and 75 DAS, respectively) was obtained from S_1 (Small tuber; 15 ± 5g) (Table 7). The results obtained from S_2 (Medium tuber; 25 ± 5g) gave intermediate result compared to highest and lowest Intercellular CO_2 concentration.

4.3.2.2 Effect of growth regulators

Different growth regulators had also significant effect on Intercellular CO_2 concentration (Appendix 10). Results revealed that the highest Intercellular CO_2 concentration (370.8 and 277.7 at 60 and 75 DAS, respectively) was achieved from G_2 (50ppm BAP) where the lowest Intercellular CO_2 concentration (356.7 and 258.1 at 60 and 75 DAS, respectively) was found from G_0 (Control). The results obtained from G_1 (100ppm GA_3) gave intermediate result compared to highest and lowest result of Intercellular CO_2 concentration (Table 7).

4.3.2.3 Combined effect of tuber size and growth regulators

Combined effect of tuber size and growth regulators had significant effect on Intercellular CO_2 concentration (Appendix 10). Results showed that the highest Intercellular CO_2 concentration (421.7 and 304.7 at 60 and 75 DAS, respectively) was observed from S_3G_2 which was statistically identical with S_3G_1 at 75 DAS but S_3G_1 at 60 DAS was significantly different from S_3G_2. The lowest Intercellular CO_2 concentration (318.3 and 235.3 at 60 and 75 DAS, respectively) was found in S_1G_0 which was statistically identical with S_2G_0 at 75 DAS but S_2G_0 at 60 DAS was significantly different from S_1G_0. (Table 7).

Table 7: Effect of tuber size and plant growth regulators intercellular CO_2 concentration

Treatment	Intercellular CO_2 concentration (ppm)	
	60 DAS	75 DAS
Effect of tuber size		
S_1	343.3	261.3
S_2	353.7	264.3
S_3	394.6	285.6
$LSD_{0.01}$	2.530	2.668
Effect of plant growth regulator		
G_0	356.7	258.1
G_1	364.1	275.4
G_2	370.8	277.7
$LSD_{0.01}$	2.526	1.489
Combined effect of tuber size and plant growth regulator		
S_1G_0	318.3	235.3
S_1G_1	352.3	260.7
S_1G_2	370.1	287.7
S_2G_0	332.7	235.7
S_2G_1	352.3	261.0
S_2G_2	379.0	292.3
S_3G_0	338.7	253.0
S_3G_1	409.7	303.3
S_3G_2	421.7	304.7
$LSD_{0.01}$	4.378	4.558
CV (%)	3.63	3.73

S_1 = Small tuber (15 ± 5g)
S_2 = Medium tuber (25 ± 5g)
S_3 = Large tuber (35 ± 5g)

G_0 = Control
G_1 = GA_3 (100ppm)
G_2 = BAP (50ppm)

4.3.3 Cu-leaf (Photosynthetic active radiation)

4.3.3.1 Effect of tuber size

Photosynthetic active radiation was significantly influenced by different tuber size in the crop field (Appendix 11). The highest photosynthetic active radiation (785.9 and 1295.0 at 60 and 75 DAS, respectively) was achieved from S_3 (Large tuber; 35 ± 5g). The lowest photosynthetic active radiation (501.6 and 1069.0 at 60 and 75 DAS, respectively) was obtained from S_1 (Small tuber; 15 ± 5g) (Table 8). The results obtained from S_2 (Medium tuber; 25 ± 5g) gave intermediate result compared to highest and lowest photosynthetic active radiation at 60 and 75 DAS.

4.3.3.2 Effect of growth regulators

Different growth regulators had also significant effect on Photosynthetic active radiation (Appendix 11). Results revealed that the highest photosynthetic active radiation (676.9 and 1301.0 at 60 and 75 DAS, respectively) was achieved from G_2 (50ppm BAP) where the lowest photosynthetic active radiation (659.0 and 979.0 at 60 and 75 DAS, respectively) was found from G_0 (Control). The results obtained from G_1 (100ppm GA_3) gave intermediate result compared to highest and lowest result of photosynthetic active radiation at 60 and 75 DAS (Table 8).

