GROWTH AND YIELD RESPONSE OF POTATO GERMPLASM TO TRICHODERMA AS BIO-STIMULATOR

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It is a fact that the remembrance of Allah brings peace in the heart. It is better to ponder over the verses to bring us even closer to Allah (swt).

DEDICATED TO-

POTATO GROWERS IN BANGLADESH

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CERTIFICATE

This is to certify that the thesis entitled ***"GROWTH AND YIELD RESPONSE OF POTATO GERMPLASM TO TRICHODERMA AS BIO-STIMULATOR"*** *submitted to the Department of Horticulture, 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 authentic research work carried out by* ***MD. RAKIBUZZAMAN****, Registration No.* ***16-07557*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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- Author

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ABSTRACT

A field experiment was accomplished in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2016 to March 2017 to evaluate the bio-stimulating effect of Trichoderma on potato germplasm. Potato germplasm viz. G_1 (Sokal), G_2 (Bijita), G_3 (JP Blue yellow), G_4 (JP Blue white), G_5 (Burma-1), G_6 (Burma-2), G_7 (Cardinal as check) and Trichoderma application : T_0 (No trichoderma application), T_1 (Once application), T_2 (Twice application) were used in this experiment arranged in Randomized Complete Block Design with three replications. Data on different growth, physiological and yield attributes parameters were taken in which all the treatment showed significant variations. Among germplasm, maximum tuber length (8.98 cm), tuber weight (133.4 g), yield/ hill (0.54 kg), dry matter content (17.48 %) were found from G_1(Sokal) whereas minimum in germplasm G_4 (JP Blue white) and for trichoderma application, maximum tuber number (5.05), tuber length (7.75 cm), tuber weight (106 g), total yield (34.4 t), dry matter percentage (19.99) found in twice application. Maximum yield per hectare (38.92 t) were found in G_1T_2 and minimum (21.7 t) in G_4T_0. Trichoderma two times spray significantly decreased the disease infestation. In view of overall performances, germplasm G_1 with twice application of trichoderma has potentiality for quality potato production.

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ABBREVIATIONS AND ACCORONYMS

AEZ	=	Agro-ecological Zone
Agric.	=	Agricultural
ANOVA	=	Analysis of Variance
BARI	=	Bangladesh Agricultural Research Institute
Biol.	=	Biology
Cv	=	Coefficient of variance
DAP	=	Days after planting
et al.	=	And others
Ex.	=	Experiment
FAO	=	Food and Agriculture Organization
g	=	Gram
Hort.	=	Horticulture
i.e.	=	That is
J.	=	Journal
Kg	=	Kilogram
LSD	=	Least Significance difference
mm	=	Millimeter
RCBD	=	Randomized Complete Blocked Design
Res.	=	Research
SAU	=	Sher-e-Bangla Agricultural University
Sci.	=	Science
spp.	=	Species
Technol.	=	Technology
UNDP	=	United Nations Development Programme
Viz.	=	Namely

CHAPTER I
INTRODUCTION

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important vegetables crops in the world, belongs to the family Solanaceae which is originated from the Andean region (Hawkes, 1978). Potato is considered the king of all vegetables because of taste and nutrition and demand. It is the 3rd most consumed food crops in the world just after rice and wheat (Champouret, 2010). The potato is herbaceous annual plant and propagated by planting pieces of tuber. Tuber is rich in starch and is good source of protein, vit. B, vit. C, Potassium, phosphorus and iron. In Bangladesh, potato is used as vegetables, chop, chips, flakes, French fry and so on. In recent year, bakeries and fast food shop have started preparing potato based food delicacies.

There are more than 5000 germplasm available worldwide. Among them large parts are consumed as table potato and a few are utilized as industrial purposes. Potato cultivation is gaining popularity in Bangladesh and production is increasing day by day. Basically, in Bangladesh potato has been categorized as two grouped i.e deshi or local varieties and modern or HYV. Deshi varieties are low yielding and not suitable for industrial purposes as a result farmers deprive from their profit whereas HYV are high yielder. Evaluation of potato germplasm is needed for suitable variety for continuous production. So, there is a need to evaluate germplasm for higher yield and to identify the suitable group for desirable purposes like industrial raw material, table potato demand.

However, Potato plant growth and tuber yield is affected by several fungal diseases which reduce the yield as well as market value. *Phytophthora spp, Rhizoctonia solani* are the serious fungal pathogen. Late blight of potato caused by *Phytophthora infestans* is an important diseases in potato growing areas around the world and crop losses due to this can reach 50% (Goodwin et al., 1994). Farmers used various fungicides to control the fungal affect in the potato field which increases chemical hazardous situation. To control the

fungal disease as well as to improve the crop growth and development, application of fungicides and chemicals against pathogen is not cost effective and environment friendly.

On the other hand, biological control agent may combat the disease and enhance plant growth and development. Trichoderma is a free living fungi, contains many strains and species, of which some are saprophytic while others are pathogenic to other fungi such as pythium, phytophthora. It is used in agricultural biotechnology and widely used as biological control agent against important aerial and soil borne pathogen. It is also used as a biostimulants. Trichoderma is formulated and marketed as biological agent to control different fungal pathogen and have significant effect on growth and yield. By application of *Trichoderma spp*. on crops yields were increased significantly (Elad et al., 1981). Trichoderma have substantial direct influence on plant development and crop productivity (Harman, 2006). The application of trichoderma to the soil as a biological agent not only resulted to reduce disease severity but also enhanced plant growth and development as stimulator (Inbar et al., 1994). Based on other study found that trichoderma as a bio-fertilizer for reduce potato disease, increase potato root zone & nutrients availability and absorbed that trichoderma promotes growth, yield attributes, yield and quality of crops under field conditions, increase yield and quality of Potato.

Objectives

1. To study the bio-stimulating effect of Trichoderma on potato germplasm
2. To study the performance of different potato germplasm

CHAPTER II
REVIEW AND LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Potato (*Solanum tuberosum* L.) is one of the most important vegetables crop in Bangladesh as well as many countries of the world. However, its demand and production is increasing day by day. Lack of industrial potato variety is the crucial issue and Late blight of potato caused by *Phytophthora infestans* is an important disease in Bangladesh. Farmers basically produce table potato and for controlling the disease uses chemical fungicides. *Trichoderma spp*. is biological control agent have stimulating effect to increase growth and yield as well as combat the disease as eco-friedly. Therefore, information available regarding trichoderma and potato germplasm and other crops has been reviewd and presented in this section.

Ahmad et al. (2011) conducted an experiment to compare the growth and yield of five promising cut rose (*Rosa hybrida* L.) cultivars in two production systems viz. greenhouse and field under agro-ecological conditions of Faisalabad, Pakistan on all the plant growth parameters. Among cultivars, Rosy Cheeks and Whisky Mac had vigorous vegetative growth while Amalia and Anjlique produced higher flower yield of best quality than other cultivars compared in the study. Therefore, Amalia and Anjlique are preferred cultivars for commercial production than Rosy Cheeks, Whisky Mac and Kardinal.

An experiment was carried out to study the morphological characteristics and yield potentialities of 23 potato varieties viz., Almera, Ampera, Asterix, Aziza, Courage, Dheera, Diamant, Eldena, Espirit, Felsina, Granola, Innovator, Ladyolympic, Lady Rosetta, Laura, Marbel, Markies, Melody, Processor, Provento, Quiney, Remarka and Terragold. The varieties Lady Rosetta, Diamant, Provento, Granola and Dheera showed greater number of seed tuber emergence (>90%) while Terragold, Ladyolympic, Processor, Laura, Remarka and Almera showed poor performance (<40%) within 20 days after planting. Plant height ranged between 37 to 76 cm. Highest number of sprout per hill

was produced in Diamant (8.53) followed by Innovator or Asterix while the lowest in Ladyolympic (2.73). The Largest canopy foliage expansion was noticed in Diamant (93%) followed by Quincy, Dheera and Innovator, and minimum (47%) in Ladyolympic (Awal et al., 2007).

Amanullah et al. (2010) conducted an experiment in farmer's field in the village of AraziPostompur under sadar thana of Thakurgaon district to study the effect of different irrigation regimes on the yield and yield contributing characters of high yielding potato varieties namely Binella, Cardinal, Chamak and Heera. Five irrigation treatments: no irrigation, irrigation at IW/CPE ratios of 0.25, 0.50, 0.75 and 1.00 were tried in the silty loam soil of the Himalayan Piedmont Plain having pH value 5.3, average bulk density 1.43 gm/cc and field capacity 26.85% (dry basis). The experiment was laid out in split plot design and replicated thrice. Among all the varieties Chamak was found to be superior in respect of tuber yield followed by Heera, Binella and Cardinal under the different irrigation regimes.

Baker et al. (1991) observed that *Trichoderma* spp. were more efficient biocontrol agents and induced greater increased growth responses from a seed treatment than wild-type parents.

Capezio (1987) studied an experiment to find out the effects of season and tuber size on dry matter and starch contents of potato and were laid out in a randomized complete block design with three replications. A linear positive relationship was observed between the *Trichoderma spp*. and the dry matter content.

Dam et al. (1999) conducted a study to genetic characterisation of tetraploid potato (*Solanum tuberosum* L.) emphasising genetic control of total glycoalkaloid content in the tubers in Netherland. . The populations were used, in replicates, to estimate genetic parameters for total glycoalkaloid (TGA)

content in the tubers, and for other agronomic and morphological traits such as tuber weight, dormancy and plant height. The minimum number of tubers genes contributing to TGA-content was estimated to be between 3 and 7.

Dutta and Banik (2007) studied a designed to determine the effect of foliar feeding of nutrients and plant growth regulators on physico-chemical quality of guava cv. sardar grown in red and lateritic tract of West Bengal. Nutrients and plant growth regulators were administered three times. viz. before flowering, followed by second and third at fruit setting and three weeks after fruit setting. Experimental results revealed that foliar feeding of nutrients and plant growth regulators significantly increased the fruit length, diameter, individual fruit weight and ultimately crop yield. Maximum (6.24 cm) length of fruit was obtained with the treatment. This treatment also found effective in maximizing individual fruit weight and crop yield. The bio-chemical constituents were also influenced by different spraying of nutrients and growth regulators.

A field experiments was conducted on *Trichoderma harzianum* preparations used in commercial strawberry nurseries and fruiting fields. Disease severity of *Rhizoctonia solani* in daughter plants was reduced by 18–46 % in the treated nursery plots. Infestation of nursery soil with the pathogen, as tested by planting beans in soil samples was reduced by the Trichoderma treatment by up to 92% as compared to the untreated control. A rapid decline of the disease was observed in soil from T. harzianum treated plots, successively planted with bean seedlings. *Trichoderma* sp. had antagonistic to *R. solani*, were found in the infested field as compared to the non-infested. *Trichoderma harzianum* treated plants, transferred to the commercial field gave a 21–37% increase in early yield of strawberries. A combined treatment in the nursery and in the fruiting field resulted in a 20% yield increase as compared to control plots (Elad et al., 1981).

Evans (1998) conducted an experiment to find out the efficacy of nitrogen and Photosynthesis in the Flag Leaf of Wheat. The amounts of chlorophyll, soluble protein, nitrogen, and phosphorus were determined for each flag leaf and found that chlorophyll content and RuP_2 carboxylase activity were approximately proportional to leaf nitrogen content.

Fatima, et al. (2015) studied the antagonistic effect of trichoderma against phytophthora disease and 38 *Phytophthora infestans* isolates were obtained from leaves, tubers and stems of infected crops of potato and tomato in different regions of the North West of Algeria in 2010, 2011 and 2012. Based on morphological and physiological characteristics, they were tested for the virulence test on potatoes tubers and tomatoes leaves then, for a biological control by using *Trichoderma spp*. as antagonistic agent. Trichoderma species are among important antagonists of plant pathogenic fungi. The main purpose of this study was to evaluate the biocontrol potential of native *Trichoderma harzianum*. Their antagonistic activities including competition and colonization against *Phytophthora infestans* with an inhibition rate of 86%.

An experiment was conducted to evaluate the comparative performance of 11 tomato cultivars in the Northern Areas of Pakistan during 2003. It was found that all parameters showed significant differences among the various cultivars under the trial. Maximum days to first picking (96.40) were recorded in cultivar Local round followed by Shalkot (95.25 days) while Rio grande gave the earliest fruit maturity (82.40 days). Cultivar Local round also showed maximum plant height (110.50 cm), number of branches per plant (10.77) and fruits per plant (98.30) followed by Shalkot, Nagina and Peto-mech-II with 58.47, 51.33 and 46.15 fruits per plant, respectively. The lowest number of fruits per plant (29.47) was found in Nemadina. Cultivar Shalkot attained maximum fruit weight per plant (3.03 kg), fresh fruit yield (68.36 t ha^{-1}) and dry fruit yield (4.49 t ha^{-1}) while cultivar Local round gave the lowest fruit

weight per plant (0.83 kg), fresh fruit yield (20.30 t ha^{-1}) and dry fruit (1.01 t ha^{-1}) yield (Fayaz et al., 2007).

A field experiment was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka from November 01, 2014 to April 30, 2015 to find out the effect of 4 different vermi compost (Vm) levels *viz*., Vm1 (control), Vm (2 t ha^{-1}), Vm3 (4 t ha^{-1}) and Vm4 (6 t ha^{-1}) on growth, yield and quality of 4 potato varieties *viz*., V_1 (BARI TPS-1), V_2 (BARI Alu-28, Lady Rosetta), V_3 (BARI Alu-29, Courage), V_4 (BARI Alu-25, Asterix). The experiment was conducted in spilt plot Design with 3 replications. The variety BARI Alu-28 produced maximum yield (28.89 t ha^{-1}) whereas BARI TPS-1 showed minimum yield (22.95 t ha^{-1}) (Gopal, 2015).

Ganga et al. (2014) conducted an experiment on teen varieties of potato tubers namely kufri, Cipsona, Atlantic, Kufrisurya, Kufri khaytia, Jyoti, Pushkar, Bahar, Ashoka, J-24 revealed that tubers mean length varied significantly between the cultivars ranging from 5.9 cm to 7.6 cm and diameter ranged from 4.4 cm to 5.6 cm. Ashoka showed large mass (113 g), highest volume (106.9cc) and longest diameter (5.8 cm) while pushkar had significantly smallest mass, lowest volume.Highest number of natural depressions were found in Cipsona while Kufri khaytia produced highest slices (84.0 %) as well as chips (22.83%) and thus ranked first.

Harman (2006) observed that *Trichoderma spp*. be used in reasonably large quantities in plant agriculture, useful for disease control and yield increases.

Harman et al. (2004) conducted a study to evaluate the *Trichoderma spp*. on plant that common in soil and root ecosystems. Recent discoveries show that they are opportunistic, avirulent plant symbionts, as well as being parasites of other fungi. They produce or release a variety of compounds that induce localized or systemic resistance responses, and this explains their lack of

pathogenicity to plants. These root-microorganism associations cause substantial changes to the plant proteome and metabolism. It was highly remarkable that plants are protected from numerous classes of plant pathogen by responses that are similar to systemic acquired resistance and rhizobacteria-induced systemic resistance. Therefore, root colonization by *Trichoderma spp*. also frequently enhances root growth and development, crop productivity, resistance to abiotic stresses and the uptake and use of nutrients.

