GROWTH AND YIELD PERFORMANCE OF MICRO PROPAGATED POTATO (*Solanum tuberosum* L.) GERMPLASM UNDER FIELD CONDITION

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CERTIFICATE

This is to certify that the thesis entitled, ***"GROWTH AND YIELD PERFORMANCE OF MICRO PROPAGATED POTATO (Solanum tuberosum* L.*) GERMPLASM UNDER FIELD CONDITION****" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE IN AGRICULTURAL BOTANY,*** *embodies the result of a piece of bona fide research work carried out by* ***MD. NASIRUL ALAM*** *Registration No.* ***10-04177*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2016

Place: Dhaka, Bangladesh

Prof. Dr. Md. Moinul Haque
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

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SAU, Dhaka

GROWTH AND YIELD PERFORMANCE OF MICRO PROPAGATED POTATO (*Solanum tuberosum* L.) GERMPLASM UNDER FIELD CONDITION

BY

MD. NASIRUL ALAM

ABSTRACT

A field experiment with 19 micro-propagated potato (*Solanum tuberosum* L.) germplasm collected from different sources was conducted at Sher-e-Bangla Agricultural University, Dhaka during 01 December 2015 to March 2016 to study the growth and yield performance of the germplasm. The tested 19 germplasm were G1, G2, G3, G4, G5, G6, G7, G8, G9, G10, G11, G12, G13, G14, G15, G16, G17, G18 and G19. The experiment was laid out in Randomized Complete Block Design with three replications. All the germplasm differed significantly with regard to plant height leaves plant^{-1}, leaf chlorophyll content (SPAD value), plantlets plant^{-1}, tubers plant^{-1}, individual tuber weight, tuber yield plant^{-1}, tuber yield plot^{-1} (plot area:12 m^2) and tuber yield ha^{-1}. Maximum number of small sized tuber was produced by G5 (149.0) followed by G12 (137.0), G6 (85.0), G8 (50.0), G13 (50.0) and G16 (50.0) while maximum number of medium sized tuber was recorded in G5 (20), G12 (15.0), G6 (13.0) and G16 (13.0). The germplasm G7 recorded the highest number of large sized tuber (13.0) which was followed by G6 (12.0). The highest plant height was found from G7 (55.0) closely followed by G19 (53.00 cm), G11 (49.67 cm) and G4 (51.33 cm) and the lowest from G1 (28.00 cm). G19 recorded the maximum number of leaves plant^{-1} (32.67) which was statistically similar to G15 and G6. Maximum chlorophyll content (SPAD value) was recorded from G15 closely followed by G19 and its minimum value from G14. G5 gave the maximum number of plantlets plant^{-1}. Maximum individual tuber weight was obtained from G14 and the minimum from G17. G12 produced the highest tuber yield plant^{-1} (283.67 g) which was statistically similar to G8 (283.00 g), G19 (280.94 g), G6 (257.67 g) and G14 (253.00 g). Positive correlation of yield was observed with leaves plant^{-1}, plantlets plant^{-1}, tubers plant^{-1}, individual tuber weight and tuber yield plant^{-1}. The maximum tuber yield was produced by G8 (2.73 kg plot^{-1} and 39.05 t ha^{-1}) closely followed by G12 (2.70 kg plot^{-1} and 38.52 t ha^{-1}) and G19 (2.67 kg plot^{-1} and 38.14 t ha^{-1}).

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LIST OF ACCRONYMS AND ABBREVIATIONS

Abs	Absorbance
Agric.	Agriculture
Agril.	Agricultural
Anon.	Anonymous
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centimeter
cm^2	Square centimeter
CRD	Completely Randomized Design
CV	Coefficient of Variation
Dev.	Development
df	Degrees of freedom
DMC	Dry Matter Content
DMRT	Duncan's Multiple Range Test
Environ.	Environmental
et al.	And others
Expt.	Experimental
FAO	Food and Agriculture Organization
g	Gram (s)
m^2	Meter squares
mg	Milligram
min	Minute
ml	Milliliter
mm	Millimeter
M.S	Master of Science
Sci.	Science
i.e.	idest (L), that is

LIST OF ACCRONYMS AND ABBREVIATIONS

Res.	Research
J.	Journal
Kg	Kilogram (s)
SAU	Sher-e-Bangla Agricultural University
SE	Standard Error
t ha^{-1}	Ton per hectare
TPOD	Total Potato Defects
TPS	True Potato Seed
TSS	Total Soluble Solids
UNDP	United Nations Development Programme

CHAPTER I

INTRODUCTION

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INTRODUCTION

Potato is one of the most important food crops as well as vegetable crops in the world. (Kesaulya *et al*., 2015). It is (*Solanum tuberosum* L.) popularly known as "The king of vegetables". It is the fourth most important food crop in the world after rice, wheat and maize. It occupies the top most position among tuber crops followed by cassava, sweet potato and yam. Potato is an ideal crop grown very well in multiple cropping system and in the countries having tropical and subtropical agro climatic conditions (Ganga *et al*., 2013). It is increasingly regarded as a vital food-security crop. The crop belongs to the botanical family Solanaceae and within it to the genus *Solanum* which consists of more than 2,000 species (Hawkes, 1978). Apart from the cultivated potato *S. tuberosum* L. ssp. *tuberosum*, seven others cultivated and 228 wild potato species have been identified. Potato is a good and cheap source of carbohydrates, vitamins, minerals and proteins. It also provides most of the trace elements which can meet the energy requirements of humans (Sharma, 2001).

Nutritionally, potatoes are best known for their carbohydrate content. The predominant form of this carbohydrate is starch. A small but significant portion of this starch is resistant to digestion by enzymes in the stomach and small intestine, and so reaches the large intestine essentially intact. This resistant starch is considered to have similar physiological effects and health benefits as fibers. It provides bulk, offers protection against colon cancer, improves glucose tolerance and insulin sensitivity, lowers plasma cholesterol and triglyceride concentrations, and possibly even reduces fat storage (Hylla *et al*., 1998). Potato is one of the most important vegetable crops and having a balanced food containing about 75 to 80% water, 16 to 20% carbohydrates, 2.5 to 3.2% crude

protein, 1.2 to 2.2% true protein, 0.8 to 1.2% mineral matter, 0.1 to 0.2% crude fats, 0.6% crude fiber and some vitamins (Rahman, 2014).

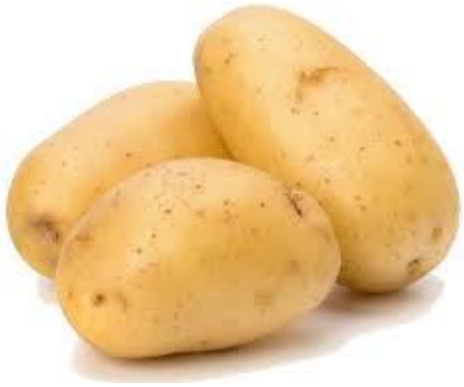
In Bangladesh, it ranks second after rice in production (FAOSTAT, 2013). The total area under potato crops, per ha yield and total production in Bangladesh are 444534.41 hectares, 19.35 t ha^{-1} and 8603000 metric ton, respectively. The total production is increasing day by day as such consumption is also rapidly increasing in Bangladesh (BBS, 2013).

Global interest in potato increased recently as world food prices soared, threatening the global food security and stability. Potato is normally vegetative propagated. Contamination of seed material by pathogens (bacteria, virus and fungi) causes severe reduction in yield. That is why, despite tremendous efforts little success had been achieved in conventional seed plant potato production scheme. In this event plant biotechnology offers a great potential to complement conventional breeding methodology for potato improvement and production via plant tissue culture techniques. But, lack of budget, limited resource allocation and relatively high recurrent cost (chemical expenses) this technology has been envisaged as a major obstacle in benefiting from this technology in developing countries, particularly in Bangladesh.

In vitro propagation by nodal cutting has become an established most of the world potato producers use micro propagation techniques to achieve healthy tuber seed (Jones, 1988). The *in vitro* micro propagated potato plants can produce plantlets and micro tubers (MT) (Goodwin and Adisarwanto, 1980; Uyen and Zaag, 1985). These materials can be planted in a greenhouse or can be directly planted in the field. Usually, the tubers harvested from these materials planted in pots are small and are called mini tubers. Plantlets, mini tubers and MT have advantages and disadvantages and although the production of MT has

increased its utilization is still low. At present, one of the reasons for the low utilization of MT as potato seed by the growers in field cultivation, is the high production cost of MT (Zaag, 1990). Donnelly *et al*. (2003) claimed that as the number of stem segments per culture flask increased, the total weight of the MT per flask increased, but the number of large MT decreased. Large MT also took more time to be produced, raising then the production costs. Studies have been conducted on the field performance of potato plants grown from mini tubers of different sizes (Lommen, 1994) plants from MT and conventional seed tubers (CT) (Haverkort *et al*., 1991), and plants from CT and field transplanted plantlets (Leclerc and Donnelly, 1990). However, there are few studies on the field performance of micro propagated potato germplasm in Bangladesh. The aim of this study was to examine the growth and yield of potato plants field grown from MT of different sizes in comparison. The study is to determine the growth and yield performance of micro propagated potato. Keeping in view of the above facts the present research work was conducted with the following objectives:

- To characterize the morphological traits of different micro-propagated germplasm;
- To assess the yield potentiality of germplasm; and
- To select the best germplasm.