4.3.3.3 Combined effect of tuber size and growth regulators

Combined effect of tuber size and growth regulators had significant effect on photosynthetic active radiation (Appendix 11). Results showed that the highest photosynthetic active radiation (838.30 and 1405.0 at 60 and 75 DAS, respectively) was observed from S_3G_2 which was statistically different from all other treatment combinations but comparatively higher photosynthetic active radiation was found from S_3G_1 and S_2G_2. Again, the lowest photosynthetic active radiation (416.00 and 744.70 at 60 and 75 DAS, respectively) was found in S_1G_0 which was also significantly different from all other treatment combinations but

S_2G_0 and S_3G_0 also showed comparatively lower photosynthetic active radiation (Table 8).

Table 8: Effect of tuber size and plant growth regulators on Cu-leaf (Photosynthetic active radiation)

Treatment	Cu-leaf (Photosynthetic active radiation) (w/m^2)	
	60 DAS	75 DAS
Effect of tuber size		
S_1	501.6	1069.0
S_2	709.4	1102.0
S_3	785.9	1295.0
$LSD_{0.01}$	1.828	2.456
Effect of plant growth regulator		
G_0	659.0	979.0
G_1	661.0	1186.0
G_2	676.9	1301.0
$LSD_{0.01}$	1.828	2.457
Combined effect of tuber size and plant growth regulator		
S_1G_0	416.0	744.7
S_1G_1	640.0	1157.0
S_1G_2	728.7	1271.0
S_2G_0	448.7	900.3
S_2G_1	715.0	1227.0
S_2G_2	777.7	1323.0
S_3G_0	622.0	1035.0
S_3G_1	804.3	1336.0
S_3G_2	838.3	1405.0
$LSD_{0.01}$	3.167	4.322
CV (%)	4.06	6.06

S_1 = Small tuber (15 ± 5g)
S_2 = Medium tuber (25 ± 5g)
S_3 = Large tuber (35 ± 5g)

G_0 = Control
G_1 = GA_3 (100ppm)
G_2 = BAP (50ppm)

4.3.4 Chlorophyll content

4.3.4.1 Effect of tuber size

Chlorophyll content was significantly influenced by different tuber size used in the present study (Appendix 12). Results indicated that the highest chlorophyll content (50.34 and 49.72 at 60 and 75 DAS, respectively) was achieved from S_3 (Large tuber; 35 ± 5g) which was statistically identical with S_2 (Medium tuber; 25 ± 5g) at 75 DAS. The lowest chlorophyll content (49.83 and 45.29 at 60 and 75 DAS, respectively) was obtained from S_1 (Small tuber; 15 ± 5g) at 75 DAS (Table 9).

4.3.4.2 Effect of growth regulators

Different growth regulators had also significant effect on chlorophyll content (Appendix 12). Results revealed that the highest chlorophyll content (51.50 and 48.60 at 60 and 75 DAS, respectively) was achieved from G_2 (50ppm BAP) where the lowest chlorophyll content (48.89 and 47.90 at 60 and 75 DAS, respectively) was found from G_0 (Control) which was statistically identical with G_1 (100ppm GA_3) at 75 DAS (Table 9).

4.3.4.3 Combined effect of tuber size and growth regulators

Combined effect of tuber size and growth regulators had significant effect on chlorophyll content (Appendix 12). Results showed that the highest chlorophyll content (50.34 and 50.13 at 60 and 75 DAS, respectively) was observed in S_3G_2 which was statistically identical S_3G_1 at all growth stages but closely followed by S_1G_2 and S_2G_2 at 75 DAS. Again, the lowest chlorophyll content (49.07 and 44.20 at 60 and 75 DAS, respectively) was found in S_1G_0 which was significantly different from all other treatment combinations but comparatively lower chlorophyll content was found from S_2G_0 and S_3G_0 (Table 9).