Hasan et al. (2013) conducted an experiment at seed production centre, Debigonj, Bangladesh and observed that the tallest (85.71 cm) plant was found in the germplasm LB6 and the shortest (44.23 cm) in the Diamont and Diamant had more under sized (below 28 mm) tubers (95.0 tubers) and LB7 had the least (39 tubers). Tuber weight also showed similar results. The clone LB7 produced more marketable (28-55 mm size). The highest yield (49.69 t ha^{-1}) and dry matter content (21.32 %) were produced by LB7 followed by LB3.

A field trial was conducted to optimize the sowing date and crop growth period of potato at the Agricultural Research Institute, Dera Ismail Khan, North-West Frontier Province (NWFP), Pakistan during 2004-05. The tubers were planted on four dates with one-week interval in 2004. Total numbers of tubers per unit area and percentage of large sized tubers (> 55 mm) were the highest at the earliest planting of September 24. Smaller tubers (< 35 mm) increased with delay in planting. Total tuber yield was higher at earlier planting as compared to planting at later dates. However, dry matter was higher at delayed planting. Plant dry bio-mass was higher by planting the potato earlier. Harvesting potato at various intervals also affected these parameters significantly. Total number of tubers, percent larger and medium sized tubers, tuber yield and plant dry bio-mass increased with the delay in harvesting. Therefore, dry matter in tuber was found higher at earlier harvestings (Khan et al., 2011).

Linta et al. (2018) conducted an experiment at Horticultural farm, Sher-e-Bangla Agricultural University, during the period from October 2014 to April 2015 to evaluate the growth and yield characteristics of twenty two potato germplasm (G_1-G_{22}). The experiment was laid out in randomized completely block design (RCBD) with three replications. The tallest plant was found from G_1 (107.0 cm) and maximum stems hill^{-1} was found from G_{19} (5.00). The highest yield t ha^{-1} was found from G_{13} (29.9 t ha^{-1}).

Lo and Lin (2002) studied several strains of *Trichoderma spp*. isolated from rhizosphere soils and rhizoplane of agricultural crops Taiwan were selected to detect the root growth of bitter gourd, loofah and cucumber. Among the strains some species of Trichoderma in the study promoted the root growth of these cucurbitaceous crops as compared with untreated plants. Tests in greenhouse showed the strains of the Trichoderma species significantly increased of 26 to 61% in seedling height, 85-209% in root exploration, 27 to 38% in leaf area, 38 to 62% in root dry weight for 15 days after sowing seeds of bitter gourd. Similarly, Trichoderma strains also increased seedling growth of loofah and cucumber chlorophyll and the results indicated that the concentration of chlorophyll was significantly increased in the plants treated with Trichoderma.

Lorito et al. (2010) reviewed the case of *Trichoderma spp*. the most widely applied biocontrol fungi, which have been extensively studied using a variety of research approaches, including genomics, transcriptomics, proteomics, metabolomics, etc. Known for almost a century for their beneficial effects on plants and the soil, those were the subject of investigations that represent a successful case of translational research, in which ‘omics-generated novel understanding is directly translated in new or improved crop treatments and management methods. The study presented an overview of the latest discoveries on the Trichoderma expressome and metabolome, of the complex and diverse biotic interactions established in nature by these microbes, and of their proven or potential importance to agriculture and industry.

Lynch et al. (1991) conducted an experiment where a variety of strains of Trichoderrna cultured on a molasses medium were added to a peat/sand potting compost at 1% and 0.1 "h dry w/w. When lettuce (*Lactuca satiua* L) seeds were planted in the compost, some strains of the fungus prompted seedling emergence and produced larger plants, while other strains had an inhibitory effect on those processes. The study clearly indicated the potential of specific strains of Trichoderma to consistently increase plant growth.

Mahmud et al. (2014) conducted an experiment of four CIP potato clones with 1 check variety Asterix were produced during 2010-11 and 2011-12 at Horticulture Research Farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh to study the effect of water stress on canopy structure, yield and growth rate of potato. The study validated that all the genotypes showed reduction in plant height, number of above ground shoots per plant, tuber number per plant and yield by different degrees of drought. Significant yield reduction was found among the genotypes due to drought treatments. Genotype CIP 396244.12 and CIP 393371.58 performed better and producing higher number of tuber per plant and yield. CIP 396244.12 produced the highest leaf area index in all drought treatments whereas the CIP 391004.18 produced the minimum. In growth stage, crop growth rate was affected by drought treatments where CIP 396244.12 showed the highest crop growth rate followed by CIP 393371.58 and CIP 391004.18 being the lowest. In severe and moderate drought condition genotype CIP 396244.12 maintained a higher tuber growth rate but under well watered condition CIP 396244.12 and Asterix achieved superior.

Masarirambi et al. (2012) conducted a field study carried out with the potato (*Solanum tuberosum* L.) variety BP1 to determine the influence of plant population density and seed tuber size on the crop's physiological growth components and yield performance under optimal field conditions. Two factors considered were seed tuber size and population density. Factor A, involved

four seed sizes: S_1 (small), 200-350 mm; S_2 (medium), 350-450 mm; S_3 (large), 450-550 mm and S_4 (very large), greater than 550 mm and Factor B, was population density (E) with three levels: level 1 at 90 by 15 cm, level 2 at 90 by 30 cm, level 3 at 90 by 45 cm spacing. Shoot emergence (germination), haulm growth and yield were the parameters. Significant variation in mean percentage germination at 9, 10, 11 and 12 days after planting across the four seed sizes. It has observed that plant population density for good yield was 90 by 30 cm and that large and very large seed sets gave the best yield.

Mehraj et al. (2014) conducted an experiment at Horticultural farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to asses the response of foliar application of GA3 with different concentrations to cherry tomato plants. The assessment expressed that the foliar application of 200-ppm gibberellic acid solution provided maximum number of leaves (16.7), the tallest plant (70.0 cm), early flower bud initiation (13.0 days), early flowering (16.0 days) and early fruiting (20.3 days); utmost fruit diameter (25.9 mm) and number of fruits (105.0 fruits) per plant; maximum single fruit weight (11.1 g) and total fruit weight (1.2 kg) per plant, whereas the control was the lowest.

An experiment was carried out to evaluate the potentiality of plant rhizosphere associated bacteria for the biocontrol of potato black scurf disease caused by *Rhizoctonia solani* Khun AG-3. Twenty-eight bacteria isolated from diseased and healthy potato plants grown in the soil of Naran and Faisalabad, Pakistan were evaluated for their antagonistic potential. Nine bacterial strains were found to be antagonistic in vitro, reduced the fungal growth and caused the lysis of sclerotia of *R. solani* in dual culture assay as well as in extracellular metabolite efficacy test. Selected antagonistic bacteria were also characterized for growth promoting attributes i.e., phosphate solubilization, nitrozen fixation and IAA production. Biocontrol efficacy and percent yield increase by these antagonists was estimated in greenhouse experiment. Statistical analysis

showed that two *Pseudomonas spp*. StT2 and StS3 were the most effective with 65.1 and 73.9 percent biocontrol efficacy, as well as 87.3 and 98.3 percent yield increase, respectively. Potential antagonistic bacterial strain StS3 showed maximum homology to Pseudomonas sp. as determined by 16S rRNA gene sequencing. These results suggest that bacterial isolates StS3 and StT2 have excellent potential to be used as effective biocontrol agents promoting plant growth with reduced disease incidence (Mohsin et al., 2010).

Montaser et al. (2014) studied the antagonistic activity of five Trichoderma species (*Trichoderma spirale, T. hamatum, T. polysoprium, T. harzianum and T. viride)* against *F. oxysporium* f. sp. melongenae was evaluated using dual culture technique. *T. viride* (isolate TVM-5) and *T. hamatum* (isolate THM-2) showed the highest antagonistic activity, while *T. spirale* (TSM-1) was the lowest one. In pot experiment, the obtained data showed that all Trichoderma species reduced significantly area under wilt progress curve caused by *F. oxysporum*. *Trichoderma viride* and *T. hamatum* recorded the highest reduction of area under wilt progress curve (AUWPC) (244.0 and 325.33 AUWPC as compared to 1125.33 in control treatment, respectively). Under field conditions results showed that, these treatments significantly reduced AUWPC and increased all tested plant growth parameters (Plant height, No. of branches plant^{-1}) and fruit yield components (number of fruits plant^{-1}, fruits yield plant^{-1}, fruit weight, No. of fruit kg^{-1}, fruit length, fruit diameters and fruits yield fed.$^{-1}$) compared with control during growing seasons (2011-2012 and 2012-2013*). Trichoderma viride* and *T. hamatum* were the best biocontrol agents as manifested by the significant reduction in both disease severity and increase plant growth parameters and fruit yield components.

Musa et al. (2009) conducted an experiment during the growing season 2006 and 2007 eight potato varieties from Netherlands: Kondor (as standard check), Agria, Agata, Sinora, Virgo, Aladin, Armada, Riviera and Romano, were tested in the fields of the Agricultural Research Institute of Peja. The experiment was conducted at two most important agro-climatic regions for potato production in

Kosova, Vitomirica (Dukagjini plain) and Pestova (Kosova plain). The experiment laid out in randomized block design with three replications. All the varieties were treated in the same manner from planting till harvesting. Potato tubers of two inner rows were analyzed for parameters such as tuber yield, dry matter content and some other relevant parameters. The findings have shown that there are highly significant differences as for the tuber yield and dry matter content, among tested potato varieties. The highest tuber yield was realized with variety Aladin (32.89 kg) while the lowest with variety Riviera (26.19 kg). The highest content of dry matter was realized with variety Agria (19.92%) and the lowest one with variety Armada (12.26%). The results of other parameters like colour of skin, colour of flesh, disintegration of the flesh after cooking, crisps and pomfrit were shown to be different with regard to the varieties under testing.

A field experiment was conducted during rabi-2010 to find out the response of foliar application of micronutrients on vegetative and reproductive growth attributes, in two varieties of tomato viz. Utkal Kumari and Utkal Raja. The treatments consisted of boron, zinc, molybdenum, copper, iron, manganese, mixture of all and control and the experiment was laid out in RBD with three replications. All the treatments resulted in improvement of plant growth characteristics viz. plant height, number of primary branches, compound leaves, tender and mature fruits per plant in both the varieties out of which application of micronutrients mixture showed the maximum effect. In both the varieties, combined application of micronutrients produced the maximum fruit yield followed by application of boron and zinc (Naga et al., 2013).

Three rhizosphere fungal isolates viz., PGPFYCM2, PGPFYCM-8 and PGPFYCM-14 of *Trichoderma harzianum*, applied as seed treatment to a highly susceptible sunflower cultivar were evaluated for their ability to promote growth and induce resistance in sunflower against downy mildew disease caused by *Plasmopara halstedii*. Treatment of sunflower seeds with both conidial suspension significantly promoted growth and reduced disease

incidence under both greenhouse and field conditions. Among the treatments, PGPFYCM-14 was highly significant (P00.05) in inducing resistance of 63 and 69 %, followed by PGPFYCM-2 which offered 41 and 42 % disease protection under greenhouse and field conditions respectively. There was a significant increase in NPK macronutrients uptake in all the treated plants compared to the untreated control and maximum NPK uptake was observed with PGPFYCM-14 Under in vitro conditions and increased in seed germination and vigour index over the control. Tested plant growth promoting fungal (PGPF) isolates remain significant in enhancing vegetative and reproductive growth parameters, including plant height, early flowering, reduced crop duration, ear head size and crop yield under field conditions when compared to the untreated control (Nagaraju et al., 2012).

Olotuah and Fadare (2012) conducted a study to determine the seed quality variation within 5 varieties of *Vigna unguiculata*; Ife brown, Drum, Sokoto, Oloyin and Erusu. These varieties were replicated thrice, with each replicate having 5 seeds per pot. The pots were labeled for easy identification while the necessary agronomic practices were performed. It was observed that there were significant differences on the growth parameters taken while in the proximate analysis on the harvested seeds, Ife Brown had the highest protein content of 36.75%.

Padmavathi (2013) conducted a study to evaluate the capability of the bio-control agent *Trichoderma harzianum* to trigger plant growth and improvement in biomass response was investigated by inoculating roots of medicinal plant (*Ocimum sanctum*) seedlings with *Trichoderma harzianum* inpots, under aseptic, green house environmental conditions. *Trichoderma harzianum* was isolated from ten different agro climatic zones of Karnataka. Biological and biochemical analysis revealed that inoculation with *T. harzianum* initiated increased Phosphate (P), Nitrogen (N) and soluble sugars uptake by the *O. sanctum* plants. Inoculation with *T. harzianum* increased the biomass of the

plants in terms of height, number of leaves and number of branches, providing evidence that *T. harzianum* induce growth and increased biomass mechanisms in plants. The whole cell protein was extracted from all the ten isolates of *T. harzianum* and then subjected to electrophoresis (SDS-PAGE). The protein profile on the gel was scored and the dendrogram was constructed using Phylip software of *T. harzianum*. Exploiting bio-control agents to enhance the plant growth and biomass production of medicinal plants is a topic of current interest.

Pulok et al. (2016) studied the effect of potassium (K) and mulch materials on grading of different types of tuber were investigated at the Agronomy research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2013 to March 2014. The experiment consisted of four different doses of K viz., 0 kg K ha^{-1}, 100 kg K ha^{-1}, 125 kg K ha^{-1}, 150 kg K ha^{-1} and four different types of mulch materials viz., soil mulch, rice straw, water hyacinth and saw dust and was laid out in a split plot design with 3 replications. Maximum large sized tubers were produced by 150 kg K ha^{-1} with rice straw mulch. Application of 125 kg K ha^{-1} with rice straw produced maximum seed potato and tuber for French fry. Without K and soil mulch produced highest tuber for chips (% by t ha^{-1}).

An experiment was conducted at Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka during the period March to October 2016 to evaluate the growth and yield characteristic of eight brinjal varieties (V1, Green Round, V2, Bankim Purple Long, V3, Debjhuri Hajari, V4, Black Magic, V5, Muktojhuri, V6, Green Express, V7, Black Boy, V8, Tal Begun). The experiment was laid out in Randomized Completely Block Design (RCBD) with three replications. Significant variations were found within the varieties. The highest plant height (60.7 cm), number of branches $plant^{-1}$ (8.3), number of leaves $plant^{-1}$ (77.0), maximum individual leaf area (200.0 cm^2) number of flowers $plant^{-1}$ (41.0), largest fruit size (185.7 cm^2), and maximum

fruit yield (47.1 t ha^{-1}) were observed in variety Green Express (V6), giving it superiority over all other varieties (Rahul et al., 2017).