CHAPTER II
REVIEW OF LITERATURE

CHAPTER II
REVIEW OF LITERATURE

Potato (*Solanum tuberosum* L.), the most valuable tuber crop is produced in 150 countries. As a crop in developing world, it comes fourth in dollar value among major food crops. Potatoes currently have the highest rate of production growth in most developing countries and the main stay in the diet of people in many parts of the world. On an average, about 28% of total potato produced throughout the world is processed. The related literature pertaining to the study entitled "Growth and yield performance of micro propagated potato germplasm under field condition" has been reviewed under the following subtitles:

2.1 Origin and domestication of Potato

Potato is believed to have originated in South America in the vicinity of Lake Titicaca near the present border of Peru and Bolivia (Horton, 1987). It was first introduced to Ethiopia in 1858 by a German Botanist Schimper (Pankhrust, 1964). Potato is one of about 2,300 species in the family Solanaceae. This family includes about 90 genera, the largest of which is the genus *Solanum*, including about 1,500 species. About 100 species of *Solanum* are tuber-bearing, and thus commonly referred to as potato. The Solanaceae includes such plants as tobacco, tomato, eggplant, chili pepper, horse nettle, bittersweet nightshade, ground cherry, and petunia. Botanically, advanced potato cultivars, today grown in North America, Europe, and other lands are classified as *Solanum tuberosum* L. (Spooner, 2009 cited in William and Steven, 2010).

The taxonomy of wild and cultivated potatoes is complicated by interspecific hybridization at the diploid and polyploidy levels, lack of breeding barriers among many of the species, the maintenance of sterile populations by asexual reproduction by tubers, and morphological similarity among species. The number of species has varied depending on the author, but recent monographic

treatments are greatly reducing the number of species from well over 200 species in 1990 to the current figure of about 100. All of these species are distributed entirely in the Americas from the southwestern United States south to Uruguay, Argentina, and Chile. Chromosome numbers vary from diploid (2n = 2x = 24), triploid (2n = 3x = 36), tetraploid (2n = 4x = 48), pentaploid (2n = 5x = 60) to hexaploid (2n = 6x = 72) (Spooner, 2009 cited in William and Steven, 2010).

2.2 Germplasm related

Rojoni *et al.* (2014) conducted an experiment "Yield potentiality of true potato seedling tubers as influenced by its size and clump planting" at the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from November 2010 to March 2011. They found BARI TPS-1 produced gross tuber yield of 27.67 t ha^{-1}. Mihovilovich *et al*. (2014) found that the potential tuber number that could be successfully produced by a plant varied with the genotypes and most cultivars had a consistent number of tubers on each stem.

Sohail *et al*. (2013) reported that the local varieties had thick juice compared to HYV varieties like TPS which can be an indication of using the local varieties for ready to drink juice along with other materials like malt and flavors. Mahmood (2005) was carried out an experiment at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh to investigate the effect of planting method and spacing on the yield of potato using Cv. BARI TPS-1. He found the highest yield (32.5 t ha^{-1}) from BARI TPS-1. Rytel (2004) reported that the rate of dry matter and starch accumulation depends on cultivar and growing conditions. Pandey *et al.* (2002) reported that the variety BARI TPS-1' attained higher yield due to its hybrid vigor in its first clonal generation.

2.3 Field performance of micro propagated potato

Field performance of potato from tissue culture was evaluated by Goodwin and Brown (1980) and Wattimena *et al*. (1983) with contrasting results. Goodwin and Brown (1980) compared the field performance of greenhouse-rooted *ex-vitro* shoots with foundation stock tubers. Stem number per plant was similar for *ex-vitro* transplants and seed tubers of 'Pontiac' but significantly lower for transplants of 'Kennebec'. Tuber number per plant was not significantly different for *ex-vitro* transplants and tubers. Tuber yield of 'Kennebec' plants grown from *ex-vitro* transplants acclimatized for 8 weeks prior to field planting was similar to that of plants from conventionally grown seed tuber. As for 'Pontiac', no plants from culture approached those from seed tubers for tuber yield, but plants yielded more from *ex-vitro* transplants acclimatized for 8 weeks than 6 weeks prior to field planting. Wattimena *et al*. (1983) observed the field performance of plants grown from *in-vitro* produced tubers (micro tubers) and *in-vitro* produced shoots rooted in the greenhouse (micro cuttings) to plants grown from seed tubers of 'Nor land' and 'Red Pontiac'. Stem number per plant was significantly less and tuber number per plant was significantly higher for plants grown from micro tubers and micro cuttings compared to plants grown from seed tubers of both cultivars. Although total tuber weight per plant was significantly higher at peak flowering time for seed tuber produced plants, there were no significant differences in tuber weight in either cultivar at the end of the growing season between plants produced from tubers and micro tuber- or micro cutting-produced plants. However, for both cultivars *ex-vitro* plants produced fewer big tubers (U81A) and more small tubers (U81B) than plant grown from seed tuber. To explain the increase in tuber number per plant for *ex-vitro* micro cuttings, Wattimena *et al*. (1983) suggested that these plants were physiologically different; tuber initiation occurred over a longer period and resorption was less than with tuber produced plants. Wattimena *et al*. (1983)

observed that single stem micro propagated plants branched vigorously. Levy (1985) found that all *ex-vitro* plants developed one vigorous sturdy stem, some of which branched vigorously at the soil creating "rosette type" multi-stem plants. To explain the differences in stem number per plant between their result and Goodwin and Brown (1980) they argued that Goodwin and Brown counted the branches as stems, thus finding no differences in stem number per plant between *ex-vitro* transplants and tuber-grown plants. Levy (1986) compared the yield of *in-vitro* proliferated cuttings transferred directly into the field to those that were acclimatized prior to field planting. The survival rate of cuttings directly transferred into the field ranged from 17 to 75 % while the survival rate of acclimatized cuttings was 98 %. Protecting the plant let from drought and wind immediately upon planting considerably increased plant establishment in the field (Levy, 1985). The length of the growing period, the distance between plant and the Climatological conditions were all found to affect the multiplication rate and the number of tubers greater than 10 mm 15 in diameter. Levy (1988) compared the field performance of *ex-vitro* plant lets to plants originating from single or double node cuttings of *in-vitro* plant let's rooted in peat. He found that this method could increase the material available for planting thus increasing the overall multiplication rate. The author also reported an increase in the establishment of these transplants in the field, as well as a greater uniformity in growth compared to *ex-vitro* plantlets. Bourque (1983) studied the acclimatization and reestablishment of tissue cultured 'Russet Burbank' and 'Norland' and found that 5 d under a poly tent, 5 d under a mist of 30 sec every 30 min and either 7 or 14 d under a mist of 60 sec every 30 min yielded the most productive plants. Carbon dioxide enrichment *in-vitro* was not found to be beneficial and did not increased growth once the plantlets were removed from culture. A temperature of twenty-degree Celsius was found to be adequate for storage of plantlets for rapid multiplication and low temperature was found to enhance subsequent growth. A light intensity of 2 Klux and a 16

day were found to promote high survival rates in storage. Thornton and Knutson (1986) studied the effect of container volume and length of growing season on tuber production and yield of *ex-vitro* 'Centennial Russet' and 'Russet Burbank' plantlets. They found that increasing the container volume increased total tuber yield and yield of tubers larger than 35 mm in diameter.

Optimizing the transplant container volume to reduce the greenhouse space requirement while maximizing yield of *ex-vitro* potato plantlets becomes an important issue. Lengthening the growing season significantly increased the total tuber yield and yield of larger tubers (Thornton and Knutson, 1986). Since the main purpose of growing micro propagated plants has been to provide disease free seed tubers (Johansen *et al.* 1984), one should take into consideration the length of the growing season and the heat unit accumulation. These parameters were also found to be important in the recontamination of virus free stocks (Smith and Storch, 1984). Therefore, determination of the optimum growing season length has to take into account both yield and disease-spread factors. These become even more important in light of McDonald (1987) results. He compared the reinfection levels of PVS and PVY in daughter tubers of conventiona1ly propagated potato plants and *ex-vitro* plantlets of four cultivars. The use of micro propagated plantlets to produce seed tuber stock appeared to increase the risk of infection with both viruses although the results for tuber infection with PVY was significant only one year out of two.