Table 9: Effect of tuber size and plant growth regulators on chlorophyll content

Treatment	Chlorophyll content (%)	
	60 DAS	75 DAS
Effect of tuber size		
S_1	49.83	45.29
S_2	50.04	49.47
S_3	50.34	49.72
$LSD_{0.01}$	0.2921	0.3416
Effect of plant growth regulator		
G_0	48.89	47.90
G_1	49.83	47.98
G_2	51.50	48.60
$LSD_{0.01}$	0.4260	0.1365
Combined effect of tuber size and plant growth regulator		
S_1G_0	49.07	44.20
S_1G_1	50.10	48.53
S_1G_2	50.63	49.70
S_2G_0	48.20	45.47
S_2G_1	50.33	49.47
S_2G_2	51.63	49.73
S_3G_0	49.07	46.20
S_3G_1	52.23	50.00
S_3G_2	50.34	50.13
$LSD_{0.01}$	0.4440	0.4167
CV (%)	2.95	3.36

S_1 = Small tuber (15 ± 5g)
S_2 = Medium tuber (25 ± 5g)
S_3 = Large tuber (35 ± 5g)

G_0 = Control
G_1 = GA_3 (100ppm)
G_2 = BAP (50ppm)

4.4 Economic analysis

Input cost for land preparation, seed cost, fertilization, irrigation and man power required for all the operations from sowing to harvesting of potato were recorded for unit plot and converted into cost per hectare. Prices of potato were considered in market of Agargaon, Dhaka rate basis. The economic analysis was done to find out the gross return, net return and the benefit cost ratio in the present experiment which has been presented under following headings-

4.4.1 Gross return

In the combination of tuber sizes and PGR showed different gross return under the trial (Table 10). The highest gross return (Tk 464,550) per hectare was calculated from S_3G_2 and the second highest gross return (Tk 443,550) per hectare was calculated from S_3G_1. The lowest gross return (Tk 360,900) per hectare was calculated from S_1G_0.

4.4.2 Net return

In case of net return different treatment combination showed different amount of net return. The highest net return (Tk 324,590) per hectare was calculated from S_3G_2 and the second highest net return (Tk 303,390) per hectare was calculated from S_2G_2. The lowest net return (Tk 239,230) per hectare was calculated from S_1G_0 treatment (Table 10).

4.4.2 Benefit cost ratio

The highest (3.32) benefit cost ratio was calculated from S_3G_2 (100 ppm BAP) and the lowest benefit cost ratio (2.96) was calculated from S_1G_0 (control) treatment (Table 10). From economic point of view, it appeared from above results that the combination of S_3G_2 i.e. large tuber couple with 50 ppm BAP was more profitable compare to other treatment.

Table 10: Cost and return of potato production as influenced by different tuber size and growth regulators

Treatment	Yield ($t\ ha^{-1}$)	Gross return ($Tk.\ ha^{-1}$)	Total cost of production ($Tk.\ ha^{-1}$)	Net return ($Tk.\ ha^{-1}$)	Benefit cost ratio
S_1G_0	24.06	360900	121670	239230	2.96
S_1G_1	27.90	418500	131050	287450	3.19
S_1G_2	28.42	426300	128960	297340	3.20
S_2G_0	25.43	381450	126540	254910	3.01
S_2G_1	28.24	423600	135450	288150	3.12
S_2G_2	30.45	436750	133360	303390	3.27
S_3G_0	26.27	394050	128740	256360	3.06
S_3G_1	29.57	443550	142050	301500	3.12
S_3G_2	30.97	464550	139960	324590	3.32

Selling price of potato Tk. 15000/ton

S_1 = Small tuber (15 ± 5g)
S_2 = Medium tuber (25 ± 5g)
S_3 = Large tuber (35 ± 5g)

G_0 = Control
G_1 = GA_3 (100ppm)
G_2 = BAP (50ppm)

CHAPTER V

SUMMARY AND CONCLUSION

An investigation was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2014 to February 2015 to study the effect of tuber size and plant growth regulators on growth and yield of potato. The experiment consisted of 3 sizes of seed tuber (S_1 = Small tuber; 15 ± 5g, S_2 = Medium tuber; 25 ± 5g and S_3 = Large tuber; 35 ± 5g) and 3 levels of PGR (G_0 = Control, G_1 = 100ppm GA_3 and G_2 = 50ppm BAP) thus there were 9 treatment combinations. The two factor experiment was laid out in Randomized Complete Block Design with three replications. The size of each unit pot was 1.8 m × 1.2 m and 12 plants were accommodated in each plot following a spacing of 60 cm × 30 cm. The crop was harvested at the sign of full maturity. Data were statistically analyzed for evaluation of the treatment effect.