A research entitled Influence of Trichoderma on Photosynthesis, drymatter partitioning and nutrient uptake in sunflower was conducted at the students farm, College of agriculture, Rajendranagar, Hyderabad, 2014-15. The field trail was conducted following randomized block design with three replications and ten treatments viz. *Trichoderma harzianum*-Th4d, *Trichoderma asperellum*-TaS1, *Trichoderma asperellum*- Tv5, *Trichoderma sps*-Ta DOR673, *Trichoderma koningii*, *Trichoderma asperellum*- TaDOR7316, *Trichoderma virens*, *Trichoderma asperellum*- N13, *Trichoderma hamatum*, and one control. The morphological traits such as plant height, number of leaves and physiological indices such as LAI, CGR, RGR, NAR, SCMR and photosynthetic rate were evaluated at 15 days interval. Results of the morphological characteristics showed that highest and lowest plant height were recorded in Trichoderma. Maximum SPAD values were recorded in Trichoderma asperellum-TaS1 throughout the crop growth period except at 15 DAS. At 15 DAS Maximum SPAD values were recorded in Trichoderma sps-Ta DOR 673. Highest total dry matter yield attributes like diameter of head, head weight, number of filled seed per head, 100 seed weight and harvest index was increased in treated plants compared to control plants. Among the treatments *Trichoderma asperellum*-TaS1 and *Trichoderma sps*-Ta DOR673 recorded better values for morphological, physiological characters and yield attributes over other treatments and control plants (Ramyasri, 2015).

Ranjbar et al. (2012) studied the phenotypic diversity of potato, *Solanum tuberosum* was assessed using morphological traits to verify the diversity among the main potato varieties in the growing areas in Iran. Eleven potato varieties, Ramose, Sante, Shepody, Marfona, Maradona, Milova, Santana, Boren, Cosima, Granola and Agria, were evaluated under vivo and situ experimental conditions in Isfahan, conditions, Iran. Seven phenological, floral

and morphological vegetative aerial descriptors, Crop Growth Rate (CGR), Net Assimilation Rate (NAR), Leaf Area Duration (LAD), Leaf Area Ratio (LAR) and specific Leaf Area (SLA) were recorded. Certain defined groups were observed, indicating that the diversity of the cultivars were structured with a considerable morphological variation in between the varieties with a very high significant growth indices.

Roslee et al. (2017) reported that *Trichoderma spp*. have several mechanisms and positive effects to enhance plant growth. The effectiveness of *Trichoderma spp*. to promote *B. juncea* growth was evaluated experimentally using completely randomized design under greenhouse condition. *B. juncea* has been treated by two types of treatment namely *Trichoderma spp*. treatment and control treatment. The study indicated that the treated *B. juncea* with *Trichoderma spp*. significantly increased plant height (<0.001), leaf number (0.001), root length (0.007), root fresh weight (<0.001) and root dry weight (<0.001) compared to the untreated plants (control). In fact, the treatment of *Trichoderma spp*. also showed significant result on the chlorophyll relative content (0.028). The study concluded that *Trichoderma spp*. can be applied as potential growth promoting agent in B. juncea cultivation and at the same time, the use of *Trichoderma spp*. can assist the farmers in improving the agronomic state.

A study was conducted to determine the effects of varying light intensity and nitrogen nutrition on photosynthetic physiology and biochemistry were examined in the sun plant *Phaseolus vulgaris* (common bean) and in the shade plant *Alocasia macrorrhiza* (Australian rainforest floor species). Thus, the RuBPCase/chlorophyll ratio was quite responsive to N availability and light intensity in both species (but for different reasons), ranging from 6 grams per gram for Phaseolus and 2 grams per gram for *Alocasia* at high leaf N and 1.5 gram per gram for *Phaseolus* and 0.5 gram per gram for *Alocasia* at low leaf N. These large changes in the proportions of components of the photosynthetic

apparatus had marked effects on the sensitivity of these species to photoinhibition (Seemann et al., 1987).

A field experiment was conducted during 2015 to 2016 at the Agricultural Research Farm, Institute of Agricultural Sciences, and Banaras Hindu University. Aim of this present study was to see the effect of super absorbent polymer (hydrogel) and Trichoderma fungus on growth and quality of linseed varieties. Hydrogel and Trichoderma and its combination found effective to improving growth, yield and quality attributes of linseed. Results of the study found that Furrow application of hydrogel @ 5 kg Trichoderma treated seed @ 10 g kg^{-1} significantly improves the plant height, plant biomass, number of branches, seed yield, protein content, protein yield and oil yield. Highest protein content was recorded with variety Garima but oil content was found maximum with variety Deepika. Protein and oil yield was maximum with variety RLC-92 (Singh, 2018).

Srivastava et al. (2006) studied that *Trichoderma harzianum* and *T. viride* were significantly effective in improving germination (6-14%), tiller population (21-78%), millable canes (5-30%), yield (6-38%) and CCS t/ha (30-34%) over the control in plant cane of CoS 94257. The metabolites improved tiller count (53-78%), millable canes (27-30%) and yield (34-38%). The yield boost up by the metabolites was up to 81.9 t/ha with *T. viride* and 79.8 t/ha with *T. harzianum* over 59.3 t/ha of control. The differences in yield due to both the species were significant. *T. viride* alone was tested for improving the yield of ratoon. The emergence of clumps was enhanced with spore suspension, TMC and metabolites of *T. viride*. The metabolites were, significantly superior for increasing the number of clumps (43.2%) than the other treatments (1.7-20.1%) and control. *T. viride* metabolites were also better for producing more tillers (75%) and millable canes (40%). The improvement in yield ranged from 53.16 t/ha to 76.31 t/ha with metabolites and 72.13 t/ha with double dozes of TMC, half applied at clump emerging stage and half at tiller stage. CCS t/ha was also enhanced in ratoon crop by 40% with metabolites and 36% with double dozes

of TMC. Application of *T. harzianum* and *T. viride* was found to be economical, non-hazardous and useful for soil health.

Uddin et al. (2017) studied the potentiality of trichoderma as consistent plant growth stimulators of strawberry at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, during January 2015 to April 2015. Four concentrations of trichoderma, viz. T_0, control; T_1, 100 g/m^2; T_2, 200 g/m^2 and T_3, 300 g/m^2 were applied in randomized completely block design with four replications. Number of runner, number of stolon, chlorophyll percentage, plant survival percentage (%), number of fruits/plant, fruit length (mm) , fruit diameter (mm), fruit weight (g), total fruit weight (g/plant) were showed significant variation among all treatments. Results showed that the highest fruit yield/plant found in T_1 (702.9.0 g), whereas minimum (220.05g) from T_2. Rate of survival ability of strawberry plants observed the highest (79.5) in T_1 (100 g/m^2) and the lowest (42.7) was in control.

A field experiment was carried out at the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka, during mid-January 2015 to end April 2015, to evaluate the performance of *Trichoderma spp*. on growth and yield of BARI tomato-14. Four Trichoderma treatments were performed, i.e T_0,0 Control; T_1, 100 g/m^2 ; T_2, 200 g/m^2 and T_3, 300 g/m^2 in Randomized Completely Blocked Design with three replications. All parameters of tomato plant showed significant variation among Trichoderma treatments. Highest percentage of survival observed in 100 g/m^2 and lowest was controlled. On the other hand, chlorophyll percentage was maximum for T_2 (69.4%) and minimum (43.2%) was in control (T_0). Moreover, highest yield/plant (3.0 kg) obtained for 100 g/m^2 treatments of Trichoderma and lowest (1.4 kg) was for control (Uddin et al., 2016).

Uddin et al. (2014) conducted an experiment to evaluate the effects of trichoderma on growth and yield of tomato. Four different trichoderma concentrations were used as treatments, viz., T_0, control; T_1, 100 g/m^2 ; T_2, 200

g/m^2 and T_3, 300 g/m^2 and was conducted in randomized completely block design (RCBD) with four replications. Trichoderma concentrations were showed significant variation among the growth and yield characteristics of tomato. Highest yield per plant of tomato (3.0 kg) obtained in T_1 (100 g/m^2) treatment and lowest (1.4 kg) was in control. Results also revealed that T_1 (87.1%) showed the higher seedling survival rate than the control (57.9%).

A study was conducted to control the late blight by some strains of the *Trichoderma* genus were used as agents and were able to control many plant disease in crops. Antifungal metabolites produced by the isolate HNA14 significantly prevented the linear growth of the *P. infestans* colony. Mycoparasitism appeared to contribute to the aggressive nature of the *Trichoderma* isolate HNA14 against *P. infestans* when observed under scanning electron microscope (SEM). In planta bioassay, the isolate HNA14 significantly reduced the disease index, increased the plant stem height, and foliar fresh and dry weight. Under field conditions, the *Trichoderma* isolate HNA14 was the most efficient against the pathogen out of all *Trichoderma* strains, and significantly reduced the disease severity compared to the control. Collectively, the strategic approach described in this paper demonstrates an effective way of screening a biocontrol agent for control of potato pathogens (Yanpo et al., 2015).

CHAPTER III
MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

A field experiment was accomplished at the Horticultural Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh during the period from November, 2016 to March, 2017 to observe the performance of potato germplasm to Trichoderma. This chapter contains a brief description of location of the experimental site, climatic condition and soil, materials used for the experiment, treatment and design of the experiment, production methodology, intercultural operations, data collection procedure and statistical and economic analysis etc. which are presented as following headings:

3.1 Experimental sites

The experiment was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, during the period from November, 2016 to March, 2017 to study the performance of seven potato germplasm to different times of Trichoderma application. The location of the site is $23^0$74' N latitude and $90^0$35' E longitudes with an elevation of 8.2 meter from sea level (Anon., 1989) in Agro-Ecological Zone of Madhupur Tract (AEZ No. 28).

3.2 Climatic conditions

The experiment site was located in the subtropical monsoon climatic zone, set aparted by heavy rainfall during the months from April to September (Kharif season) and scanty of rainfall during the rest of the year (Rabi season). In addition, under the sub-tropical climatic, which is individualized by high temperature, high humidity and heavy precipitation with seasonal unexpected winds and relatively long in Kharif season (April- September) and sufficient sunlight with moderately low temperature, intensity of humidity and short day period of during Rabi season (October-March). The information of weather regarding the atmospheric temperature, relative humidity, rainfall, sunshine

hours and soil temperature persuaded at the experimental site during the whole period of observation (Appendix I).

3.3 Characteristics of soil

The experimental soil belongs to the Modhupur Tract under AEZ No. 28 (UNDP-FAO, 1988). The land which selected was medium high and the soil series was Tejgaon. The soil characteristics of experimental plot were analyzed in the SRDI, Soil Testing Laboratory, Khamarbari, Dhaka and the experiment field primarily had a Ph of 6.5.

3.4 Experimental materials

3.4.1 Planting materials

Sokal, Bijita, JP Blue Yellow, JP Blue White, Burma-1, Burma-2 and Cardinal (as standard check) potato germplasms were used in this experiment. The genetically pure and healthy seed tubers were collected from different sources with in India, Japan and Burma.

3.4.2 Trichoderma preparation

Trichoderma added with autoclave water for prepared trichoderma viride solution. This liquid *Trichoderma* collected from ACI.

3.5 Treatments of the experiment

The experiment was conducted to detect the performance of mentioned potato germplasms to *Trichoderma* on growth, yield and quality attributes. There were two factors in this experiment. They were as follows:

Factor A: Germplasm

In experiment, seven different germplasm were used. These were –

G_1 - Sokal,

G_2 - Bijita,

G_3 - JP Blue Yellow,

G_4 - JP Blue White,

G_5 - Burma-1,

G_6 - Burma-2,

G_7 – Cardinal (as check),

Factor B: Trichoderma application

Trichoderma were applied on this experiment are given below:

T_0 - (No Trichoderma application)

T_1 - 100ppm (Single application, 15 Days after germination)

T_2 - 100ppm (Twice application, 15 and 45 days after germination)

Trichoderma were used to this experiment. First application was done 15 DAG and second application was done 45 DAG. Three blocks were assigned for seven potato germplasm and replicated three times in each Trichoderma applications and in control conditions.

The treatment combinations were:

G_1T_0, G_2T_0, G_3T_0, G_4T_0, G_5T_0, G_6T_0, G_7T_0, G_1T_1, G_2T_1, G_3T_1, G_4T_1, G_5T_1, G_6T_1, G_7T1, G_1T_2, G_2T_2, G_3T_2, G_4T_2, G_5T_2, G_6T_2, G_7T_2

3.6 Application of Trichoderma

Application of Trichoderma was done to the potato field soil along with the leaf and the whole plant. First application was done at 15 days after germination period and twice application was done at 45 days after germination. No pesticides and fungicides were used on this experiment (plate 1. d.).

3.7 Design and layout of the experiment

The two factorial experiment was provoked Completely Randomized Block Design (RCBD) with three replications thus comprised 63 plots in the experiment (Figure 1).

3.7.1 Spacing and plot size

The size of each plot was 2.4 m × 1.5 m. The distance between blocks and plots were 0.5 m and 1 m respectively. Row to row distance was maintained 60 cm and plant to plant distance was 25 cm.

3.8 Production methodology

3.8.1 Land preparation

The land was first open by ploughing with the help of power tiller and then it kept open to sun for seven days prior to further ploughing. Afterwards it was prepared by ploughing and cross ploughing followed by laddering. The weeds and stubbles were removed after each laddering. Simultaneously, the clods were broken and the soil was made into good tilth.

3.8.2 Application of manure and fertilizers

In this experiment Urea, TSP and MoP were applied at the rate of 240 kg/ha, 150 kg/ha, and 250 kg/ha, respectively (BARI 2005).

Table 1. Manures and fertilizer with BARI recommended dose along with plot wise application dose

SL No.	Manures/ fertilizers	Recommended Dose
1	Cowdung	10 t/ha
2	Urea	240 kg/ha
3	TSP	150 kg/ha
4	MoP	250 kg/ha

During experiment whole amount of cowdung, half of urea, whole amount of TSP, MoP has been applied at the time of tuber seed sowing. Rest of the urea has been applied 30-35 DAP and 50-60 DAP with three installments followed by earthing up.

3.8.3 Planting of seed tuber

The well sprouted healthy and uniform sized potato tubers were planted according to treatment. Seed potatoes were planted in such a way that potato does not go much under soil or does not remain in shallow. On an average, potatoes were planted at 4-5 cm depth in soil on November 21, 2016.

3.9 Intercultural operations

Following operations were done:

3.9.1 Weeding

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

3.9.2 Irrigation and Drainage

Three times irrigation was done in the field to keep upon moisture status of soil retained as requirement of plants. Excess water was not given, because it always harmful for potato plant.

3.9.3 Top dressing

After basal doses, the remaining doses of urea top dressed in 30-35 days after planting. The fertilizers were applied on both sides of plant rows and mixed with the soil by hand. Earthing up was done with the help of spade immediately after top dressing of nitrogen fertilizer.

3.9.4 Earthing up

Earthing up process was done by pouring the soil in the base of the plant at two times, during crop growing period. First pouring was done at 45 days after planting and second was at 60 DAP.

3.9.5 Roguing

Roguing refers to the act of identifying and removing plants with undesirable characteristics from agricultural fields. Rogues are removed from the fields to preserve the quality of the crop being grown. Diseased plants were removed from the potato field.