2.4 Correlation among Character.

According to Amadi *et al*. (2008), multiple correlation coefficients for the relationship between tuber yield and other attributes were highly significant and positive (0.963). This means that 96.3% of the variation in tuber yield can be attributed to the influence of the 11 characters assessed. The multiple

regressions of the 11 characters on tuber yield were also very highly significant. The very high coefficient of determination (92.8%) showed that the most important agronomic characters determining tuber yield in potato were covered in the assessment.

Numerous researchers (Birhman and Kang, 1993; Amadi, 2005, and Amadi and Obong., 2007) had used simple correlation coefficients to study the interrelationships between tuber yield and other characters. According to the work of these researchers, tuber yield per plant was positively and significantly correlated with plant vigor, number of leaves per plant, number of tubers per plant, average tuber weight and dry matter content of tuber. There were significant correlations among the yield contributing characters. Number of compound leaves per plant, number of tubers per plant and dry matter content were also significantly correlated with plant vigor at genetic level. Plant height was only positively correlated with number of leaves per plant at genotypic level while the latter was only related to maturity. Days to maturity also had a negative significant relationship with tuber yield per plant (rg = - 0.592 and rg = - 0.590, respectively) indicating the importance of early maturing germplasm for higher yield per plant. The significant positive genotypic correlation of average weight of tuber with number of tubers per plant, yield of tuber per plant and dry matter content indicated strong genotypic relationship between them. Weight of tubers per plant showed a positive relationship with yield per plant. Positive and significant relationships of yield per plant with plant vigor, number of tubers per plant and dry matter content suggested that tuber yield can be increased by simple selection of these characters (Sattar *et al*. 2007).

The correlation study suggested that the important characters like plant height, fresh weight/plant and number of leaves plant^{-1} showed positive association with fresh weight of tuber at 80 days after planting i.e. increases of plant height

and number of leaves plant^{-1} showed positive association and reflects tuber yield increase. On the other hand, positive associations with plant height and leaf numbers indicate that vegetative fresh and vigorous plant stature with more tuber produces more yield. Thus, the characters number of leaves/plant and plant height are the important tuber yield attributes to be estimated in the selection criteria for yield improvement (Ara *et al*., 2009)

Although information about the correlation of agronomic and morphological characters with yields is helpful in the identification of the components of this complex character, yet they do not provide precise information on the relative importance of direct and indirect influences of each of the component characters. With increasing number of variables it becomes necessary to measure the contribution of these variables to the observed correlation and hence partition the correlation coefficient into components of direct and indirect influence (Guler *et al*., 2001; Onder and Babaoglu, 2001) and path coefficient analysis helps to determine the direct effect of trait and their indirect effect on other traits, (Iqbal *et al*., 2006; Yucel *et al*., 2006), giving a clearer picture of the individual contributions of each variable to yield. Since path analysis permits a critical examination of the specific factor that produces a given correlation, it could be successfully employed in formulating an effective selection strategy (Kumbhar *et al.*, 1980).

According to Ara *et al*., (2009), path coefficient analysis revealed that main shoot number showed highest (0.716) positive direct effect followed by fresh weight/plant at 80 days after planting (0.464) and number of leaves /plant (0.341). Higher values of direct effect of main shoot number on fresh weight/plant after 90 days after planting were the reflection of significant positive correlation of these characters with fresh tuber yield.

The various characteristics of crop plants are generally interrelated or correlated. Such correlations can be either negative or positive. In plant breeding and genetic studies, correlated characters are of prime importance because genetic causes of correlations through pleiotropic action or developmental interactions of genes and changes brought about by a natural or artificial selection (Sharma, 1999). In order to facilitate selection in breeding for high yield therefore, it is logical to examine various components and give more attention to those having great influence on yield. Character association studies provide reliable information on the nature, extent and directions of selection (Kumar and Chauhan, 1979).

The knowledge of genetic correlations between different yield attributes is vital when the breeder is confronted with problem of introducing a quantitatively inherited character into some agronomically superior cultivars from wild or uneconomic germplasm. Seed yield is a polygenically controlled complex character and is dependent on a number of component traits that are also quantitatively inherited. Selection on seed yield per se is often less effective, making it imperative to go for indirect selection through component traits (Singh, 1983).

Sharma (1998) discussed the presence of three types of correlations in quantitative genetics and these are phenotypic, genotypic and environmental correlations. The association between two characters that can be directly observed is the correlation of phenotypic values or phenotypic correlations. Phenotypic correlations measure the extent to which the two observed characters are linearly related. It is determined from measurements of the two characters in a number of individuals of the populations. Genetic correlation is the associations of breeding values (i.e., additive genetic variance) of the two characters. Genetic correlation measures the extent to which degree, the same

genes or closely linked genes cause co-variation (simultaneous variations) in two different characters.

The correlation of environmental deviations together with non-additive genetic deviations (i.e., dominance and epistatic genetic deviations) is referred to as environmental correlation (Sharma, 1998). Studies on genotypic and phenotypic correlations among characters of crop plants are useful in planning, evaluating and setting selection criteria for the desired characters in breeding program (Johanson *et al*., 1955).

Correlations between different characters of crop plants may arise either from genotypic or environmental factors. Environmental correlations arise from the effect of overall environmental factors that vary at different environments. Correlations due to genetic causes are mainly pleiotropic effects of genes and linkage (a phenomenon of genes inherited together) between genes affecting different characters. Pleiotropy is the property of a gene, which affects two or more characters; as a result it causes simultaneous variations in the two characters when the genes are segregating (Falconer and Mackay, 1996). Correlation coefficient analysis helps to determine the nature and degree of relationship between any two measurable characters (Burhan, 2007).

Characters that are not easily measured or which are largely influenced by the environment has low heritability ratio hence, there is a need to examine the relationships among various characters. Knowledge of the correlations that exists between important characters may facilitate the interpretations of the results already obtained, and provide the basis for planning more efficient breeding program in the future. However, as the number of independent variables influencing a particular dependent variable increases, certain amount of interdependence is expected. Thus, correlations may be insufficient to

explain the associations in a manner that will enable one to decide on either a direct or an indirect selection strategy (Dewey and Lu, 1995).

Correlation coefficients may range in value from -1 to +1. Phenotypic correlations can normally be estimated with a high degree of accuracy. Estimates of genetic correlations however, usually have high standard errors because of difficulties to avoid the directional effects of confounding factors (i.e., dominance and epistatic genetic effects) on additive genetic correlation estimates. In addition, genetic correlations are strongly influenced by gene frequencies, and therefore, may differ markedly in different populations (Falconer and Mackay, 1996).

According to Grafuis (1959) increasing total yield would be made easier by selecting for components because the components are more simply inherited than the total yield itself. There are a number of reports indicating correlations of characters among themselves and with yield in potato. On other hand, Meris (1969) reported that the correlation between plant height and tuber yield was positive and strong. Significant association between plant height and tuber yield had been reported by Jaime *et al*. (2014) was found plant height to be of little importance for tuber yield.

Tesfaye *et al*. (2012) indicated presence of a strong, positive association between tuber dry matter content, starch content and starch yield ($r = 0.81$; $P < 0.01$), DMC and SY ($r = 0.67$; $P < 0.01$) and SC and SY ($r = 0.82$; $P < 0.01$) and suggested the possibility of simultaneous improvement of these quality governing factors as they are controlled by the same genetic factors. On the other hand, tuber weight was negatively correlated with tuber dry matter content although the correlation was non-significant. Rasui *et al.* (1995) reported that tuber yield per hectare was significantly and positively correlated with plant

vigor (r=0.86), foliage cover (r=0.38), starch content (r=0.42), yield per hill (r=0.95), and specific gravity (r=0.42).

Sandhu and Kang (1998) also reported significant and positive correlation of tuber yield with shoot height, shoot number and leaflet index. Maturity has positive correlation with plant height, mean tuber weight, tuber number and tuber yield. The correlation between maturity and plant height however, was weak whereas correlation between maturity and mean tuber weight, tuber number per plant and tuber yield per plant strong and highly significant (Meris, 1969). Thus, studies on correlation enable the breeder to know the mutual relationship between various characters and determine the component characters on which selection can be used for genetic improvement.

2.5 Yield and yield contributing characteristics of potato varieties.

Yield and yield contributing characteristics of potatoes are influenced by many factors such as season, soil type, agronomic practices, species and varieties

Ganga *et al*. (2013) studied on ten varieties of potato tubers and revealed that tubers mean length varied significantly between the cultivars ranging from 5.9 cm in J/99-242 to 7.6 cm in Kufri Ashoka. Mean breadth of tubers ranged 4.4 cm to 5.6 cm with shortest in Kufri Pushkar and longest in Kufri Ashoka. Kufri Ashoka showed significantly large mass (113 g), highest volume (106.9 cc) and longest diameter (5.8 cm) while Kufri Pushkar had significantly smallest mass, lowest volume where as Kufri Surya recorded significantly shortest diameter. Majority of the cultivars were oval shaped with brown colored skin and cream flesh, number of eyes were less in most of the cultivars with shallow eye depth, without scars and green tint. Highest numbers of natural depressions were found in Kufri Chipsona-2. Kufri Khayti produced highest slices (84.00%) as well as chips (22.83%) and thus ranked first. Specific gravity increased yield of slices as well as yield of chips which was significant at 0.05 levels.