Results also revealed that the tallest plant (36.71, 48.98 and 50.58 cm at 45, 60 and 75 DAS respectively) was achieved with S_2 (Medium tuber; 25 ± 5g) but the highest number of stem hill^{-1} (2.40, 2.44 and 2.44 at 45, 60 and 75 DAS respectively), leaf area (155.8 and 167.3 cm^2 at 60 and 75 DAS respectively), stem diameter (0.93 and 1.01 cm at 60 and 75 DAS respectively), number of tuber plant^{-1} (7.38), tuber weight plant^{-1} (519.50 g), tuber weight plot^{-1} (6.09 kg) and tuber yield ha^{-1} (28.20 t) were achieved with S_3 (Large tuber; 35 ± 5g) where the lowest plant height (34.36, 45.29 and 47.36 cm at 45, 60 and 75 DAS respectively), number of stem hill^{-1} (2.09, 2.10 and 2.10 at 45, 60 and 75 DAS respectively), leaf area (140.0 and 157.1 cm^2 at 60 and 75 DAS respectively), stem diameter (0.86 and 0.94 cm at 60 and 75 DAS respectively), number of tuber plant^{-1} (6.20), tuber weight plant^{-1} (500.40), tuber weight plot^{-1} (5.97 kg) and tuber yield ha^{-1} (27.64 t) were obtained from S_1 (Small tuber; 15 ± 5g).

In terms of physiological factors the highest Net assimilation rate (7.39 and 9.33 at 60 and 75 DAS respectively), intercellular CO_2 concentration (394.6 and 285.6 at 60 and 75 DAS respectively), photosynthetic active radiation (785.9 and 1295.0 at 60 and 75 DAS respectively) and chlorophyll content (50.34 and 49.72 at 60 and 75 DAS respectively) were achieved from S_3 (Large tuber; 35 ± 5g) where the lowest net assimilation rate (5.96 and 8.50 at 60 and 75 DAS respectively), intercellular CO_2 concentration (343.3 and 261.3 at 60 and 75 DAS respectively), photosynthetic active radiation (501.6 and 1069.0 at 60 and 75 DAS respectively) and chlorophyll content (49.83 and 45.29 at 60 and 75 DAS respectively) were obtained from S_1 (Small tuber; 15 ± 5g).

Different growth regulators had also significant effect on different parameters at different duration of crop cultivation. Results indicated that the tallest plant (48.31 and 51.18 cm at 60 and 75 DAS respectively) was achieved from G_1 (100ppm GA_3) but the highest number of stem hill^{-1} (3.09 and 3.09 at 60 and 75 DAS respectively), leaf area (154.2 and 169.8 cm^2 at 60 and 75 DAS respectively), stem diameter (0.91 and 1.01 cm at 60 and 75 DAS respectively), number of tuber plant^{-1} (7.38), tuber weight plant^{-1} (529.80 g), tuber weight plot^{-1} (6.47 kg) and tuber yield ha^{-1} (29.94 t) were achieved in G_2 (50ppm BAP) where the lowest plant height (46.58 and 48.24 cm at 60 and 75 DAS respectively), number of stem hill^{-1} (1.66 and 1.63 at 60 and 75 DAS respectively), leaf area (140.6 and 155.3 cm^2 at 60 and 75 respectively), stem diameter (0.86 and 0.93 cm at 60 and 75 DAS respectively), number of tuber plant^{-1} (6.40), tuber weight plant^{-1} (472.30 g), tuber weight plot^{-1} (5.60 kg) and tuber yield ha^{-1} (25.91 t) were obtained from G_0 (Control).

Results also signified that the highest net assimilation rate (7.31 and 9.53 at 60 and 75 DAS respectively), intercellular CO_2 concentration (370.8 and 277.7 at 60 and 75 DAS respectively), photosynthetic active radiation (676.9 and 1301.0 at 60 and 75 DAS respectively) and Chlorophyll content (51.50 and 48.60 at 60 and 75 DAS respectively) were achieved from G_2 (50ppm BAP) where the lowest net assimilation rate (6.46 and 8.54 at 60 and 75 DAS respectively), intercellular CO_2 concentration (356.7 and 258.1 at 60 and 75 DAS respectively), photosynthetic active radiation (659.0 and 979.0 at 60 and 75 DAS respectively) and chlorophyll content (48.89 and 47.90 at 60 and 75 DAS respectively) were found from G_0 (Control).