3.9.6 Haulm cutting

Haulm cutting was done at 80 DAP, 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. The cut haulm was collected, bagged and tagged separately for further data collection.

3.9.7 Harvesting

Haulm killing was done before seven days of harvesting. The crop was harvested depending upon the maturity of each variety.

3.10 Parameters of the experiment

Data were collected in respect of following parameters:

1. **Growth related parameters**
    a. Plant height (cm)
    b. Number of leaves hill^{-1}
    c. Number of stem hill^{-1}
    d. Days to maturity
2. **Physiological parameters**
    a. Chlorophyll content (SPAD value)
    b. Disease infestation
3. **Yield attributing parameters**
    a. Number of tuber hill^{-1}
    b. Tuber length (cm)
    c. Tuber diameter (mm)
    d. Individual tuber weight (g)
    e. Yield hill^{-1}(kg hill^{-1})
    f. Yield ha^{-1}(t ha^{-1})
4. **Quality attributing parameters**
    a. Dry matter content (%)

3.11 Data collection

Three plants were randomely selected from each unit of plot for the collection of data. The plants in the outer rows and the extreme end of the middle rows were excluded from the random selection to avoid the border effect. However, the yield of of all plants was considered per plot yield. Data have been collected on the basis of four attributed like- growth related parameters, physiological parameters, yield attributing parameters and quality attributes parameters.

3.11.1 Plant height (cm)

Plant height of each sample plant was measured in centimeter from the ground level to the tip of the longest leaf and mean value was calculated and expressed in cm. (Plate 1.a.)

3.11.2 Number of leaves per plant

The number of leaves per plant was counted from the selected plants and their average mean was taken as the number of leaves per plant. It was recorded during different days at 30, 45, 60 and 75 days after planting. (Plate 1.b.)

3.11.3 Number of stem hill^{-1}

Number of stem per hill was recorded by counting all branches of selected plants after 40 DAP till 80 DAP and mean was calculated. (Plate 1. b.)

3.11.4 Days to maturity

Maturity of potato tubers were counted after observing their visual maturity. Mature plants have changed its color from green to brown color.

3.11.5 Chlorophyll content (SPAD value)

Chlorophyll content of leaves was measured at an interval of 15 days starting from 20 DAP till 80 DAP. Mature leaf (fourth leaves from top) were measured all time. Three mature plant of each plot were measured by using portable Chlorophyll Meter (SPAD-502, Minolta, Japan) and then calculated an average SPAD value for each plot at each sampling time. (SPAD-502) is a simple and portable diagnostic tool that measures the greenness or the relative chlorophyll concentration of leaves (Kariya *et al.,* 1982) (Plate 1. c.).

3.11.6 Disease infestation (%)

During the growth period late blight, potato leaf roll virus and potato virus Y was found in the experimental plots. Three plants were selected from individual Trichoderma treatment on every plot for observation of disease infestation percentage (%) according to lesion on leaf and stem and count them and affected plants were rogued.

3.11.7 Number of tuber hill^{-1}

The number of tubers per hill was counted individually after final harvested plants of each plot.

3.11.8 Tuber length (cm)

The length of tuber was measured with a slide calipers and their average was calculated in centimeter (cm) (Plate 1. e.).

3.11.9 Tuber Diameter (mm)

Tuber diameter was measured using Digital slide caliper -515 (DC-515) in millimeter (mm) and mean was calculated (Plate 1. e.).

3.11.10 Individual tuber weight (g)

Tuber weight was measured by Electronic Precision in gram. Total tuber weight of each plot was obtained by addition of weight of the total number and average tuber weight was obtained from division of the total tuber weight by total number of tuber (plate 1. f.).

3.11.11 Yield hill^{-1}(kg hill^{-1})

Weight of tubers per hill was recorded from the mean weight of tubers found from the total harvested plants of each plot and expressed in Kilogram (kg).

3.11.12 Yield ha^{-1}($t\ ha^{-1}$)

The yield obtained unit plot was converted into per hectare yield and expressed in tons.

3.11.13 Dry matter content (%)

Hundred grams potato tuber cut into pieces were oven dried for 72 hours at 70-80°C in an oven after days of sun drying until the constant weight. Then the dried pieces were weighted. From which the weights of tuber flesh dry matter content (%) were recorded.

3.12 Statistical Analysis

The data recorded for different parameters were statistically analyzed using MSTAT-C computer package programme to find out the significance of variation among the treatments and treatment means were compared by Duncan‟s Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

a

b

c

d

e

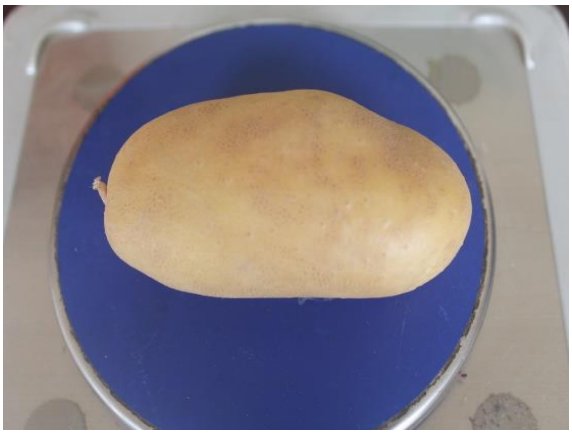

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Plate 1: Pictorial presentation a. Measurement of plant height using meter scale in cm; b. Leaf and stem number count; c. Measurement of chlorophyll percentage using SPAD; d. Trichoderma solution; e. Tuber length & diameter measurement using Digital Caliper -515(DC-515); f. Measurement of tuber weight using Electric Precision Balance.

CHAPTER IV
RESULTS AND DISCUSSION

CHAPTER IV

RESULT AND DISCUSSION

The research work was conducted for the evaluation of the performance of potato germplasm and their performance against Trichoderma. The research work on "Growth and yield response of Potato Germplasm to Trichoderma as a bio-stimulator" was undertaken in the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka. The experimental results on growth, yield and quality parameters obtained during the entire period of study are presented as follows:

4.1. Growth related parameters

4.1.1 Plant height (cm)

Plant height (cm) is obviously important growth parameters in potato which is positively correlated with yield and the growing conditions significantly influenced this trait. Significant variation was found among the performances of germplasm in terms of plant height (Appendix II). Highly significant differences exist among different germplasm with regard to plant height (cm) at 20 days, 35 days, 50 days, 65 days and 80 days after planting. Significant increase in plant height (cm) was observed from 20-80 days after transplanting in all the germplasm. The mean plant height ranged from 59.63 cm to 80.83 cm, the maximum plant height was at 80 days after transplanting. The tallest plant was found from G_1 (74.29 cm) where is the shortest from G_4 (61.98 cm) at 80 days after planting. There was also significant difference among the germplasm G_2 (71.0 cm), G_3 (63.26 cm), G_5 (67.97 cm), G_6 (64.2 cm) and G_7 (66.14 cm) in this respect (Figure 2). Gopal (2015) found that plant height varied due to the varietal differences. Fayaz et al. (2007) observed that the tallness, shortness and other morphological differences are varietal characteristics, which are controlled and expressed by certain genes.

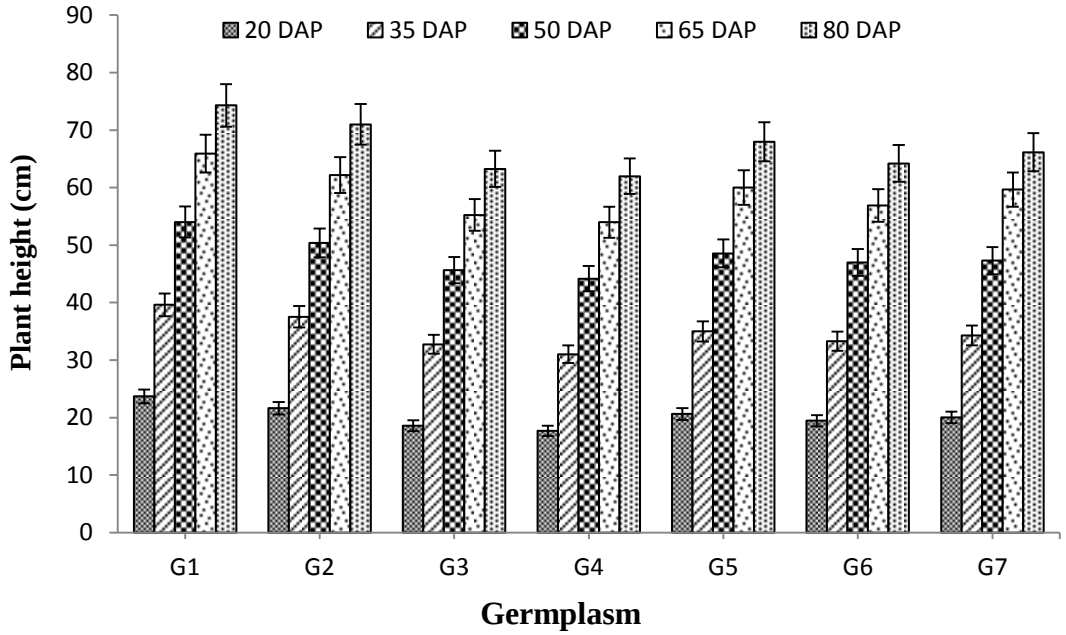


Figure 2. Performance of different potato germplasm on plant height (cm) at different days after planting (Here, G_1: Sokal; G_2: Bijita; G_3: JP Blue yellow; G_4: JP Blue white G_5: Burma-1; G_6: Burma-2 and G_7: Cardinal)

Plant height was significantly affected by Trichoderma (Appendix II). Plant height of potato germplasm exposed statistically significant inequality among control, single application and double applications at 20, 35, 50, 65 and 80 DAP (Figure 3). The tallest plant (72.63 cm) was recorded at double application of trichoderma solution (T_2) and the shortest plant (60.17 cm) was found from control condition (T_0) at 80 days after planting (Figure 2). Plant height showed significant variation with Trichoderma treatments. Uddin et al. (2016) found the higher plant height in tomato with trichoderma treatments. Similar opinion was put forwarded by Baker (1991) in tomato, bean and cucurbits. This may be due to enhanced nutrition uptake activity to the plants.

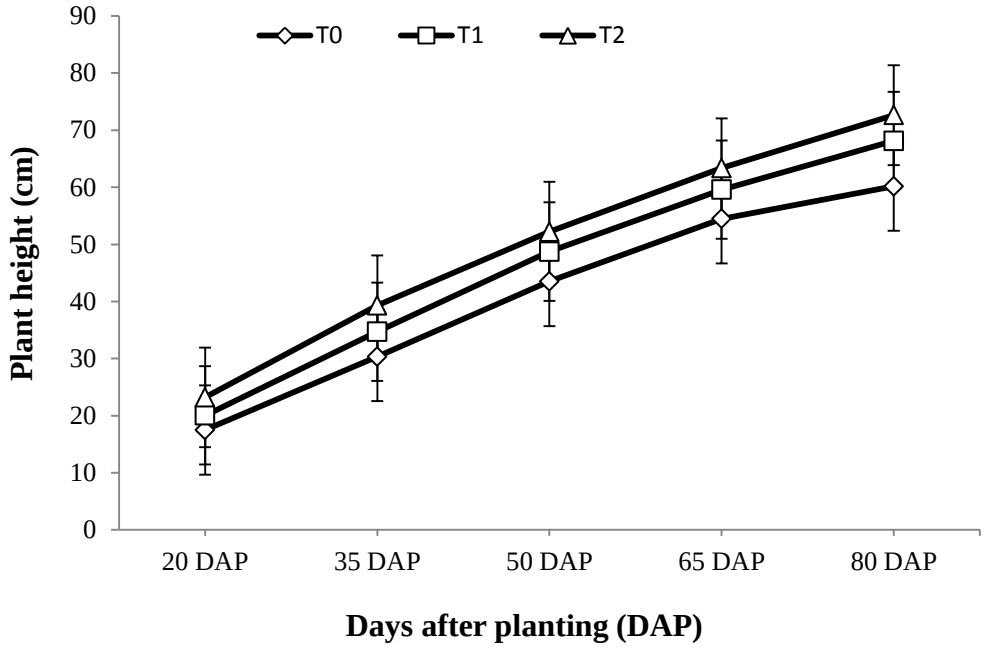


Figure 3. Effect of Trichoderma application on plant height (cm) at different days after transplanting (Here, T_0: No trichoderma application; T_1: Single application T_2: Twice application)

In case of combination of potato germplasm and Trichoderma to plant height also exposed significant variation (Appendix II). The tallest plant (80.83 cm) was found in double application and Sokal germplasm (G_1T_2) as well as the shortest plant (55.7 cm) was found in JP Blue white under control treatment (G_4T_0) at 80 days after planting (Table 2). Singh (2018) also showed that plants grow tall with trichoderma treated than the untreated condition in linseed. More plant height can be attained due to stimulating effect of trichoderma on plant growth by Baker (1988) and Lynch et al. (1991).

Table 2. Combined effect of potato germplasm and Trichoderma on plant height of potato at different days after planting**

	Plant height (cm)									
Treatment*	20 DAP		35 DAP		50 DAP		65 DAP		80 DAP	
G_1T_0	19.63	e-i	34.53	fg	48.57	fg	60.3	de	65.53	gh
G_1T_1	23.4	b-d	40.03	b-d	55.1	b	66.33	b	76.5	b
G_1T_2	28.03	a	44.27	a	58.37	a	71.13	a	80.83	a
G_2T_0	17.7	g-1	31.97	g-i	44.97	ij	56.37	f	62.83	ij
G_2T_1	21.27	c-f	37.93	de	50.93	de	63.3	c	72.67	cd
G_2T_2	25.93	ab	42.73	ab	55.27	b	66.9	b	77.5	b
G_3T_0	16.63	hi	28.7	j	41.73	kl	51.47	ij	56.6	m
G_3T_1	19.03	f-i	33.67	fg	46.4	hi	55.37	fg	64.97	hi
G_3T_2	20.13	d-g	35.9	ef	48.87	e-g	58.9	e	68.2	ef
G_4T_0	16.37	i	28.1	j	40.3	l	50.8	j	55.7	m
G_4T_1	17.43	g-i	30.6	h-j	44.8	ij	54.47	gh	62.63	jk
G_4T_2	19.37	e-i	34.4	fg	47.37	f-h	56.67	f	67.6	e-g
G_5T_0	17.53	g-i	30.1	ij	43.07	jk	54.03	gh	60.57	kl
G_5T_1	20.23	d-g	34.2	fg	49.27	ef	60.83	d	69.07	e
G_5T_2	24.13	bc	40.73	bc	53.33	bc	65.1	bc	74.27	c
G_6T_0	17.23	g-i	29.27	ij	43.33	jk	53.07	hi	59.63	l
G_6T_1	19.03	f-i	32.83	gh	46.87	g-i	56.9	f	64.53	h-j
G_6T_2	22.13	c-f	37.77	de	50.73	de	60.77	d	68.43	ef
G_7T_0	17.4	g-i	29.8	ij	42.57	k-i	55.2	fg	60.3	l
G_7T_1	19.97	d-h	33.6	fg	47.83	f-h	59.83	de	66.53	f-h
G_7T_2	22.73	b-e	39.47	cd	51.5	cd	63.97	c	71.6	d
CV%	10.29		4.73		2.61		1.85		1.98	
LSD Value	3.44		2.72		2.07		1.81		2.19	

*Here, G_1: Sokal; G_2: Bijita; G_3: JP Blue yellow; G_4: JP Blue white G_5: Burma-1; G_6: Burma-2; G_7: Cardinal and T_0: No Trichoderma application; T_1: Single application T_2: Twice application

**In a coloumn, means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.1.2 Number of leaves hill^{-1}

Leaves are the important organ which helps to physiological processes, photosynthesis and transpirations. Thus it influenced the growth of a plant very much and enhances the yield of a plant. The number of leaves per hill of potato significantly varied among the germplasm (Appendix III). Highly significant differences exist among different of germplasm with regard to number of leaves at 30 DAP, 45 DAP, 60DAP and 75 days after planting. The maximum number of leaves (41.78) was found from G_7 (Cardinal) and minimum (36.89) from G_4 (JP Blue white) at 75 days after transplanting and statistically similar with G_3 (JP blue yellow) (Figure 4). Hossain (2007) observed highly significant variation in respect of number of leaves per plant in Raton tomato variety. Similar results had been also reported by Rahul et al. (2017).