Abbas *et al.* (2012) conducted an experiment using thirty-two potato germplasm for processing and yield quality traits were assessed for screening. Significant differences in all the quality parameters and various characteristics were found, while the germplasm; 394021-120, 9625, Kiran, NARC 2002- 1, NARC 12006/1 and VR 90-217 gave the highest results regarding yield and quality of potato tubers except kiran, which has a high yield but low quality characters. The tuber sizes and weight was also significantly different among germplasm except weight of big size tubers. Variations existed among germplasm in tuber characteristics (skin color, tuber shape, eye depth, flesh color and general appearance)

Kushwah and Singh (2008) conducted an experiment during 2004-05, in Madhya Pradesh, India, to evaluate the effects of intra-row spacing (10.0, 12.5, 15.0, 17.5, 20.0, 22.5 and 25.0 cm) and haulm cutting date (60, 65, 70, 75 and 80 days after planting (DAP)) on the production of small-sized tubers of potato. Data were recorded for plant height, stems plant-1, fresh haulm weight, tuber yield per hectare and NPK content of soil after potato harvest. Intra-row spacing of 25 cm and haulm cutting at 80 DAP recorded the highest values for plant height, stems per plant, fresh haulm weight, tuber yield per hectare and NPK content of soil as well as the highest net returns and benefit: cost ratio.

To improve the production of seed-size potato tubers, 31 experiments were conducted in India, from 1999 to 2003 at 9 centers, situated in different agro climatic regions of the country by Dua *et al*. (2008). Two levels each of spacing (60 × 15 and 60 × 10 cm), fertilizer rates (100 + 35 + 66 and 150 + 52 + 66 kg of N - P - K ha^{-1}, respectively) and dates of haulm cutting (70 and 80 days after planting) were imposed on popular potato cultivars of the regions. The authors reported that yield of seed-size tuber at closer spacing (13.9 t ha^{-1}) increased by a 15.7% compared to that at wider spacing. Economics of potato cultivation for production of seed size tubers also favored planting at wider spacing (60 × 15

cm), with higher fertilizer rate (150 + 52 + 66 kg of N - P - K ha^{-1}) and dehaulming at 80 days after planting.

Waterer (2002) studied the influence of planting and harvest dates on yields and grade-out due to tuber damage by common scab (*Streptomyces* spp.) over three cropping seasons using two cultivars of potato grown on land heavily infested with pathogenic Streptomyces species. Early planting and delaying the harvest enhanced yields in both cultivars, but also increased tuber grade-out due to excessive levels of scab. Delaying the harvest reduced marketable yields more than did early planting. The longer harvest was delayed after top-kill, the greater was the grade out due to scab. He demonstrated that common scab of potato may be managed by minimizing the period of the crop in the ground, but this method of disease management is achieved at the expense of yields. Early planting coupled with timely harvesting after kill-down of the tops appears to be an effective compromise between the objectives of maximizing yields while avoiding excessive grade-out due to common scab.

Chaurasia and Singh (1992) conducted an experiment at Uttar Pradesh of India on potato cv. Kufri Bahar and Kufri Lalmia. Haulms were cut 80, 90, 100, 110 and 120 days after planting. Tubers were harvested 10 days after stem cutting, and stored for 30, 60 and 90 days. They observed that the percentage of tuber weight loss, sprouting and rotting decreased with the delay in haulm cutting date.

Sinha *et al*. (1992) grew potato *cvs.* Atlantic, Eramosa, Kanona, Norchip, Onaway and Saginaw Gold, and selections MS 700-70, MS 700-83 (Spartan Pearl), MS 716-15 and W-855 (Snowden) on a sandy loam in Michigan. In year 1988, average yields were 46.9 t ha^{-1} at 98 days and 54.7 t ha^{-1} at 138 days; corresponding yields in 1989 were 43.1 and 52.3 t ha^{-1}. Increase in yield between the two harvest dates ranged from 0-19.6 t ha^{-1}. Tuber yield after 138

days was highest for 'MS-700-83' (62.3 t ha^{-1}) in 1988 and 'MS-700-70' (59.4 t ha^{-1}) in 1989 and lowest in 'Eramosa' in both years (41.2 and 43.0 t ha^{-1} in 1988 and 1989, respectively). Two of the selections ‘Onaway’ and ‘Eramosa’ were the earliest maturing, contained low specific gravities, high concentrations of glucose, and resulted into dark colored chips. Specific gravities of the tubers were 1.079-1.088 in Atlantic, MS 700-70, MS 716-15 and W-855, 1.071-1.076 in Norchip, Kanona and Saginaw Gold and 1.056-1.068 in Eramosa and Onaway; harvest dates did not affect specific gravity.

De-Buchananne and Lawson (1991) studied the effect of plant population and harvest timing on potato yield and chipping quality at Muscatine and Whiting. They planted cultivars: Atlantic and Nor Chip at in-row spacing of 15, 31 cm and harvested approximately 12, 14 and 16 week after planting. They obtained greater yield and greater specific gravity for both cultivars at final harvesting at both the locations. But chip color was not significantly affected at Muscatine by harvest date while each successive date of harvest resulted in lighter colored chips at Whiting. They further reported that higher plant population increased the yield but smaller increase in specific gravity was noted for both the cultivars. However chip color was not significantly influenced by the plant population. Cultivar 'Atlantic' produced lower yield having lower specific gravity as compared to ‘Nor Chip’ throughout the season in the final harvest.

Ezekiel *et al*. (1998) illustrated that the sprouting of potato cv. Kufri Candramukhi increased with the increase in age of seed tubers. Physiologically older tubers were reported to have higher sprouting. It was also reported that, endogenous content of IAA could be related to rate of sprout elongation in potato.

Tuber yield is a complex character associated with many interrelated components. Generally, a path coefficient analysis is needed to clarify

relationships between characteristics, because correlation coefficients describe relationships in a simple manner. Path coefficient analysis shows the extent of direct and indirect effects of the causal components on the response component. In most studies involving path coefficient analysis, researchers considered the predictor characters as first-order variables to analyze their effects over a dependent or response variable such as yield.

This approach might result in multiple for variables, particularly when correlations among some of the characters are high. There may also be difficulties in interpretation of the actual contribution of each variable, as the effects are mixed or confounded because of collinearity. Agrama (1996) and Mohammad *et al*. (2013) used this model for determining interrelationships among grain yield and related characters in maize.

Yildirim *et al*. (1997) suggested that mass selection with few cycle of recurrent selection could be practiced for its improvement. Selection for tuber yield, which is a polygenic trait, often leads to changes in other characters. Although information about the correlation of agronomic and morphological characters with yields is helpful in the identification of the components of this complex character, yet they do not provide precise information on the relative importance of direct and indirect influences of each of the component characters. With increasing number of variables it becomes necessary to measure the contribution of these variables to the observed correlation and hence partition the correlation coefficient into components of direct and indirect influence (Onder and Babaoglu, 2001) and path coefficient analysis helps to determine the direct effect of trait and their indirect effect on other traits, (Iqbal *et al*., 2006), giving a clearer picture of the individual contributions of each variable to yield (Radovan, 1992).

Since path analysis permits a critical examination of the specific factor that produces a given correlation, it could be successfully employed in formulating an effective selection strategy (Kumbhar *et al*., 1980). According to Ara *et al*., (2009), path coefficient analysis revealed that main shoot number showed highest (0.716) positive direct effect followed by fresh weight plant^{-1} at 80 days after planting (0.464) and number of leaves plant^{-1} (0.341). Higher values of direct effect of main shoot number on fresh weight plant^{-1} after 90 days after planting were the reflection of significant positive correlation of these characters with fresh tuber yield.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November 2015 to February 2016 to study the growth and yield performance of micro propagated potato *Solanum tuberosum* L.) germplasm under field condition. This chapter describes a short description of the experimental site, climate, soil, experimental materials and design, methods of the study, data collection procedure and procedure of data analysis. The detailed materials and methods that were used to conduct the study are presented below under the following headings:

3.1 Site description

3.1.1 Geographical location

The experimental area was situated at 23077′ N latitude and 90033′ E longitude at an altitude of 8.6 meter above the sea level (UNDP - FAO, 1988).

3.1.2 Agro-Ecological Region

The experimental site belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as „islands‟ surrounded by floodplain (Anon., 1988).