Significant effect was found for different parameters at different growth stages in case of combined effect of tuber size and growth regulators. Results showed that the tallest plant (52.20 and 53.53 cm at 60 and 75 DAS respectively) was observed from S_2G_1 but the highest number of stem hill^{-1} (3.40 and 3.40 at 60 and 75 DAS respectively) was measured from S_3G_2 where the smallest plant (43.47 and 48.80 cm at 60 and at 75 DAS respectively) and the lowest number of stem hill^{-1} (1.39 and 1.39 at 60 and 75 DAS respectively) was measures from S_1G_0 was obtained from S_1G_0. Hence, growth regulators were applied at 45 DAS; so, only tuber size effect on plant height and number of stem hill^{-1} was measured before 45 DAS. At 45 DAS the highest and lowest plant height (40.13 and 32.27 cm respectively) was found in $S_2G_1$and S_1G_0 respectively but the highest and lowest number of stem hill^{-1} (3.27 and 1.40 respectively) was obtained in S_3G_2 and S_1G_0 respectively.

Again, the highest leaf area (162.9 and 171.4 cm^2 at 60 and 75 DAS respectively), stem diameter (0.95 and 1.04 cm at 60 and 75 DAS respectively), number of tuber plant^{-1} (9.53), tuber weight plant^{-1} (544.10 g), tuber weight plot^{-1} (6.69 kg) and tuber yield ha^{-1} (30.97 t) were obtained from S_3G_2 where the lowest leaf area (126.1 and 143.0 cm^2 at 60 and 75 DAS respectively), stem diameter (0.83 and 0.90 cm at 60 and 75 DAS respectively), number of tuber plant^{-1} (5.73), tuber weight plant^{-1} (441.50), tuber weight plot^{-1} (5.20 kg) and tuber yield ha^{-1} (24.06 t) were obtained from S_1G_0.

In case of physiological factors the highest net assimilation rate (8.28 and 10.33 at 60 and 75 DAS respectively), highest intercellular co_2 concentration (421.7 and 304.7 at 60 and 75 DAS respectively), highest photosynthetic active radiation (838.3 and 1405 at 60 and 75 DAS respectively) and highest chlorophyll content (50.34 and 50.13 at 60 and 75 DAS respectively) were measured from S_3G_2 where the lowest net assimilation rate (5.537 and 7.110 at 60 and 75 DAS respectively), lowest intercellular co_2 concentration (318.3 and 235.3 at 60 and 75 DAS respectively), the lowest photosynthetic active radiation (416.0 and 744.7 at 60 and 75 DAS respectively) and lowest chlorophyll content (49.07 and 44.20 at 60 and 75 DAS respectively) were obtained from S_1G_0.

The following conclusions have been drawn from the results of the present study:

1. The 35 ± 5g potato cut tubers produced the highest yield showing the best performance in respect of all the yield contributing characters studied.

2. Again, application of growth regulator BAP (50ppm) gave best results in respect of all the yield and yield contributing characters.

3. For the combined effect of tuber size and growth regulators, 35 ± 5g cut tuber with BAP (50ppm) was the best in respect of all the yield and yield contributing characters.

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APPENDICES

Appendix 1. Monthly records of Temperature, Rainfall, and Relative humidity of the experimental site during the period from November 2014 to February 2015

Year	Month	Air Temperature (^{0}c)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum	Mean			
2014	November	29.5	18.6	24.0	69.5	0.0	233.2
	December	26.9	16.2	21.5	70.6	0.0	210.5
2015	January	24.5	13.9	19.2	68.5	4.0	194.1
	February	28.9	18.0	23.4	61.0	3.0	221.5

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix 2. The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation

Particle size constitution:

Sand	:	40 %
Silt	:	40 %
Clay	:	20 %
Texture	:	Loamy

Chemical composition:

Constituents	:	0-15 cm depth
P^H	:	6.4
Total N (%)	:	0.07
Available P (µ gm/gm)	:	18.49
Exchangeable K (meq)	:	0.07
Available S (µ gm/gm)	:	20.82
Available Fe (µ gm/gm)	:	229
Available Zn (µ gm/gm)	:	4.48
Available Mg (µ gm/gm)	:	0.825
Available Na (µ gm/gm)	:	0.32
Available B (µ gm/gm)	:	0.94
Organic matter (%)	:	1.4