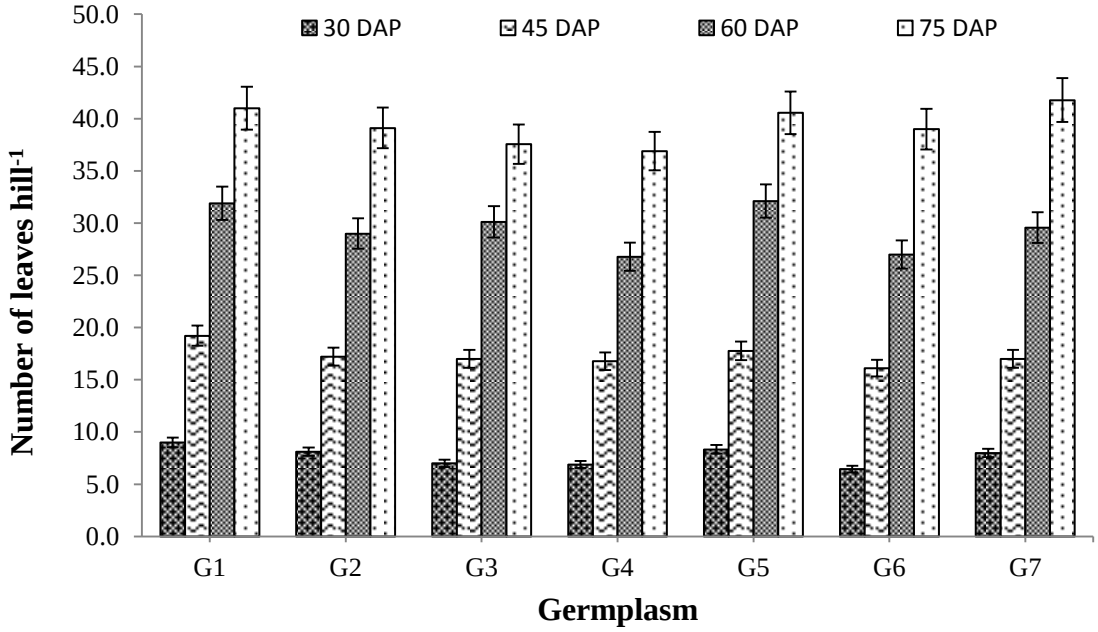


Figure 4. Performance of potato germplasm on number of leaves per plant at different days after planting (Here, G_1: Sokal; G_2: Bijita; G_3: JP Blue yellow; G_4: JP Blue white G5: Burma-1; G_6: Burma-2 and G_7: Cardinal)

In case of no trichoderma application and different trichoderma application, significant variation in number of leaves was observed (Appendix III). The

maximum number of leaves (42.19) was found from T_2 and minimum (36.33) from T_0 with 75 days after planting (Figure 5). Roslee et al. (2017) found that the leaf number was more in *Trichoderma spp*. treated plants while minimum for the control. Increase in number of leaves by the application of *T.harzianum* was reported in *Ocimum sanctum* plants by Padmavathi (2013).

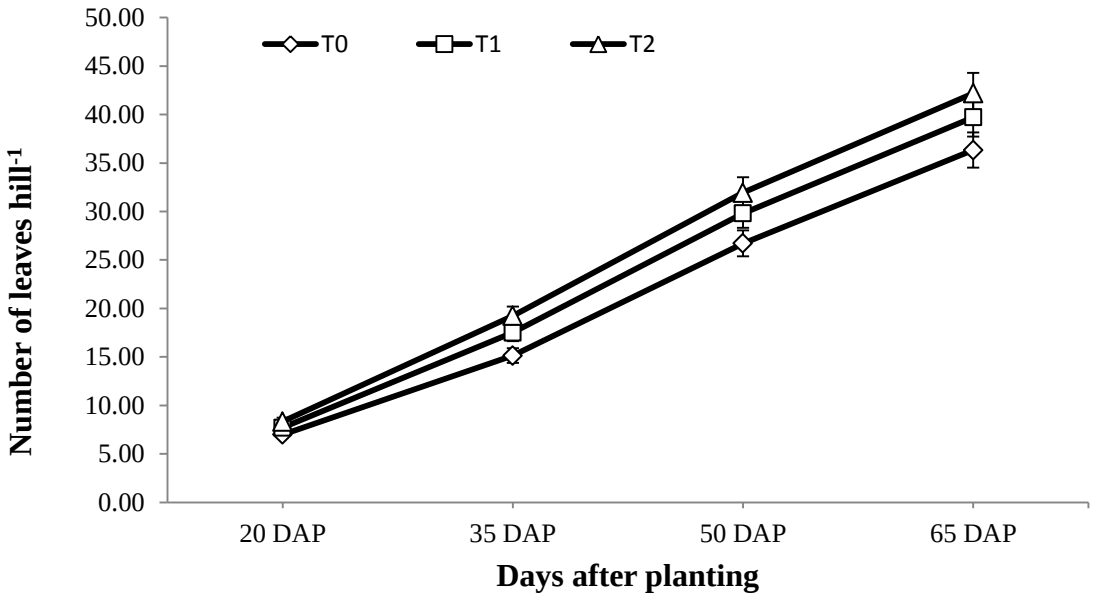


Figure 5. Effect of Trichoderma application on Number of leaves at different days after planting (Here, T_0: No Trichoderma application; T_1: Single application; T_2: Double application)

In case of combined effect of Trichoderma and potato germplasm significant variation was observed in the number of leaves per hill (Appendix III). The maximum number of leaves (44.67) was found from Sokal germplasm with double application of trichoderma (G_1T_2) and minimum (34.0) from JP Blue white in control (G_4T_0) with 75 days after transplanting (Table 3).

Table 3. Combined effect of germplasm and *Trichoderma spp*. on number of leaves per plant of potato at different days after planting**

	Leaf number			
Treatment*	30 DAP	45 DAP	60 DAP	75 DAP
G_1T_0	8.00 c-e	16.67 f	28.67 fg	37.00 l
G_1T_1	9.00 b	19.00 bc	32.33 b	41.33 c-e
G_1T_2	10.00 a	22.00 a	34.67 a	44.67 a
G_2T_0	7.67 d-f	15.33 gh	26.67 i	35.33 m
G_2T_1	8.00 c-e	17.33 ef	29.00 ef	40.33 e-g
G_2T_2	8.67 bc	19.00 bc	31.33 c	41.67 b-d
G_3T_0	6.33 hi	14.67 hi	28.00 gh	34.67 mn
G_3T_1	7.00 f-h	17.00 ef	30.33 d	38.00 j-l
G_3T_2	7.67 d-f	19.33 b	32.00 bc	40.00 f-h
G_4T_0	6.33 hi	14.33 i	24.00 j	34.00 n
G_4T_1	7.00 f-h	17.33 ef	27.33 hi	37.67 kl
G_4T_2	7.33 e-g	18.67 bc	29.00 ef	39.00 h-l
G_5T_0	7.67 d-f	15.67 g	28.67 fg	38.67 i-k
G_5T_1	8.33 b-d	18.33 cd	32.67 b	40.33 e-g
G_5T_2	9.00 b	19.33 b	35.00 a	42.67 b
G_6T_0	5.67 i	14.00 i	24.33 j	35.33 m
G_6T_1	6.67 gh	16.67 f	27.33 hi	39.33 g-i
G_6T_2	7.00 f-h	17.67 de	29.33 ef	42.33 bc
G_7T_0	7.33 e-g	15.33 gh	26.67 i	39.33 g-i
G_7T_1	8.00 c-e	17.00 ef	29.67 de	41.00 d-f
G_7T_2	8.67 bc	18.67 bc	32.33 b	45.00 a
CV%	7.32	2.60	1.96	1.86
LSD	0.93	0.74	0.34	0.54

*Here, G_1: Sokal; G_2: Bijita; G_3: JP Blue yellow; G_4: JP Blue white G_5: Burma-1; G_6: Burma-2; G_7: Cardinal and T_0: No trichoderma application; T_1: Single application (15 days after germination); T_2: Double application (15 and 45 days after germination)

**In a coloumn, means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.1.3 Number of Stem hill^{-1}

The number of stems hill^{-1} showed significant variation among the germplasm at 20, 35, 50, 65 and 80 DAP (Appendix IV). The number of stems hill^{-1} was found ranged from 3.33 to 5.67.The maximum number of stems per hill (5.67) was found in Sokal germplasm (G_1) whereas the minimum number of stem per hill (3.33) was produced in JP Blue white germplasm (G_4),which was statistically similar with (G_3) (Figure 6). Linta et al. (2018) found the similar result in potato germplams. Amanullah et al. (2010) also studied number of stem per hill where they found variation within potato gemplasm.

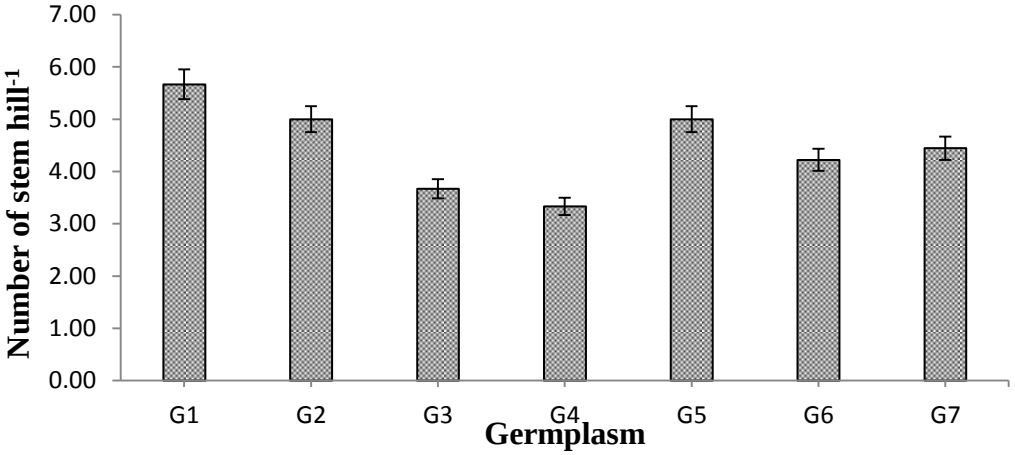


Figure 6. Performance of different potato germplasm on number of stem per hill (Here, G_1: Sokal; G_2: Bijita; G_3: JP Blue yellow; G_4: JP Blue white; G_5: Burma-1; G_6: Burma-2 and G_7: Cardinal)

In case of different trichoderma treatment significant variation was observed in the number of stem per plant (Appendix IV). Maximum number of stem (5.05) per plant was found in double application of trichoderma (T_2) and minimum number of stem per plant (3.76) was found in control treatment (T_0) (Figure 7). Many researchers studied the effect of trichoderma on vegetative parameters of plants and showed that increases vegetative growth and allows more nutrient uptake and increases photosynthesis efficiency and improve vegetative growth of plants. Uddin et al. (2014) showed the maximum significant variation in number of branches as with trichoderma treated compared to infected control.

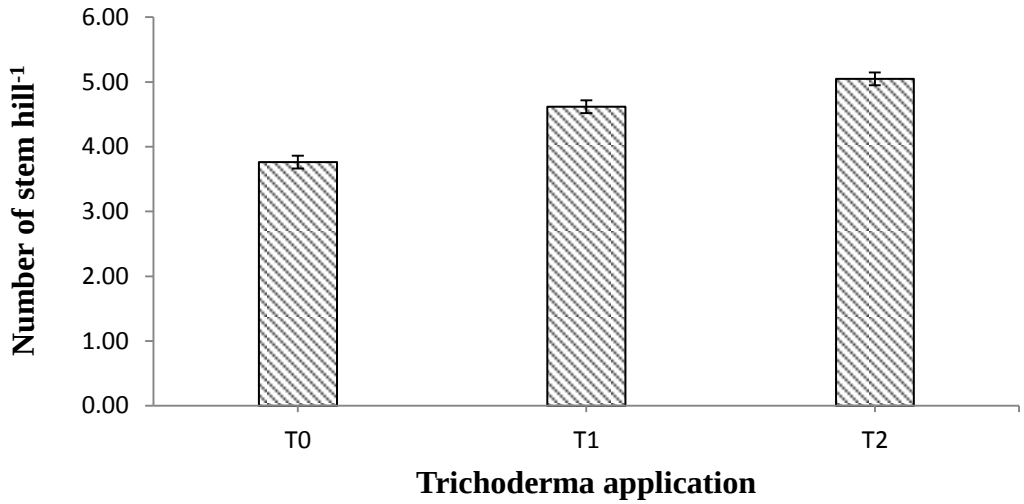


Figure 7. Effect of Trichoderma application on number of stem hill^{-1} (Here, T_0: No trichoderma application; T_1: Single application; T_2: Twice application)

In case of combined effect significant variation was observed in the number of stem hill^{-1} (Appendix IV). Maximum number of stem per hill (6.67) was found in Sokal germplasm in double trichoderma application (G_1T_2) and minimum number of stem per hill (2.67) was found in JP Blue yellow in control condition (G_3T_0) (Table 6).

4.1.4 Days to maturity

Maturity is important for harvest index. In case of germplasm, days to maturity were varied significantly (Appendix IV). Maximum days to maturity was found in from Burma-2 (G_6) germplasm (95.56) whereas minimum (88.67) from Sokal (G_1) (Figure 8). Masarirambi et al. (2012); Dam et al. (1999); Musa et al. (2009) were found similar result with the present study.

In of case Trichoderma treatment, days to maturity were significantly varied (Appendix IV). Maximum days to maturity was found in (T_0) where no trichoderma used (93.38) and minimum days were found (91.62) in double application of trichoderma treatment (T_2) (Figure 9). Trichoderma enhances maturity due to number of mechanism occurs in plant growth promotion. Harman et al. (2004) proposed the similar result in plant.