3.1.3 Climate

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

3.2 Details of the Experiment

3.2.1 Treatments

19 potato germplasm:

Lines	Germplasm
Line 1	G1
Line 2	G2
Line 3	G3
Line 4	G4
Line 5	G5
Line 6	G6
Line 7	G7
Line 8	G8
Line 9	G9
Line 10	G10
Line 11	G11
Line 12	G12
Line 13	G13
Line 14	G14
Line 15	G15
Line 16	G16
Line 17	G17
Line 18	G18
Line 19	G19

3.2.2 Experimental design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and thus the number of plots came to 48. The size of unit plot was 4m × 3m where the tubers were planted at 50 cm × 25 cm spacing. The distances between plot to plot and replication to replication were 1 m and 1.5 m, respectively. The layout of the experiment has been shown in Appendix I.

3.3 Crop management

3.3.1 Germplasm collection

There were 19 germplasm collected from U.K., Japan, Burma and India and Bangladesh Agriculture Research Institute (BARI), Joydebpur, Gazipur and Bangladesh Agricultural Development Corporation (BADC), RDA, Giant Agro. Disease free micro propagated plantlets were used in this study.

3.3.2 Land preparation

The land was first opened with a tractor one week before planting. Then it was exposed to the sunshine for 7 days prior to the next ploughing. Then it was prepared by repeated ploughing and cross ploughing followed by breaking of clods and laddering to attain a good tilth. The stubbles were removed properly to clean the land. In order to avoid water logging due to rainfall during the study period, drainage channel were made around the land. The soil was treated with insecticide when the plot was finally ploughed. Finally the land was evenly leveled and the soil particles were pulverized.

3.3.3 Fertilizer application

The experimental plots were fertilized with a basal dose of 60 kg N as urea 35 kg P_2O_5 as Triple Superphosphate (TSP) and 125 kg K_2O ha^{-1} as Muriate of Potash (MOP) was applied at planting time and an additional 60 kg N was top dressed as urea three weeks after planting (Roy *et al*., 2009).

3.3.4 Planting of plantlets

The micro propagated healthy and uniform sized potato plantlets were planted according to design and layout. Plantlets were planted in such a way that root does not go much under soil or does not remain in shallow. On an average, the

plantlets were planted at a depth of 5-8 cm furrow as schedule of spacing on 1st December 2015.

3.3.5 Tagging

Tagging was done after planting the germplasm as per replication on 1st December 2015 using card.

3.3.6 Intercultural operations

The experimental plots were always kept under careful observation. After emergence of seedlings, the following intercultural operations were accomplished for their better growth and development.

3.3.6.1 Irrigation

Just after full emergence the crop was irrigated by flooding so that uniform growth and development of the crop was occurred and also moisture status of soil retain as per requirement of plants. In total four-time irrigation were applied throughout the whole cropping period.

3.3.6.2 Weeding and mulching

Weeding and mulching were necessary to keep the plots free from weeds and to conserve soil moisture. The newly emerged weed were uprooted carefully after complete emergence of sprouts and afterwards when necessary. Mulching was done for breaking the surface crust as and when needed.

3.3.6.3 Earthing up

The earthing up was done three times during the growing period. The first was done during planting of tuber and the remaining two were done at 30 and 50 days after plantings just after top dressing of fertilizers.

3.3.6.4 Disease and pest management

Furadan 3G @ 20 kg ha^{-1} was applied during final preparation of the main field to prevent the crops and tubers from the soil insects. Ripcord and Diathan M-45 (mixed) were applied at 30 DAP as a preventive measure for controlling virus and fungal infects. Ridomil Gold (0.25%) was sprayed at 45 DAP to protect the crop from late blight disease.

3.3.6.5 Haulm cutting

Haulm cutting was done as per requirements. After haulm cutting the tubers were kept under the soil for 10 days for tuber skin curing. The cut haulm samples were collected, bagged and tagged separately for further data collection.

3.3.7 Tuber harvesting

The tubers were harvested at 80, 90, 100 and 110 DAP, respectively based on germplasm. The tubers of each treatment were separately harvested, bagged and tagged, and brought to the laboratory. Harvesting was done manually by hand.

3.3.8 Data recording

Collection of data on the following parameters was recorded from the sample plants during the course of experiment. The sampling was done randomly in each plot in such a way that the border effect was avoided for the highest precision. For this the other two lines and the border plants of the middle lines were avoided.

A. Growth characters

i. Plant height

ii. Number of leaves $plant^{-1}$

iii. Number of plantlets plant^{-1}

iv. Chlorophyll content of leaves

B. Yield and yield components

v. Number of tubers hill^{-1}

vi. Weight of tubers hill^{-1}

vii. Yield of tuber

viii. Individual tuber weight

3.3.9 Detailed procedures of recording data

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

A. Crop growth characters

i. Plant height

The height of the potato plants was recorded at 80 DAP. The length from the ground level up to the tip of the longest stem was counted as plant height. The average height of five plants was considered as the height of the plant for each plot.

ii. Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted at 80 DAPS. Leaf number plant^{-1} were recorded by counting all leaves from each plant from randomly selected five plants. The average number of leaves of five plants was considered as the number of leaves plant^{-1} for each plot.

iii. Number of plantlets plant^{-1}

Number of plantlets plant^{-1} was counted at 80 DAP. Plantlets plant^{-1} was recorded by counting all plants from randomly selected five plants. The average plantlet numbers of five plants were considered as the number of plantlets plant^{-1} for each plot.

iv. Chlorophyll content of leaves

It is taken by SPAD meter from 4th leaf of the plant to the tip of the plant.

B. Yield and yield components

v. Number of tubers m^{-2}

Number of tubers m^{-2} was counted at harvest. Tuber numbers m^{-2} was recorded by counting all tubers of square meter from each plot.

vi. Individual tuber weight

Tubers of randomly selected five hills were collected separately, counted and weighed. Then the individual tuber weight was calculated dividing the total weight by total number of tubers and recorded in gram.

vii. Weight of tubers hill^{-1}

Tubers of randomly selected five hills were collected separately from which weight of tuber hill^{-1} was recorded in gram.

viii. Yield of tuber ha^{-1}

The tuber yield obtained from each plot were collected separately and the weight of tubers of each plot was converted into t ha^{-1}.

3.3.10 Statistical analysis

The data obtained for yield contributing characters and yield were statistically analyzed to find out the significance of differences among the treatments. The mean values of all the characters of thirteen varieties were evaluated and analysis of variation was performed through MSTAT-C program. Mean separation was done by DMRT at 5% level of probability. Correlation coefficient, correlation matrix and regression analysis were performed.

Plate1. Different steps of data collection in experimental field




Plate2. Different steps of data collection in experimental field

CHAPTER IV
RESULTS AND DISCUSSION

CHAPTER IV

RESULT AND DISCUSSION

Potato is one of the most important food crops in developed as well as in developing countries. Many potato varieties have been released in Bangladesh, however the demand for potato has led the farmer to select the most suitable and round year available potato variety, so that there will be continuous supply of potato in the market. The results of the investigation on different potato germplasm assessed for growth and yield performance has been presented.

4.1 Morphological characterization in micro-propagated potato germplasm.

Ever since humans first began to grow potatoes, we have been picking the 'best' potato plants (with the biggest or tastiest potatoes, for example) to grow for our use. Just by doing this we began to change potato plants to suit our needs. The potato has changed a lot since it was first domesticated, but these changes have not always been in the same direction. Over time, different features have been considered important to potato growers. The earliest potato cultivation seems to have occurred in the upland valleys and plains of Bolivia. The initial domestication of the potato one of the first varieties to develop had a high frost resistance. However, the local importance of the potato is variable and changing rapidly. It remains an essential crop in Asia where per capita production is still the highest in the world, but the most rapid expansion over the past few decades has occurred in southern and eastern Asia. Subsequently, as potato cultivation began to spread into other areas, different qualities became important. In lowland areas there was less need to select hardy potato plants and farmers could concentrate on yield and quality. The micro propagated germplasm exhibited different distinct features in their color, flesh color, shape of tuber and size of tuber color. (Table 1)

Table 1. Morphological variations in 19 micro propagated potato germplasm

Germplasm No.	color	Flesh color	Tuber Shape	Size of tuber (No. of tuber germplasm^{-1})		
				small	medium	Large
G1	Soft red	Cream	Long	Nil	10.0	Nil
G2	Reddish orange	Cream	Round	31.0	6.0	7.0
G3	Light reddish orange	Cream	Round	21.0	4.0	3.0
G4	Soft red	Cream	Long	11.0	6.0	7.0
G5	Pale yellow	Cream	Oblong	149.0	20.0	5.0
G6	Pale yellow	Cream	Round	85.0	13.0	12.0
G7	Pale yellow	Cream	Oblong	6.0	6.0	13.0
G8	Pale yellow	Cream	Round	50.0	6.0	1.0
G9	Pale yellow	Cream	Oblong	5.0	3.0	2.0
G10	Pale yellow	Light Cream	Round	36.0	Nil	Nil
G11	Pale yellow	Light Cream	Long	13.0	3.0	4.0
G12	Pale yellow	Pale yellow	Round	137.0	15.0	1.0
G13	Pale yellow	Cream	Round	50.0	3.0	1.0
G14	Pale yellow	Light Cream	Round	5.0	1.0	1.0
G15	Light reddish orange	Light Cream	Long	11.0	5.0	5.0
G16	Pale yellow	Light Cream	Long	50.0	13.0	2.0
G17	Blue	Cream	Oblong	14.0	3.0	2.0
G18	Blue	Light Cream	Round	7.0	1.0	3.0
G19	Dark blue	Cream	Oblong	36.0	9.0	3.0

G1

G2

G3

G4

G5

G6

Plate 3. Tubers of different micro propagated potato germplasm.