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

Appendix 3: Seedling emergence of different treatment plots at different days after sowing

Source of variation	Degrees of freedom	Mean square		
		45DAS	60 DAS	75 DAS
Replication	2	0.778	2.815	2.704
Factor A	2	0.111**	0.037**	1.370**
Factor B	2	--	--	--
AB	4	--	--	--
Error	16	--	--	--

** Significant at 1% level * Significant at 5% level

Appendix 4: Effect of tuber size and plant growth regulators on plant height at different growth stages

Source of variation	Degrees of freedom	Mean square		
		45 DAS	60 DAS	75 DAS
Replication	2	2.753	3.484	2.495
Factor A	2	3.201*	3.098**	3.313**
Factor B	2	6.295*	7.613*	5.877**
AB	4	13.039**	8.898*	10.655*
Error	16	1.871	2.781	2.621

** Significant at 1% level * Significant at 5% level

Appendix 5: Effect of tuber size and plant growth regulators on number of stem $hill^{-1}$ at different days after sowing

Source of variation	Degrees of freedom	Mean square		
		45 DAS	60 DAS	75 DAS
Replication	2	0.197	0.313	0.313
Factor A	2	0.290**	1.308**	0.808**
Factor B	2	4.179*	5.148*	4.115*
AB	4	0.488**	1.313*	2.114*
Error	16	0.042	0.051	0.061

** Significant at 1% level * Significant at 5% level

Appendix 6: Effect of tuber size and plant growth regulators on leaf area (cm^2) at different days after sowing

Source of variation	Degrees of freedom	Mean square	
		60 DAS	75 DAS
Replication	2	4.125	6.880
Factor A	2	56.565*	27.538*
Factor B	2	44.507*	53.658*
AB	4	20.696*	16.585*
Error	16	5.043	7.459

** Significant at 1% level * Significant at 5% level

Appendix 7: Effect of tuber size and plant growth regulators on stem diameter (cm) at different days after sowing

Source of variation	Degrees of freedom	Mean square	
		60 DAS	75 DAS
Replication	2	0.014	0.013
Factor A	2	0.309*	0.711**
Factor B	2	1.009**	2.013*
AB	4	3.002*	5.002*
Error	16	0.201	0.702

** Significant at 1% level * Significant at 5% level

Appendix 8: Effect of tuber size and plant growth regulators on yield and yield contributing parameters at the time of harvest

Source of variation	Degrees of freedom	Mean square			
		Tuber $plant^{-1}$	Tuber weight $plant^{-1}$	Tuber weight $plot^{-1}$	Tuber yield ha^{-1}
Replication	2	0.313	5.893	0.837	1.939
Factor A	2	3.575*	85.258*	0.033**	0.697**
Factor B	2	6.086**	915.762*	1.709*	36.644*
AB	4	3.641*	16.235*	0.618**	13.251*
Error	16	0.139	2.258	0.012	4.117

** Significant at 1% level * Significant at 5% level

Appendix 9: Effect of tuber size and plant growth regulators on net assimilation rate

Source of variation	Degrees of freedom	Mean square	
		60 DAS	75 DAS
Factor A	2	2.210*	1.579*
Factor B	2	1.704**	2.916**
AB	4	1.652**	3.672*
Error	16	1.301	2.611

** Significant at 1% level * Significant at 5% level

Appendix 10: Effect of tuber size and plant growth regulators intercellular CO_2 concentration

Source of variation	Degrees of freedom	Mean square	
		60 DAS	75 DAS
Factor A	2	66.947**	69.148**
Factor B	2	450.285**	103.704**
AB	4	371.874**	316.537**
Error	16	14.524	22.259

** Significant at 1% level * Significant at 5% level

Appendix 11: Effect of tuber size and plant growth regulators on Cu-leaf (Photosynthetic active radiation)

Source of variation	Degrees of freedom	Mean square	
		60 DAS	75 DAS
Factor A	2	194.481**	134.704**
Factor B	2	864.704**	395.815**
AB	4	1712.148**	1053.704*
Error	16	363.407	344.148