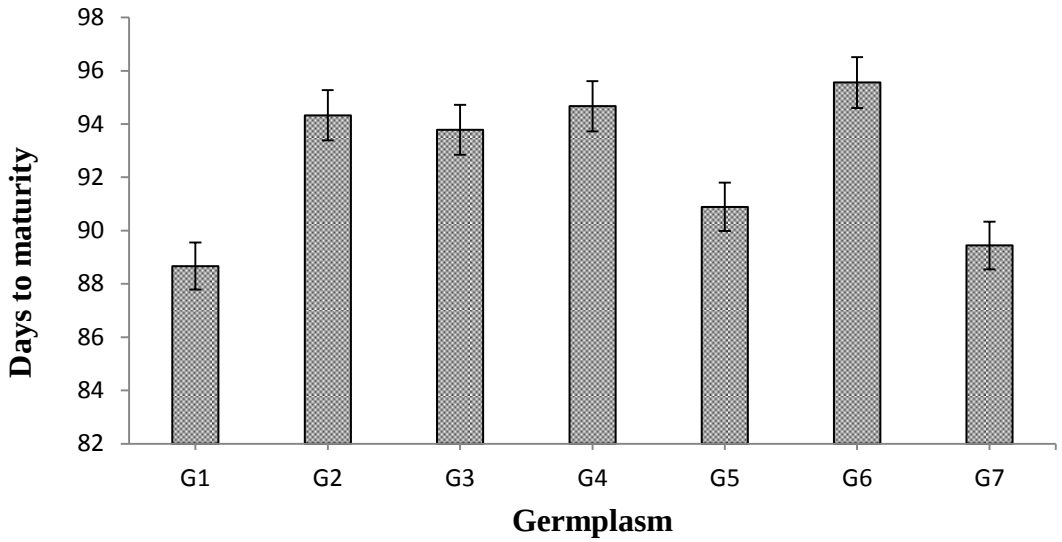


Figure 8. Performance of potato germplasm on days to maturity at different days after planting (Here, G_1: Sokal; G_2: Bijita; G_3: JP Blue yellow; G_4: JP Blue white; G_5: Burma-1; G_6: Burma-2 and G_7: Cardinal)

In case of combined effect of Potato germplasm and Trichoderma showed significant variation in respect to days to maturity (Appendix IV). Maximum days (96.33) were obtained from (G_6T_0) whereas minimum days (87.33) were obtained from (G_1T_2) (Table 5).

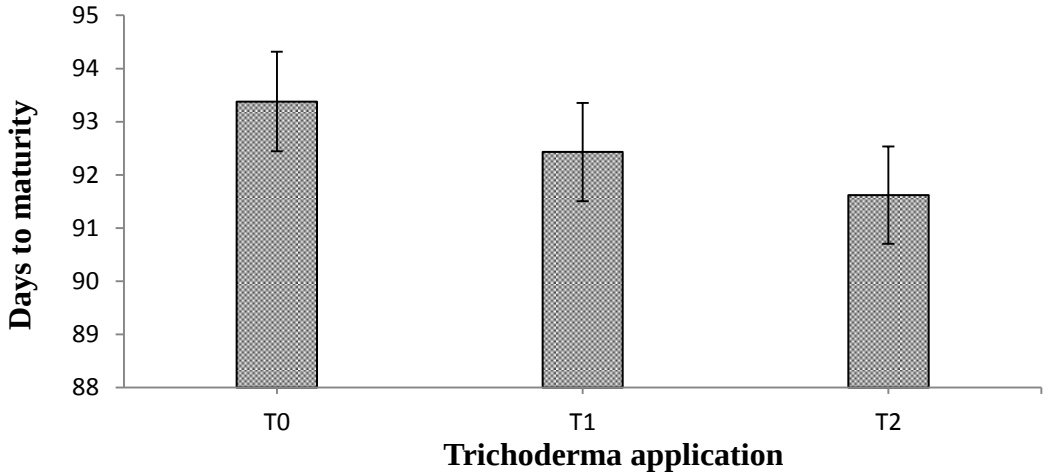


Figure 9. Influence of trichoderma on days to maturity of potato (Here, T_0: No trichoderma application; T_1: Single application; T_2: Twice application)

4.2 Physiological parameters

4.2.1 Chlorophyll content (SPAD value)

Chlorophyll enhances the growth of a plant which is correlated with the yield. Chlorophyll (%) on leaves (SPAD reading) showed significant variation among the germplasm (Appendix IV). The highest chlorophyll content (48.97) was observed from G_1 (Sokal) whereas the lowest chlorophyll content (37.84) was observed from G_4 (JP Blue yellow) (Figure 10). Olotuah and Fadare (2012) found that chlorophyll content varied with the different cowpeas variety which indicates the growth habit of the plant varieties. Chlorophyll content of leaves is frequently correlated with photosynthetic capacity, with leaf N status, and RuBP carboxylase activity (Evans, 1998; Seemann et al., 1987) and less chlorophyll content decrease the development of growth as well as grain development. Variation in chlorophyll content was also observed in Rose (Ahmad et al., 2011).

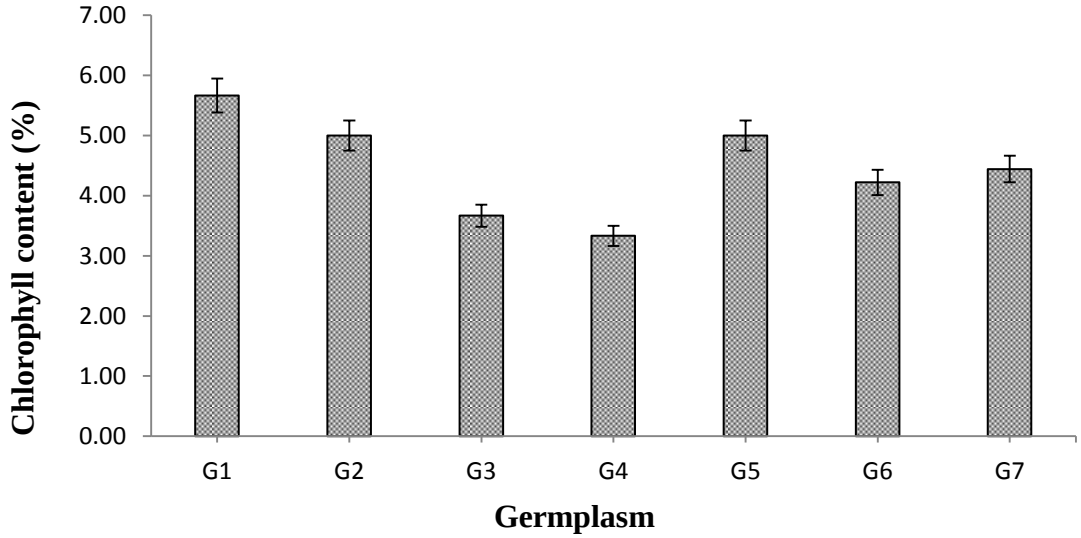


Figure 10. Performance of potato germplasm on Chlorophyll content (%) of leaves (Here, G_1: Sokal; G_2: Bijita; G_3: JP Blue yellow; G_4: JP Blue white; G_5: Burma-1; G_6: Burma-2 and G_7: Cardinal)

In different trichoderma treatment chlorophyll percentage of leaves showed significant variation (Appendix IV). Maximum chlorophyll percentage (46.96) was found double application of trichoderma treatment (T_2) and minimum (37.74) was observed in control condition (T_0) (Figure 11). Similar results were

found by Lo and Lin (2002) who showed that chlorophyll concentration in leaves was more in trichoderma treated plants than the untreated plants in cucumber.

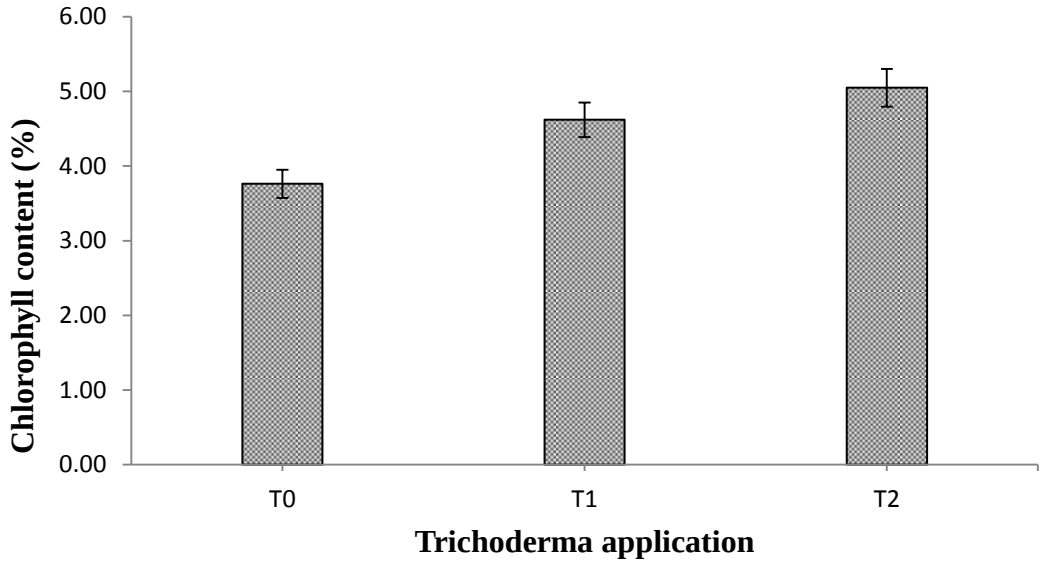


Figure 11. Influence of trichoderma treatment on Chlorophyll content (%) of potato(Here, T_0: No trichoderma application; T_1: Single application; T_2: Twice application

Combination treatment had significant variation on chlorophyll content of leaves (Appendix IV). The utmost chlorophyll percentage of leaves (53.8) was found in Sokal germplasm with double trichoderma treated (G_1T_2) and minimum chlorophyll percentage of leaves (33.7) was found from JP Blue white germplasm in control treatment (G_4T_0) (Table 5).

4.2.2 Disease infestation (%)

Trichoderma is a free living fungi and act as a biological control agent that help to combat the diseases as well as boost up plant growth (Yanpo et al., 2015). This is the most crucial parameters that growth, yield and quality parameters are largely dependent on this. Maximum leaf and stem infected plant was found (11 among selected 63 plants) where no application of trichoderma and no lesion was found from twice application of trichoderma. Diseased infested

percentage was found maximum (17.46%) in control trichoderma treatment (T_0) condition whereas the minimum infestation (6.35%) was observed in the once application of trichoderma. However, no infected plant was found in twice application of trichoderma (T_2) treatment on potato plants (Table 4). A biological control agent trichoderma was able to combat the late blight disease of potato studied by Yanpo et al. (2015). Trichoderma had antagonistic effect on phytophthora disease (Fatima et al., 2015).

Table 4. Effect of trichoderma on disease infestation (%) on potato**

Treatment*	Number of leaf and stem infected plant	Disease infestation (%)
T_0	63 plants (11infested)	17.46
T_1	63 plants (4 infested)	6.35
T_2	No lesion	_

*Here, T_0: No trichoderma application; T_1: Single application; T_2: Double application

**In a coloumn, means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 5. Combined effect of potato germplasm and Trichoderma on Dry matter content (%), Chlorophyll content (%) and Days to maturity of potato**

Combination*	Dry matter content	Chlorophyll content	Days to maturity
G_1T_0	19.95 de	42.97 g	90.00 k
G_1T_1	20.60 c	50.13 b	88.67 m
G_1T_2	22.20 a	53.8 a	87.33 n
G_2T_0	19.34 f	39.8 h	95.00 cd
G_2T_1	20.20 d	47.57 cd	94.33 ef
G_2T_2	21.20 b	49.23 bc	93.67 g
G_3T_0	18.67 i	34.83 ij	94.67 de
G_3T_1	19.32 f	40.07 h	93.67 g
G_3T_2	20.04 d	43.57 fg	93.00 H
G_4T_0	18.77 hi	33.7 j	95.33 bc
G_4T_1	19.27 f	38.93 h	94.67 de
G_4T_2	19.40 f	40.9 h	94.00 fg
G_5T_0	18.50 ij	39.37 h	91.67 i
G_5T_1	18.98 gh	46.1 de	90.67 j
G_5T_2	19.70 e	48.23 bc	90.33 jk
G_6T_0	17.43 l	36.17 i	96.33 a
G_6T_1	18.20 k	43.27 g	95.67 b
G_6T_2	19.16 fg	45.4 ef	94.67 de
G_7T_0	16.85 m	36.67 i	90.67 j
G_7T_1	17.31 l	45.33 ef	89.33 l
G_7T_2	18.27 jk	47.6 cd	88.33 m
CV%	0.86	2.86	0.38
LSD Value	0.28	2.03	0.58

*Here, G_1: Sokal; G_2: Bijita; G_3: JP Blue yellow; G_4: JP Blue white G_5: Burma-1; G_6: Burma-2; G_7: Cardinal and T_0: No trichoderma application; T_1: Single application (15 days after germination); T_2: Double application (15 and 45 days after germination)

**In a coloumn, means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.3 Yield attributing parameters

4.3.1 Number of tuber hill^{-1}

Number of tuber per hill is the most prominent parameter for attributing yield. Significant difference was revealed on number of tuber per hill with different potato germplasm (Appendix VI). Among the potato G_2 (Bijita) gave the maximum tuber (6.44) while G_4 (JP Blue white) gave minimum tuber (3.67) per hill number which is statistically similar with G_3 (3.78) (Table 7). Ranjbar et al. (2012) observed the variation in different potato germplasm.

In case of different trichoderma treatment the number of tuber per hill varied significantly (Appendix VI). Maximum number of tuber per hill (5.05) was found in double trichoderma (T_2) application and minimum number (4.14) was found in control trichoderma (T_0) application (Table 8).

Combination of potato germplasm and trichoderma had significant variation on number of tuber per hill of potato (Appendix VI) .The highest number of tuber per hill (7.0) was found in G_2T_2 whereas the minimum number of tuber per hill (3.33) was found in G_4T_0, which was the same as tuber number (3.33) in (G_5T_0), (G_7T_0) and same as statistically (Table 6).

4.3.2 Length of tuber (cm)

Tuber length is very crucial parameters for increasing yield and for commercial production. Tuber length is also important for industrial purposes. Large sized tuber are considered for French fry, medium and round for chips and small sized are in canned and many other purposes. Length of tuber (cm) was significantly differences with different potato germplasm (Appendix VI). Among the germplasm of potato G_1 (Sokal) gave the longest tuber (8.98 cm) while G_6 (Burma-2) gave the shortest tuber (5.09 cm) length which is statistically similar with G_2 (5.16 cm) (Table 7). This is may be due to variation of varietal characteristics. Hasan et al. (2013) also reported tuber length of potato clones which had varietal influence. Ganga et al. (2014) also

found the similar result and the tuber length varied significantly between the cultivars ranges from 5.9 cm to 7.6 cm.