G7

G8

G9

G10

G11

G12

Plate 3. Continued.

G13

G14

G15

G16

G17

Plate 3. Continued.

4.1.1. Salient features of tuber

Tuber characteristics include tuber color, flesh color, tuber shape, tuber size, number of tuber per germplasm. These are also called quality characteristics which are important for marketing as well as for processing. The varieties varied for these characteristics (Table 1). Consumers like potatoes of attractive look, suitable shape and size.

4.1.2. Color of skin and flesh

In the present studies, tuber skin color of potato germplasm G5, G6, G7, G8, G9, G10, G11, G12, G13, G14, and G16 had pale yellow color, germplasm G17and G18 were blue color, G19 was dark blue, G3 and G15 light reddish orange color had germplasm; G2 was reddish orange and two germplasm G1, G4 had soft red in color (Table 1). Many Kenyan consumers denoted white or red skin colored tubers to be of good quality for processing (Kabira, 2000). The flesh color of 12 germplasm of potato viz., G1, G2, G3, G4, G5, G6, G8, G9, G13, G17, G19 had cream in color, six germplasm G10, G11, G14, G15, G16, G18 had light cream color; and one germplasm G12 had pale yellow in color (Table 1). Similarly, color of skin and flesh is controlled by genetic factors. Skin and flesh color is controlled purely by genetic factor (Anwar, 1982). In Bangladesh, Bhutan, Nepal, Pakistan and Philippines red skin potatoes are traditionally preferred. Thus, characters such as tuber appearance, size, shape, color, skin finish etc. which influence consumer choice are considered as quality attributes in potato (Pandey *et al*., 2002).

4.1.3. Tuber shape

The shape of tubers is also influenced by the genetic factors and environment may also affect it to some extent. Most of the germplasm had round shaped tubers (Table 1). In the present studies ten germplasm G2, G3, G6, G8, G10, G12, G13, G14 and G18 had round shape tubers, where five germplasm G1, G4,

G11, G15, G16 had long shaped tubers, four germplasm G5, G7, G9, G17, G19 had oblong shaped tubers (Table 1). Potato tubers that are round and oval in shape are found to be suitable for making chips by most processors because they easily make the required crisp diameters (Pandey *et al*., 2009).

4.1.4. Number of tuber

The number of small sized tubers ranged from 4.0 to 149.0. The germplasm G5 produced the maximum number of small sized tuber (149.0) followed by G12 (137.0) and G6 (85) and G9, G3 produced the minimum (4.0) (Table 1). But the germplasm G1 produced no small sized tubers. Number of medium sized tuber was found in the range of 1.0 to 20 in different potato germplasm. Maximum number of medium sized tuber was recorded in G5 (20.0) followed by G12 (15.o), G6 (13.0) and G16 (13.0) while the germplasm G14 and G18 gave the lowest number of medium sized tuber (1.0). G10 did not produce any medium sized tuber. The number 0f large sized tuber in different germplasm ranged from 1.0 to 13.0. Maximum number of large sized tuber was obtained from G7 (13.0) followed by G6 (12.0), G2 (7.0) and G4 (7.0). The lowest number of large sized tuber was recorded in G12 (1.0), G13 (1.0) and G14 (1.0). The germplasm G10 was unable to produce any large sized tuber.

Table 2. Performance of 19 micro propagated potato germplasm for yield and yield contributing characters

Germplasm No.	Plant height (cm)	No. of leaves plant^{-1}	Chlorophyll content	No. of plantlets
G1	28.00 g	12.00 g	42.07 fg	2.6 fg
G2	40.00 d	20.67 b-f	46.10 b-g	6.33 cde
G3	32.67 efg	21.67 b-f	43.60 d-g	7.33 bcd
G4	51.33 ab	21.00 b-f	45.70 b - g	4.33 ef
G5	30.00 fg	17.33 d-g	42.75 efg	20.67 a
G6	47.67 bc	25.67 abc	44.73 c-g	8.67 b
G7	55.00 a	22.67 bcd	46.73 a-g	4.67 ef
G8	27.00 gh	21.33 b-f	44.93 b-g	7.67 bc
G9	36.67def	15.00 efg	46.97 a-g	2.00 g
G10	27.33 gh	14.67 fg	50.40 abc	6.00 cde
G11	49.67 ab	17.33 d-g	44.83 b-g	5.33 de
G12	35.67 def	15.33 d-g	48.27 a-f	5.67 cde
G13	20.33 h	11.67 g	49.60 a-d	5.33 de
G14	36.00 def	22.33 b-e	40.90 g	5.67 cde
G15	38.33 de	26.67 ab	52.50 a	7.33 bcd
G16	30.67 fg	18.33 c-g	44.53 c-g	5.3 de
G17	42.00 cd	18.33 c-g	49.63 a-d	4.67 ef
G18	29.67 fg	22.67 bcd	48.60 a-e	5.67 cde
G19	53.00 ab	32.67 a	51.03 ab	5.67 cde
Lsd (0.05)	7.08	7.67	6.27	2.2
CV (%)	6.13	12.49	4.36	11.19

In a column means with uncommon letter (s) are significantly different at 5% level of probability by DMRT

4.2.1 Plant height

Plant height (cm) at 60 days after planting was significantly influenced by different potato germplasm. The tallest plants were produced by the G7 (55.00 cm) closely followed by G19 (53.00 cm), G4 (51.33 cm) and G11 (49.67 cm). On the contrary, the shortest plants were found in the G13 (20.33 cm) which was statically similar to G8 and G10.

There was significant difference among the germplasm: G1 (28 cm), G2 (40 cm), G3 (32.67 cm), G4 (51.33 cm), G5 (30 cm), G6 (47.67 cm), G7 (55 cm), G10 (27.33 cm), G11 (49.67 cm), G 12 (35.67 cm), G15 (38.33 cm), G16 (30.67 cm), G17 (42.00 cm) in this respect G13 (20.33 cm) was lowest performer which was statistically similar to G8 (27 cm), G10 (27.33 cm). There was no considerable variation between G9 (36.67), G14 (36.00). These results are similar to those reported by Ahmed (1984) while characterizing local germplasm of Hippophae rhamnoides and screening of exotic germplasm for yield and growth in potato, respectively.

4.2.2 Number of leaves per plant

Significant variation was found among the germplasm in number of leaves plant^{-1} (Table 2). The maximum number of leaves plant^{-1} (32.67) was recorded from the G19 which was statistically similar to G15 (26.67) and G6 (25.57) whereas G13 was recorded the minimum (11.67). This study referred that the high yielding variety G19 produces maximum number of leaves than the other germplasm. Where Lsd was found 7.67 at 0.05 % level of significance variation for the number of leaves per plant was observed among all the germplasm. Photosynthesis in such crops due to higher number of leaves results in the increased tuber size which in turn increases the final yield. Phenotypical variation (82.77) was more as compared to the genotypic variation (71.76).

High heritability has been achieved for number of leaves per plant (Bashir, 1991).

4.2.3 Chlorophyll content

Chlorophyll content of leaves was varied from germplasm to germplasm (Table2). The maximum Chlorophyll content of leaves (52.50) was recorded from G15 closely followed by G19 (51.03), G10, G7, G9, G12, G17 and G18 whereas the minimum (40.90) was recorded from G14 (Table 2). These results are consistent with those of Fleisher *et al*. (2006)

4.2.4 Number of plantlets

Number of plantlets plant^{-1} varied significantly among the germplasm (Table 2). The maximum plantlets ware recorded from G5 (20.67) followed by G 6, G 3 and G15. However, there was no statistically significant variation among the G2, G10, G12, G14, G18 and G19. The minimum number of plantlets was recorded in G 9 and G 1 (Table 3).