** Significant at 1% level * Significant at 5% level

Appendix 12: Effect of tuber size and plant growth regulators on chlorophyll content

Source of variation	Degrees of freedom	Mean square	
		60 DAS	75 DAS
Factor A	2	2.594**	5.760*
Factor B	2	15.731*	1.325**
AB	4	1.940**	2.020**
Error	16	2.187	2.619

** Significant at 1% level * Significant at 5% level

Appendix 13: Production cost of potato per hectare

A. Material cost

Treatment combinations	Seed tubers (t/ha)	Manure and Fertilizer				Pesticide	PGR		Subtotal (A)
		Cowdung	Urea	TSP	MP		GA3	BAP	
S_1G_0	20000	10000	6600	4200	9600	2000			52400
S_1G_1	20000	10000	6600	4200	9600	2000	5100		57500
S_1G_2	20000	10000	6600	4200	9600	2000		3200	55600
S_2G_0	24000	10000	6600	4200	9600	2000			56400
S_2G_1	24000	10000	6600	4200	9600	2000	5100		61500
S_2G_2	24000	10000	6600	4200	9600	2000		3200	59600
S_3G_0	26000	10000	6600	4200	9600	2000			58400
S_3G_1	26000	10000	6600	4200	9600	2000	5100		63500
S_3G_2	26000	10000	6600	4200	9600	2000		3200	61600

Cowdung @ 1000 Tk/ton
Urea @ 22 Tk/kg
TSP @ 30 Tk/kg
MP @ 30 Tk/kg

Seed tuber @ 40 Tk/kg
GA_3 @ 300 Tk/g
BAP @ 400 Tk/g

S_1 = Small tuber (15 ± 5g)
S_2 = Medium tuber (25 ± 5g)
S_3 = Large tuber (35 ± 5g)

G_0 = Control
G_1 = GA_3 (100ppm)
G_2 = BAP (50ppm)

Appendix 13: Cont'd

B. Non material input cost

Treatment combination	Land preparation	Tuber planting	Manure & fertilizer application	Pesticide application	PGR application	Intercultural operation	Harvesting	Subtotal (B)	Total cost (A+B)
S_1G_0	7000	10000	3000	3000		10000	12000	45000	97400
S_1G_1	7000	10000	3000	3000	3000	10000	12000	48000	105500
S_1G_2	7000	10000	3000	3000	3000	10000	12000	48000	103600
S_2G_0	7000	10000	3000	3000		10000	12000	45000	101400
S_2G_1	7000	10000	3000	3000	3000	10000	12000	48000	109500
S_2G_2	7000	10000	3000	3000	3000	10000	12000	48000	107600
S_3G_0	7000	10000	3000	3000		10000	12000	45000	103400
S_3G_1	7000	10000	3000	3000	3000	10000	12000	48000	115500
S_3G_2	7000	10000	3000	3000	3000	10000	12000	48000	113600

Labour cost 200 Tk/day

S_1 = Small tuber (15 ± 5g)
S_2 = Medium tuber (25 ± 5g)
S_3 = Large tuber (35 ± 5g)

G_0 = Control
G_1 = GA_3 (100ppm)
G_2 = BAP (50ppm)

Appendix 13: Cont’d

C. Overhead cost and total cost of production

Treatment combination	Overhead cost			Subtotal (overhead cost)	Total cost of production (input cost + overhead cost)
	Land leases cost for 6 months	Interest on running capital for 6 months @ of 10 % of total input cost	Miscellaneous cost @ 5 % of input cost		
S_1G_0	15000	4870	4870	24270	121670
S_1G_1	15000	5275	5275	25550	131050
S_1G_2	15000	5180	5180	25360	128960
S_2G_0	15000	5070	5070	25140	126540
S_2G_1	15000	5475	5475	25950	135450
S_2G_2	15000	5380	5380	25760	133360
S_3G_0	15000	5170	5170	25340	128740
S_3G_1	15000	5775	5775	26550	142050
S_3G_2	15000	5680	5680	26360	139960

Land lease 30000 Tk/ha/year

S_1 = Small tuber (15 ± 5g)
S_2 = Medium tuber (25 ± 5g)
S_3 = Large tuber (35 ± 5g)

G_0 = Control
G_1 = GA_3 (100ppm)
G_2 = BAP (50ppm)