Significant variation was found for tuber length (cm) in case of different trichoderma treatment (Appendix VI). Maximum tuber length (7.75 cm) was observed in T_2 condition and minimum tuber length (7.09 cm) was observed in control trichoderma (T_0) treatment (Table 8). Uddin et al. (2017) found the significant variation in fruit length due to the application of trichoderma in strawberry. Similar finding in respect of fruit length were also observed from (Dutta and Banik, 2007).

In case of combined effect of potato germplasm and Trichoderma tuber length of potato showed significant variation (Appendix VI). The highest tuber length (9.4 cm) was found in Sokal germplasm in double trichoderma application (G_1T_2) and minimum tuber length (4.67 cm) was found in Bijita germplasm in control trichoderma treatment (G_2T_0) (Table 6).

4.3.3 Tuber Diameter (mm)

The difference in varieties for tuber diameter (mm) was found significant (Appendix VI). Where, maximum tuber diameter was recorded 55.83 mm in G_7 (Cardinal), and the lowest diameter of tuber was 33.6 mm in G_6 (Burma-2) (Table 7). Pulok et al. (2016) studied tuber diameter for grading potato tubers and showed the variation in tuber diameter due to varietal differences. Khan et al., (2011) also studied tuber size and they found variation in tuber diameters.

In case of different trichoderma treatment significant variation was observed in the tuber diameter (Appendix VI). Maximum tuber diameter was (47.24) recorded in double application of trichoderma (T_2) and minimum tuber diameter (44.75) was found in control treatment (T_0) (Table 8). This is due to the foliar application of trichoderma. Similar findings in terms of fruit diameter of tomato due to foliar application of micronutrient were also found from

(Naga et al., 2013). Nagaraju et al. (2012) reported that sunflower treated with *Trichoderma spp*. significantly increased in the diameter of heads as compared to untreated plants.

In case of combined effect of potato germplasm and Trichoderma on tuber diameter of potato showed significant variation (Appendix VI). The highest tuber diameter (56.53) was found in Cardinal in double trichoderma application (G_7T_2) and it was statistically similar with G_7T_1 and minimum tuber diameter (39.63) was found in G_4T_0 (Table 6).

4.3.4 Individual tuber weight (g)

Individual tuber weight showed significant variation among the potato germplasm (Appendix VII). Maximum weight/ tuber (133.4g) was found in Sokal (G_1) germplasm followed by (G_3) JP Blue yellow (121.5g) and G_7 (121.2 g) and minimum weight/tuber (72.47g) was found in Burma-2 (G_6) germplasm (Table 7). Awal et al. (2007) found the variation in individual tuber weight.

Tuber weight varied significantly with the trichoderma application (Appendix VI). Maximum tuber weight (106.8 g) of potato was found in double applications of trichoderma treatment (T_2) followed by (104.5g) single application of trichoderma (T_1) treatment whereas lowest in control (T0: 102.9 g) (Table 8). Montaser et al. (2014) showed that *Trichoderma spp.* increase the single fruit weight in eggplant.

In case of combination treatment the individual tuber weight varied significantly (Appendix VI). Maximum weight/ tuber (135.6 g) was found in Sokal germplasm with double application of trichoderma treatment (G_1T_2) and minimum weight/ tuber (71.83 g) was found in Burma-1 germplasm under control treatment (G_6T_0), which was statistically similar with G_6T_1 **(**Table 9).

Table 6. Combined effect of potato germplasm and Trichoderma on stem number per hill, Tuber number/ hill, Tuber length (cm) and Tuber diameter (mm) of potato**

Combination*	Stem number per hill		Tuber number per hill		Tuber length (cm)		Tuber diameter(mm)	
G_1T_0	4.33	e-g	3.67	fg	8.63	de	45.03	gh
G_1T_1	6.00	ab	4.00	e-g	8.90	bc	46.73	f
G_1T_2	6.67	a	4.33	ef	9.40	a	47.13	ef
G_2T_0	4.00	f-h	6.00	bc	4.67	n	42.04	jk
G_2T_1	5.33	b-d	6.33	ab	5.20	l	45.57	g
G_2T_2	5.67	bc	7.00	a	5.60	k	49.67	c
G_3T_0	2.67	j	4.00	e-g	8.53	ef	47.67	e
G_3T_1	4.00	f-h	4.33	ef	8.80	cd	48.50	d
G_3T_2	4.33	e-g	4.67	de	9.00	b	49.57	c
G_4T_0	3.00	ij	3.33	g	6.87	j	39.63	n
G_4T_1	3.33	h-j	3.67	fg	7.10	i	40.43	m
G_4T_2	3.67	g-i	4.00	e-g	7.30	h	41.40	kl
G_5T_0	4.67	d-f	3.33	g	7.60	g	42.63	j
G_5T_1	5.00	c-e	3.67	fg	8.60	e	43.67	i
G_5T_2	5.33	b-d	4.33	ef	8.90	bc	44.80	h
G_6T_0	3.67	g-i	5.33	cd	4.90	m	41.33	l
G_6T_1	4.33	e-g	5.67	bc	5.10	l	41.40	kl
G_6T_2	4.67	d-f	6.33	ab	5.27	l	41.57	kl
G_7T_0	4.00	f-h	3.33	g	8.40	f	54.90	b
G_7T_1	4.33	e-g	4.33	ef	8.70	de	56.07	a
G_7T_2	5.00	c-e	4.67	de	8.80	cd	56.53	a
CV%	12.19		10.78		1.58		0.84	
LSD Value	0.90		0.82		0.20		0.64	

*Here, G_1: Sokal; G_2: Bijita; G_3: JP Blue yellow; G_4: JP Blue white G_5: Burma-1; G_6: Burma-2; G_7: Cardinal and T_0: No trichoderma application; T_1: Single application (15 days after germination); T_2: Double application (15 and 45 days after germination)

**In a coloumn, means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.3.5 Tuber weight per hill (kg)

The findings of the experiment revealed that the potato germplasm showed significant variation for yield per hill (Appendix VII). Maximum yield per hill (0.54 kg) was found from Sokal (G_1) germplasm while minimum (0.37 kg) from JP Blue white (G_4) germplasm (Table 7). Olaniyi and Fagbayide, (2010) showed the variations of yield may also depend on genetic differences among the varieties, since they were grown under the same environmental conditions. Mehraj et al., (2014) also observed that yield per plant varied significantly among the tomato varieties by applying gibberellic acid.

Significant variation in yield per hill was observed under different trichoderma treatment conditions (Appendix VII). Maximum yield per hill (0.51kg) found from T_2 treatment whereas control trichoderma conditions (T_0) produced minimum yield per plant (0.42 kg) (Table 8). Srivastava (2006) showed the significant variation of yield per plant in sugarcane.

The combined effect of potato germplasm and Trichoderma had significant variation (Appendix VII). Maximum yield per hill (0.59 kg) was found from Sokal germplasm with the twice application of trichoderma (G_1T_2) while JP Blue white germplasm produced minimum yield per hill (0.33 kg) in control trichoderma condition (G_4T_0) (Table 9).

4.3.6 Yield (t ha^{-1})

There were significant differences among the potato germplasm respect to yield were highly variation (Appendix VII). The highest tuber yield per hectare (35.24 t) was found from Sokal germplasm (G_1). The lowest (24.71 t) was significantly obtained from JP Blue white germplasm (G_4) (Table 7). This may be due to the inherent ability of the hybrids and their better response to controlled environment condition. Mahmud et al. (2014) observed higher yield in all germplasm ranges from 25.79 t to 32.57 t in 2010-11.

Different Trichoderma application showed significant variation in respect to potato tuber yield per hectare (t) (Appendix VII). Maximum tuber yield per hectare (34.38 t) was obtained from twice application of trichoderma (T_2) whereas minimum tuber yield per hectare (27.71 t) was obtained in control treatment (T_0) (Table 8). Mohsin et al. (2010) showed that trichoderma increased the efficacy, protected the potato plant and ultimately increased yield compare to control conditions.

In case of combined effect of potato germplasm and trichoderma treatment, significant variation was found in tuber yield per hectare (t) (Appendix VII). Maximum tuber yield per hectare (38.92 t) was obtained from Sokal with twice of trichoderma application (G_1T_2) whereas minimum tuber yield per hectare (21.66 t) was obtained from JP Blue white germplasm with control (G_4T_0) (Table 9).

4.4 Quality attributes parameters

4.4.1 Dry matter %

Dry matter content is important for both fresh markets and processing. Tubers with dry matter above 18-20% tend to be more susceptible to bruising and tubers disintegrate more readily when cooked. However, for processing high dry matter content is required to achieve a good fry colour and often 20-25% is specified. Significant difference was revealed on dry matter content with different potato germplasm (Appendix V). Among them G_1 (Sokal) gave the highest (20.92 cm) while G_7 (Cardinal) gave the lowest (17.48) percentage (Figure 12). Capezio (1987) also found the variation in dry matter content among the different potato varieties.

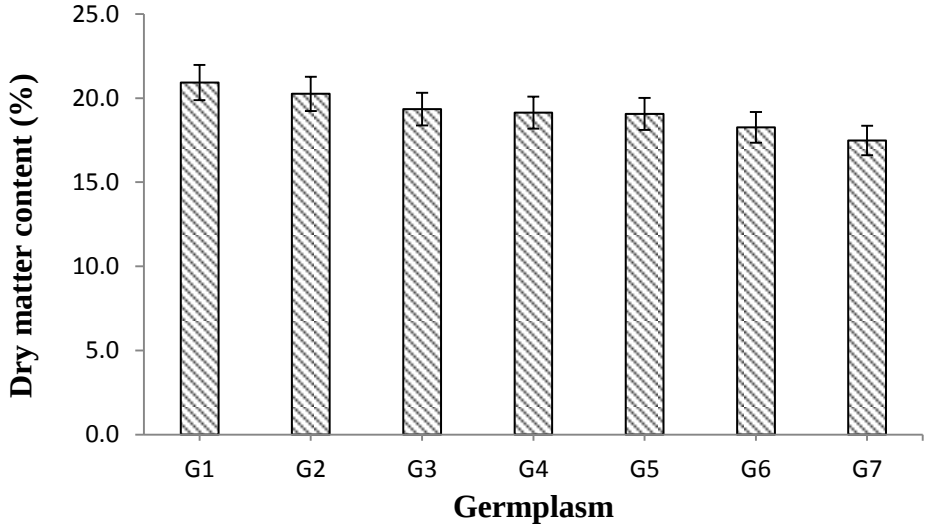


Figure 12. Performance of different potato germplasm on Dry matter content (%) of potato tuber (Here, G_1: Sokal; G_2: Bijita; G_3: JP Blue yellow; G_4: JP Blue white; G_5: Burma-1; G_6: Burma-2 and G_7: Cardinal)

In case of different trichoderma treatment significant variation was observed on dry matter content in potato tuber (Appendix V). Maximum dry matter content (19.99%) was found in double application (T_2) and minimum (18.5%) was found in no trichoderma application (T_0) (Figure 13). Ramyasri (2015) also found variation in dry matter content on sunflower. The increase in the total dry matter due to Trichoderma treatment can be attributed to the cumulative effect of increased leaf area index, SCMR values, increased nutrient uptake and increased rate of photosynthesis. Fatima (2015) observed the antagonistic effect of trichoderma against phytophthora disease.

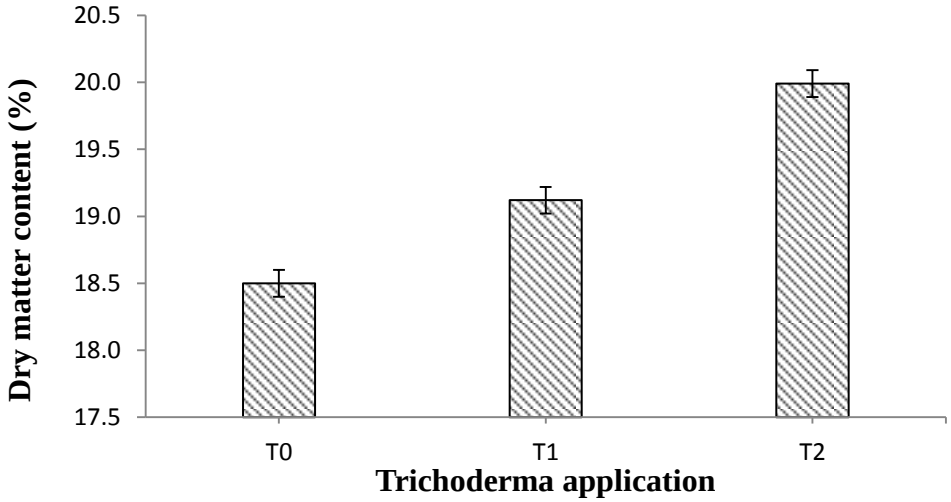


Figure 13. Effect of Trichoderma application on dry matter content (%) of potato tuber (Here, T_0: No trichoderma application; T_1: Single application T_2: Twice application)

In case of combined effect significant variation was observed in dry matter content (Appendix V). Maximum number of dry matter content (22.2%) was found in Sokal germplasm with double treated of trichoderma (G_1T_2) and minimum number of dry matter (16.85%) was found in Cardinal in no trichoderma treatment (G_7T_0) (Table 5).