Table 3. Performance of 19 micro propagated potato germplasm for yield and yield contributing characters

Germplasm No.	Tuber plant^{-1} (no.)	Individual tuber weight (g)	Tuber yield per plant (g)	Tuber yield per plot (Kg)	Tuber yield t ha^{-1}
G1	2.47 j	68.67 c	169.47 e-h	1.59 e-h	22.69 e-h
G2	15.00 a	7.33 j	109.67 hi	0.99 hi	14.14 hi
G3	11.00 b	13.33 ij	145.67 f-i	1.35 f-i	19.29 f-i
G4	6.67 fgh	30.72 efg	204.35 c-f	1.94 c-f	27.67 c-f
G5	5.67 gh	37.67 de	212.67 c-f	2.02 cde	28.86 cde
G6	9.33 bcd	27.67 fgh	257.67 abc	2.47 abc	35.29 abc
G7	5.00 h	36.67 de	182.67 d-g	1.73 d-g	24.71 d-g
G8	7.33 efg	38.67 d	283.00 a	2.73 a	39.05 a
G9	6.33 fgh	30.99 efg	194.60 c-f	1.85 c-f	26.42 c-f
G10	2.83 ij	77.33 b	219.00 a-e	2.09 a-e	29.90 a-e
G11	5.50 gh	21.84 h	119.89 ghi	1.11 ghi	15.74 ghi
G12	8.67 cde	32.67 def	283.67 a	2.70 ab	38.52 ab
G13	7.67 def	27.33 fgh	210.00 c-f	1.96 c-f	28.00 c-f
G14	2.87 ij	88.33 a	253.00 abc	2.39 abc	34.14 abc
G15	9.67 bc	24.97 gh	241.76 a-d	2.28 a-d	32.54 a-d
G16	8.67 cde	24.78 gh	215.27 b-e	2.01 cde	28.75 cde
G17	4.73 hi	20.60 hi	97.62 i	0.84 i	11.95 i
G18	6.67 fgh	33.00 def	221.00 a-e	2.07 b-e	29.57 b-e
G19	10.00 bc	28.03 fgh	280.94 ab	2.67 ab	38.14 ab
Lsd (0.05)	1.97	7.6	67.1	0.64	9.17
CV (%)	8.91	6.97	10.58	10.72	10.73

In a column means with uncommon letters are significantly different at 5% level of probability by DMRT.

4.3.1 Number of tubers per plant

Number of tubers per plant were significantly influenced by potato germplasm (Table 3). The maximum number of tubers per plant (15.00) was recorded in G2 followed by G3 (11.00), G19 (10.00), G15 (9.67) and G6 (9.33) whereas the minimum (2.47) was in G1. The study showed that all germplasm except G1, G10 and G14 produced maximum number of tubers per plant. The potential tuber number that can be successfully produced by a plant varies with the genotype, similar result was reported by Mihovilovich *et al.* (2014).

4.3.2 Individual tuber weight

Individual tuber weight ranged from 7.33 to 88.33 g (Table 3). Maximum weight was found in G14 (88.33 g) followed by G10 (77.33 g) and G1 (68.67 g) while G2 had minimum weight (7.33 g) which was identical to G3 (13.33g). The difference may be attributed to germplasm and adequate vegetative growth. Some other researchers also reported variation among potato germplasm for individual tuber weight. Significant genotypic and phenotypic differences for individual tuber weight were also found by Desai and Jaimini (1997) and Mehdi *et al*. (2008). Higher individual tuber weight may be due to sufficient vegetative growth for tuberisation (Ravikant and Chandha, 2009). More average tubers weight, (more than 51g) may be due to rapid plant emergence and better plant growth (Patel *et al*., 2008).

4.3.3 Tuber yield plant^{-1}

Significant variation was found among the germplasm in respect of tuber yield per plant (Table 3) which ranged from (283.67 g) to (97.62 g). The highest yield per hill was obtained from the G12 (283.67 g) and G 8 (283.67 g) closely followed by G6 (257.67 g), G10 (219.00 g), G14 (253.00 g), G15 (241.76 g) and G18 (221.00 g). The lowest tuber yield per plant was found in G17 (97.62 g) closely followed by G2, G3 and G11.

4.3.4 Tuber yield plot^{-1}

Tuber yield plot^{-1} was significantly influenced by different micro-propagated potato germplasm (Table 3). The G8 recorded the maximum tuber yield per plot (2.73kg/12m^2), which was closely followed by G12 (2.70kg/plot), G19 (2.67kg/plot), G6 (2.47kg/plot), G15 (2.39kg/plot), G14 (2.28kg/plot) and G10 (2.09kg/plot). The minimum tuber yield per plot was found from the G17 (0.88kg/plot) closely followed by G2, G3 and G11.

4.3.5 Tuber yield ha^{-1}

Tuber yield ha^{-1} varied significantly among the germplasm under trial. It was found that G8 gave the highest yield (39.05 t ha^{-1}), which was closely followed by G12 (38.52 t ha^{-1}), G19 (38.14 t ha^{-1}), G6 (35.29 t ha^{-1}), G14 (34.14 t ha^{-1}), G15 (32.54 t ha^{-1}) and G10 (29.90 t ha^{-1}) (Table 3). Khatun (1995) got 33.2 t ha^{-1} tuber yield from the variety Aziba and it was the highest yield. The germplasm 6, (35.29 t ha^{-1}), G 14 (34.14 t ha^{-1}), G 15 (32.54 t ha^{-1}) did not show significant variation in yield. The exotic G17 yielded the lowest (11.95 t ha^{-1}) which was statistically similar to that of the G2, G3 and G11. The production of tuber varies from genotype to genotype and all germplasm Mihovilovich *et al*. (2014).

Table 4. Correlation coefficients among different pairs of yield and yield contributing characters for different germplasm of potato.

SI No.	Plant height (cm)	No. of Leaves plant^{-1}	Chlorophyll content	No. of plantlets plant^{-1}	Tuber per plant (no.)	Individual tuber weight	Tuber yield per Plant	Tuber yield (t ha^{-1})
Plant height (cm)	1	0.517	0.0733	-0.1578	0.1345	-0.2811	-0.129	-0.125
No. of Leaves plant^{-1}		1	0.1474	0.0797	0.3828	-0.211	0.2945	0.3001
Chlorophyll content			1	-0.1718	0.1828	-0.2478	0.1269	0.1258
No of plantlets plant^{-1}				1	0.0864	-0.0638	0.1333	0.1368
Tuber per plant (no.)					1	-0.7529	0.0175	0.0139
Individual tuber weight						1	0.3327	0.3311
Tube yield per Plant							1	0.9879
Tuber yield (t ha^{-1})								1

4.4 Correlation studies

From the correlation study (Table 4) it was found that plant height had negative correlation with yield. It indicated that the higher vegetative growth resulted in decreasing yields. Number of leaves per plant showed positive association with chlorophyll content and number of plantlets. Plant height showed positive association with chlorophyll content and tuber per plant. It revealed that higher the plant height, higher would be the tuber per plant. There was negative association between number of plantlets and individual tuber weight but positive correlation with number of tuber per plant, tuber yield per plant and tuber yield ha^{-1}. Individual tuber weight showed positive association with tuber yield due to positive correlation but negative correlation with plant height, number of leaves and number of plantlets. Number of plant lets was found negatively correlated with plant height. That might be due to the higher vegetative growth. Positive correlation with yield was observed with number of leaves, number of plantlets, number of tubers per plant, individual tuber weight and yield per plant. Strong positive correlation between tuber yield per plant and tuber yield was observed.

CHAPTER V
SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

An investigation was carried out to study the comparative performance of the nineteen-exotic potato germplasm. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications, at horticultural firm of Sher-e-Bangla Agricultural university, Dhaka-1207. During the months from December 2015 to March 2016 (Rabi season). The planting materials comprised micro propagated healthy and uniform sized potato plantlets of nineteen different germplasm. They were

G1-Line1, G2-Line2, G3-Line3, G4-Line4, G5-Line5, G6-Line6, G7-Line7, G8-Line8, G9-Line9, G10-Line10, G11-Line11, G12-Line12, G13-Line13, G14-Line14, G15-Line15, G16-Line16, G17-Line17, G18-Line18 and G19-Line19.

Phenotypic differences were observed in some plant characteristics studied such as plant height, number of leaves per plant, number of plantlets per plant, chlorophyll content yield and yield components, number of tubers per hill, weight of tuber per hill, average tuber weight and yield of tuber ha^{-1}.

All the germplasm gave more than 90% emergence at 20-35 DAP (Days after Planting). Significantly higher plant height was recorded in G19 (53.00 cm). On the contrary, the shortest plants were found in the G13 (20.00 cm). There was significant difference among the germplasm

The maximum number of leaves $plant^{-1}$ (32.67) was recorded from the germplasm G19 which was statistically similar to G6 (25.67). Chlorophyll content of leaves was varied from germplasm to germplasm.

The maximum Chlorophyll content of leaves (52.50) was recorded from G15 whereas the minimum (42.07) was recorded from G1. Number of plantlets varied significantly among the germplasm. The maximum number of plantlets

was recorded from G5 (20.67) followed by G3, G6 and G8. The maximum number of tubers per plant (15.00) was recorded in G2 whereas the minimum (2.47) was in G1. Individual tuber weight of potato tuber ranged from 7.33 to 88.33 g. Maximum weight was found in G14 (88.33 g) followed by G10 (77.33 g), G1 (68.67 g), while G2 had minimum weight (7.33 g). It was found that G8 gave the highest yield (39.05 t ha^{-1}). The next highest yield was found from the G12 (38.52 t ha^{-1}) followed by G19 (38.14 t ha^{-1}).