Table 7. Performance of potato germplasm on tuber number, tuber length(cm), tuber diameter (mm), single tuber weight (g), tuber weight/hill (kg) and yield/ ha (t) of potato

Germplasm*	Tuber number	Tuber length (cm)	Tuber diameter (mm)	Single tuber weight (g)	Tuber weight/ hill (kg)	Yield/ ha (t)
G_1	4.00 cd	8.98 a	46.3 c	133.4 a	0.54 a	35.24 a
G_2	6.44 a	5.16 f	45.76 d	79.62 e	0.51 ab	34.51 b
G_3	4.33 c	8.78 b	48.58 b	121.5 b	0.49 bc	34.18 c
G_4	3.67 d	7.09 e	40.49 g	101.8 d	0.37 e	24.71 g
G_5	3.78 d	8.37 d	43.7 e	103.2 c	0.41 d	26.7 f
G_6	5.78 b	5.09 f	41.43 f	72.47 f	0.43 d	28.73 e
G_7	4.11 cd	8.63 c	55.83 a	121.2 b	0.48 c	32.64 d
CV%	10.78	1.58	0.84	0.69	7.34	0.77
LSD Value	0.47	0.11	0.37	0.69	0.03	0.23

Table 8. Effect of Trichoderma on tuber number, tuber length(cm), tuber diameter (mm), single tuber weight (g), tuber weight/hill (kg) and yield/ ha (t) of potato

Treatment*	Tuber number	Tuber length	Tuber diameter (mm)	Tuber weight (g)	Tuber weight (kg)	Yield/ha (t)
T_0	4.14 c	7.09 c	44.75 c	102.9 c	0.42 c	27.71 c
T_1	4.57 b	7.49 b	46.05 b	104.5 b	0.46 b	30.85 b
T_2	5.05 a	7.75 a	47.24 a	106.8 a	0.51 a	34.31 a
CV%	10.78	1.58	0.84	0.69	7.34	0.77
LSD	0.31	0.07	0.24	0.45	0.02	0.15

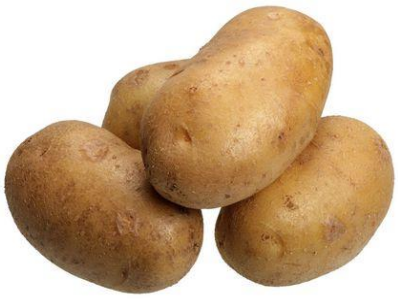
Here, *Here, G_1: SAU Sokal; G_2: SAU Bijita; G_3: JP Blue yellow; G_4: JP Blue white; G_5: Burma-1; G_6: Burma-2 and G_7: Cardinal
And T_0: No trichoderma application; T_1: Single application; T_2: Twice application

Table 9. Combined effect of potato germplasm and Trichoderma on single tuber weight (g), tuber weight/ hill (kg), yield/ha (t) of potato**

Combination*	Single tuber weight(g)		Tuber weight/ hill(kg)		Yield/ ha (t)	
G_1T_0	131.50	c	0.49	c-e	31.76	g
G_1T_1	133.10	b	0.53	bc	35.03	d
G_1T_2	135.60	a	0.59	a	38.92	a
G_2T_0	77.97	n	0.47	d-g	31.63	g
G_2T_1	79.83	m	0.51	cd	34.24	e
G_2T_2	81.07	l	0.56	ab	37.66	b
G_3T_0	119.20	fg	0.45	e-i	31.7	g
G_3T_1	121.10	e	0.49	c-e	33.54	f
G_3T_2	124.30	d	0.53	bc	37.3	b
G_4T_0	99.93	k	0.33	m	21.66	o
G_4T_1	101.60	j	0.37	k-m	24.63	m
G_4T_2	103.80	h	0.42	g-k	27.83	j
G_5T_0	102.10	ij	0.36	lm	23.94	n
G_5T_1	103.20	hi	0.40	i-l	25.89	l
G_5T_2	104.10	h	0.46	d-h	30.27	h
G_6T_0	71.83	p	0.39	j-l	26.02	l
G_6T_1	72.10	p	0.44	f-j	28.33	i
G_6T_2	73.47	o	0.46	d-h	31.85	g
G_7T_0	118.10	g	0.42	h-k	27.28	k
G_7T_1	120.30	ef	0.49	c-f	34.3	e
G_7T_2	125.20	d	0.52	bc	36.34	c
CV%	0.69		7.34		0.77	
LSD Value	1.20		0.05		0.39	

*Here, G_1: SAU Sokal; G_2: SAU Bijita; G_3: JP Blue yellow; G_4: JP Blue white G_5: Burma-1; G_6: Burma-2; G_7: Cardinal and T_0: No trichoderma application; T_1: Single application (15 days after germination); T_2: Double application (15 and 45 days after germination)

**In a coloumn, means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability



G_1

G_2

G_3

G_4

G_5

G_6

G_7

Plate 2: Pictorial presentation of potato tuber G_1 = Sokal, G_2 = Bijita, G_3 = JP Blue yellow, G_4 = JP Blue white, G_5 = Burma-1, G_6 = Burma-2, and G_7 = Cardinal

CHAPTER V
SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

Potato (*Solanum tuberosum* L.) is one of the most important food crops, belongs to the family Solanaceae. In Bangladesh, potato is used as vegetables, chop, chips, flakes, French fry and so on. In recent year, bakeries and fast food shop have started preparing potato based food delicacies. There are more than 5000 germplasm available worldwide. Among them large parts are consumed as table potato and a few are utilized as industrial purposes. Potato cultivation is gaining popularity in Bangladesh and production is increasing day by day. On the other farmers deprive to get their profit because of having lack of industrial potato germplasm. However, Potato plant growth and tuber yield is affected by several fungal diseases which reduce the yield as well as market value. *Phytophthora spp, Rhizoctonia solani* are the serious fungal pathogen. Late blight of potato caused by *Phytophthora infestans* is an important disease in potato growing areas around the world and crop losses. In addition, farmers use huge amount of chemical fertilizers and fungicides to combat the fungal disease which leads to increase the cost as well as affect environment. Therefore, potential value of potatoes has to be promoted by evaluating the germplasm to biological control agent in our climatic condition.

In order to study the effect of Trichoderma and the performance of potato germplasm, a research was conducted to inspect the growth and yield responses of potato germplasm to Trichoderma as bio-stimulator at Horticultural farm, Sher-e-Bangla Agricultural University, Dhaka during period from November, 2016 to March, 2017. Two factorial experiment included potato germplasm viz. G_1 (Sokal), G_2 (Bijita), G_3 (JP Blue yellow), G_4 (JP Blue white), G_5 (Burma-1), G_6 (Burma-2), G_7 (Cardinal) and Trichoderma application viz. T_0 (Control) no trichoderma application, T_1-100ppm (Once application, 15 days after

germination) and T_2-100ppm (Double application, 15 and 45 days after germination) was outlined in Completely Randomized Block Design (RCBD) with three replications.

Collected data were statistically analyzed for the evaluation of treatments for the detection of the best potato germplasm and the best treatment. The findings and conclusion have been described in this segment.

Significant variations were observed in case of germplasm as well as trichoderma application of all parameters like as following –

The highest plant height was found from G_2 (74.29 cm) and from T_2 (72.63 cm) whereas the shortest from G_4 (61.98 cm) and from T_0 (60.17 cm) at 80 days after planting. In case of treatment combination, the tallest plant (80.83 cm) was found in G_1T_2 as well as the shortest plant (55.7 cm) was found in G_4T_0 at 80 days after plantation.

The maximum number of leaves (41.78) was found from G_7 and minimum (36.89) from G_4 at 75 DAP. The maximum number of leaves (42.19) was found from T_2 and minimum from T_0 (36.33) with 75 days after planting. In case of combined effect, maximum number of leaves (44.67) was found from G_7T_2 and minimum (34.0) from G_4T_0 with 75 DAP.

Maximum number of stem (5.67) was found in G_1 and minimum (3.33) in G_4 and G_3 (3.67). In case of trichoderma treatment, maximum number of stem (5.05) was found in T_2 and minimum (3.76) in T_0. Combined effect of germplasm and trichoderma, maximum number of stem (6.67) was found in G_1T_2 and minimum (2.67) in G_3T_0.

Considering the germplasm, G_1 (Sokal) needed least number of days (88.67) for maturity and while utmost number of days (95.56) required by G_6 (Burma-

2). Concerning trichoderma treatment, maximum days (93.38) needed to mature from control and minimum (91.62) days required in T_2, in case of combination G_6T_0 required maximum days (96.33) while minimum days (87.33) was needed in G_1T_2.

The highest chlorophyll content (48.97%) observed from G_1 whereas the lowest (37.84%) from G_4. Considering the trichoderma treatment, maximum chlorophyll percentage (46.96) was found under T_2 and minimum (37.74) was in T_0. In case of combination treatment, maximum chlorophyll percentage (53.8) was found in G_1T_2 and minimum (33.7) from G_4T_0.

Maximum number of disease infestation (17.46%) plant was found in T_0 and T_2 treatment showed no infested lesion on plant leaf and stem.

Maximum number of tuber per hill (6.44) was found in G_2 and T_2 (5.05) whereas minimum (3.78) in G_3 and T_0 (4.14). In case of combination treatment, maximum number of tuber (7.0) was found in G_2T_2 and minimum (3.33) in G_5T_0 and G_7T_0.

Considering the germplasm, the longest tuber (8.98 cm) was found in G_1 while the shortest tuber (5.09 cm) in G_6. In case of trichoderma application, maximum tuber length (7.75 cm) was observed under T_2 and minimum (7.09 cm) in T_0. In combined effect, maximum tuber length (9.4 cm) was found in G_1T_2 and minimum (4.67 cm) in G_2T_0.

Maximum fruit diameter was recorded in G_7 (55.83 mm) and T_2 (47.24 mm) and the smallest in G_6 (33.6 mm) and T_0 (44.75 mm). The combination between treatments indicated that maximum tuber diameter (56.53) was found from G_7T_2 and minimum (39.63 mm) from G_4T_0.

Maximum tuber weight (133.4 g) was observed in G_1 and minimum (72.47 g) in G_6. Considering trichoderma application, maximum tuber weight (106g) was found in T_2 and minimum (102.9 g) in T_0. In case of combined effect, maximum tuber weight (135.6 g) was found in G_1T_2 and minimum (71.83 g) in G_6T_0.

Considering the germplasm, maximum yield per plant (0.54 kg) was found in G_1 while the minimum yield (0.37 kg) in G_4. In case of trichoderma application, maximum yield per hill (0.51 kg) was observed under T_2 and minimum (0.42 kg) in T_0. In combined effect, maximum yield per hill (0.59 kg) was found in G_1T_2 and minimum (0.33 kg) in G_4T_0.

Significant variation was observed among the potato germplasm in regard to yield per hectare. The highest yield (35.24 t/ha) was found from G_1 and the lowest (24.71 t/ha) from G_4. In case of trichoderma application, maximum yield per hectare (34.38 t/ha) was obtained from T_2 whereas minimum (27.71 t/ha) from T_0. In case of combined effect, maximum yield (38.92 t/ha) was obtained from G_1T_2 whereas minimum (21.66 t/ha) from G_4T_0.

In case of germplasm, maximum dry matter content (20.92 %) was observed in G_1 and minimum (17.48 %) in G_7. Considering trichoderma application, maximum dry matter percentage in tuber (19.99) was found in T_2 and minimum (18.5) in T_0. In case of combined effect, maximum tuber dry matter content (22.2 %) was found in G_1T_2 and minimum (16.85 %) in G_7T_0.

5.2 Conclusion

In respect as the above results it can be concluded that potato germplasm showed significant variation to Trichoderma According to result, germplasm, G_1 (Sokal) showed tallest plant height, maximum stem number, chlorophyll content, tuber length, tuber weight and ultimately the highest yield and even,

showed maximum dry matter content. On the other hand, twice application trichoderma performed as excellent among the trichoderma treatment applied in terms of all parameters. Besides the combination, Germplasm, G_1 treated twice with Trichoderma performed as the best combination. Regarding correlation studies, it can be easily stated that stem number, plant height and disease infestation (%) was significantly positively correlated with all of yield. To sum up, it can be articulated that Germplasm (G_1) was the most outstanding germplasm and (T_2) twice application of trichoderma and combination treatment (G_1T_2) was the best for growth, yield and quality attributes of potato.

5.3 Recommendation

Based on the findings of the research, recommendations are:

1. Germplasms- G_1 (Sokal) could be recommended for production in farmer's field after regional participatory yield trial
2. To use of trichoderma to combat the disease and as well as stimulate the plant to increase growth and yield of potato

5.4 Suggestions

Further research in the subsequent areas may be suggested:

1. To be study on enhance early tuber formation and hence stimulate plant growth by applying Trichoderma.
2. Should not use any other chemical fungicides.

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APPENDICES

APPENDICES

Appendix I. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November, 2016 to March, 2017				
Month	***Air temperature (^{o}C)**		***Relative humidity (%)**	***Rainfall (mm) (total)**
	Maximum	**Minimum**		
November,2016	29.6	19.2	53	34.4
December, 2016	26.4	14.1	50	12.8
January, 2017	25.4	12.7	46	7.7
February, 2017	28.1	15.6	37	28.9
March, 2017	32.5	20.4	38	65.8

*Monthly average,

*Source: Bangladesh Meteorological Department (Climate & weather division) Agargaon, Dhaka-1207

Appendix II. Analysis of variance on plant height at different days after planting of potato						
Source of Variation	**Degrees of freedom**	**Mean Square for plant height (cm)**				
		20DAP	**35DAP**	**50DAP**	**65DAP**	**80DAP**
Factor A (Potato germplasm)	6	35.489*	77.452*	95.623*	154.625*	176.811*
Factor B (Trichoderma application)	2	171.783*	422.697*	402.893*	417.674*	836.859*
Interaction (A×B)	12	3.637*	3.177*	1.930*	3.362*	4.984*
Error	40	4.345	2.707	1.579	1.198	1.762
***: Significant at 0.05 level of probability**						

Appendix III. Analysis of variance on the number of leaves per plant at different days after planting of Potato					
Source of Variation	**Degrees of freedom**	**Mean Square for Number of leaves**			
		30DAP	**45DAP**	**60DAP**	**75DAP**
Factor A (Potato germplasm)	6	7.608*****	8.693*****	40.217*****	29.249*****
Factor B (Trichoderma application)	2	9.349*****	88.825*****	145.635*****	`181.540*****
Interaction (A×B)	12	0.108*****	0.622*****	0.598*****	2.114*****
Error	40	0.316	0.202	0.335	0.535
***: Significant at 0.05 level of probability**					

Appendix IV. Analysis of variance on the data of Number of stem/hill and days to maturity of potato			
Source of Variation	**Degrees of freedom**	**Mean Square of**	
		Number of Stem /hill	**Days to maturity**
Factor A (Potato germplasm)	6	5.989*****	68.471*****
Factor B (Trichoderma application)	2	9.000*****	16.333*****
Interaction (A×B)	12	0.370*****	0.241*****
Error	40	0.298	0.124
***: Significant at 0.05 level of probability**			

Appendix V. Analysis of variance on the data of Chlorophyll content (%) and Dry matter content (%) of potato			
Source of Variation	**Degrees of freedom**	**Mean Square of**	
		Chlorophyll content (%)	**Dry matter content (%)**
Factor A (potato germplasm)	6	128.015*	11.888*
Factor B (Trichoderma application)	2	489.303*	11.821*
Interaction (A×B)	12	1.930*	0.242*
Error	40	1.510	0.028
***: Significant at 0.05 level of probability**			

Appendix VI. Analysis of variance on the data of number of tuber/ hill, tuber length (cm), tuber diameter (mm) of potato				
Source of Variation	**Degrees of freedom**	**Mean Square of**		
		Number of tuber/ hill	**Tuber length (cm)**	**Tuber diameter (mm)**
Factor A (potato germplasm)	6	10.508*	25.960*	240.006*
Factor B (Trichoderma application)	2	4.302*	2.364*	32.575*
Interaction (A×B)	12	0.079*	0.112*	4.276*
Error	40	0.244	0.014	0.151
***: Significant at 0.05 level of probability**				

Appendix VII. Analysis of variance on the data of Individual tuber weight (g), Yield per hill (kg), Yield per hill (t) of potato				
Source of Variation	**Degrees of freedom**	**Mean Square of**		
		Individual tuber weight (g)	**Yield per hill (kg)**	**Yield per hill (t)**
Factor A (potato germplasm)	6	4586.084*	0.032*	159.403*
Factor B (Trichoderma application)	2	78.789*	0.043*	228.743*
Interaction (A×B)	12	2.981*	0.001*	2.578*
Error	40	0.525	0.001	0.057
***: Significant at 0.05 level of probability**				