From the correlation study it was found that plant height had negative correlation with yield. It indicated that the higher percentage of vegetative growth caused in decreasing yield. Tuber weight showed positive association with tuber yield due to positive correlation but negative correlation with plant height, number of leaves and number of plant lets. Positive correlation with yield was observed with number of leaves, number of plants let, tuber per plant, tuber weight and yield per plant. Strong positive correlation of weight of tuber per plant with tuber yield was observed.

Based on the above discussion the following conclusion might be drawn:

1. The studied nineteen micro propagated potato germplasm showed morphological variation in respect of tuber skin color, tuber flesh color, tuber shape and size.
2. The maximum plant height was recorded from G7 closely followed by G19; whereas, G19 produced the highest number of leaves per plant. The germplasm G5 gave the maximum number of plantlets per plant, which was followed by G6 and G8.
3. The highest number of tubers per plant was obtained from G12 closely followed by G19. The germplasm G14 gave the maximum individual tuber weight.
4. The maximum tuber yield $plant^{-1}$ was recorded from G12 closely followed by G8, G19, G6 and G14.

5. There was a strong positive correlation between tuber yield per plant and tuber yield ha^{-1}.
6. The maximum yield ha^{-1} was produced by G8 closely followed by G12, G19 and G6.
7. G8, G12, G19 and G6 were found promising in this study.

Recommendation:

- The germplasm G8, G6, G12 and G19 can be recommended for potato cultivator for higher.
- Further trial should be conducted to select the most suitable germplasm and for more conformation of the result.

REFERENCES

REFERENCES

Abbas, G., Hafiz, I. A., Abbasi, N. A. and Hussain A. (2012). Determination of processing and nutritional quality attributes of potato germplasm in Pakistan. *Pakistan J. Bot*., 44(1): 201-208.

Ahmed, M (1984). Relationship of stem density with seed size and weight in four potato cultivars. *J. Agric. Res*., 232(A): 309-312.

Amadi, C. O. (2005). Evaluation of potato germplasm for adaptation to heat stress. PhD Thesis, Michael Okpara University of Agriculture Umudike.

Amadi, C. O. and Ene-obong, E. E. (2007). Genetic variability and inter-relationships of some potato attributes in Jos Plateau, Nigeria. *Nigerian J. Bot.* 20 (1): 232-245.

Amadi, C. O., Ene-Obong, E. E., Okocha, P. I. and Dung, E. A. (2008). Path analysis of yield of some potato hybrids and their progenitors in Northern Guinea Savanna of Nigeria. Patnsuk journal. Com / current tissue. 4 (2): 28-37.

Anonymous. (1988). Land resources appraisal of Bangladesh for agricultural development. Report No. 2. Agro-ecological Regions of Bangladesh, UNDP and FAO. pp. 472-496.

Anwar, J. (1982). Screening of new exotic potato germplasm under Faisalabad conditions. M.Sc. (hons). Thesis, Department of Horticulture, University of Agriculture, Faisalabad.

Ara, A., Haydar, M. A., Islam, M. A., Azad S. and Khokan, E. H. (2009). Path analysis in potato. *J. Soil. Nature*. 3(2):20-23.

Bashir, A (1991). Screening of exotic germplasm for yield and growth in potato. Thesis (M.Sc), Department of Horticulture, University of Agriculture, Faisalabad.

BBS (Bangladesh Bureau of Statistics). (2013). Agricultural Statistics Yearbook-2013, ministry of planning, Government of the People's Republic of Bangladesh.

Birhman, R. K. and Kang, G. S. (1993). Analysis of variation and inter - relationships in potato germplasm. *Euphytica* 68:17-26.

Bourque, J. E. (1983). Acclimatization and reestablishment of tissue cultured potato plantlets. Ph.D. Thesis, Colorado State U. Dissertation abstract 44-08:2297.

Burhan, A. (2007). Relationship among yield and some yield characters in potato. *Journal of Biological science*, 7:973-976.

Chaurassia, S. N. S. and Singh, K. P. (1992). Effect of nitrogen levels and haulm cutting on storage behavior of potato cv. Kufri Bahar and Kufri Lalima. *J. Indian Potato Assoc*. 19 (3-4):148-153.

De-Buchananne, D. A. and Lawson, V. F. (1991). Effect of plant population and harvest timing on yield and chipping quality of Atlantic and Nor Chip potatoes at two Iowa locations. American Potato J., 68: 287-297.

Desai, M. and Jaimini, S. N. (1997). Genetic variability, heritability and Genetic advance for yield in potato. *J. Indian Potato Assoc*. 24(1-2): 52-58.

Donnelly, D. J., Coleman, W. K. and Coleman, S. E. (2003). Potato micro tuber production and performance: a review. *Am. J. Potato Res*. **80**: 103-115.

Dua, P. C., Basavaraj, N. and Birbal, R. (2008). To improve the production of seed-size potato tubers. *J. Potato*. **35** (1&2): 23-28.

Ezekiel, R and Bhargava, R. (1998). Influence of pre-sprouting period on the contents of endogenous growth regulators in seed potatoes. *J. Indian Plant Physiol*. **3**(1): 5-10.

Falconer, D. S. and Mackay, F. C. (1996). Introduction to Quantitative Genetics and environmental variability in Soya bean. *Agronomy Journal*, 47: 314-318.

FAOSTAT (FAO, Statistics Division). (2013). Statistical Database. Food and Agricultural Organization of the United Nations, Rome, Italy.

Fleisher, D. H., Timlin, D. J., Reddy, V. R., (2006). Temperature influence on potato leaf and branch distribution and on canopy photosynthetic rate. *Agron. J*. **98**:1442-1452.

Ganga, H., Kulkarni, U. N., Yenegi, N. B., Basavaraj, N., Uppinal, N. and Ramachandra, K. N. (2013). Study on physical characteristics of potato germplasm. *Karnataka J. Agric*. Sci. **26** (2): 281-284.

Goodwin, P. B. and G. Brown. (1980). Field performance of potato shoot-tips proliferated in culture. Potato Res. **23**:449-452.

Goodwin, P. B. and Adisarwanto, T. (1980). Propagation of potato by shoot tip culture in petri dishes. *Potato Res*. **23**: 445-448.

Grafuis, J. E. (1959). Heterosis in barely. *Agron. J.* **51**: 554-567.

Guler, M., Adak, M. S., and Ulukan, H. (2001). Determining the relationships among yield and some yield components using path coefficient analysis in chickpea (*Cicer arietinum* L.). *European J. Agron*. **14**:161-166.

Haverkort, A. J., Waart, van de M. and Marinus, J. (1991). Field performance of potato micro-tubers as propagation material. *Potato Res.* **34**: 353-364.

Hawkes, J. G. (1978). Biosystematics of the potato. *In*: The Potato Crop (Ed.: Harris, P. M.). Chapman & Hall, London. pp. 15 -69.

Horton, D. (1987). Potatoes: Production, Marketing, and Program for developing countries. Westview Press, Boulder. P. 243.

Hylla, S., Gostner, A., Dusel, G., Anger, H., Bartram, H., Christl, S. U., Kasper, H., and Scheppach, W. (1998). Effects of resistant starch on the colon in healthy volunteers: possible implications for cancer prevention. *Ame. J. Clin. Nutr*. **67**: 136-42.

Iqbal, M. K., Hayat, R. S.A. Khan, Sadiq and N. Islam (2006). Correlation and path coefficient analysis for earliness and yield in cotton (*G. hirsutum*). *Asian J. plant Sci*. **5**: 341-344.

Iqbal, M. K., Hayat, R. S. A. Khan, Sadiq and N. Islam, (2006). Correlation and path coefficient analysis for earliness and yield in cotton (*G. hirsutum*). *Asian J. plant Sci*., **5**:341-344.

Jaime, S., Ivette, A., Florence, E. and Philippe, B. (2014). Resistance to *Phytophthora infestans* in *Solanum tuberosum* landraces in Southern Chile. vol. **39**(4):307-315.

Johansen, D. G., Knutson, K. W., S. R. Slack and E. D. Jones. (1984). Recommendations for standards and guidelines for acceptance of tissue cultured potato seed stocks into certification programs. *Amer. Potato J***. 61**: 368-370

Johnson, H. W., Robinson, H. F. and Comstock, R. E. (1955). Estimates of genetic and environmental variability in Soybean. Agronomy Journal, **47**, 314-318.

Jones, E. D. (1988). A current assessment of in vitro culture and other rapid multiplication methods in North America and Europe. *Ame. Potato J*. **65**: 209-220.

Kabira, J. N. (2000). French fries and crisps processing characteristics of selected potato varieties in Kenya. African Potato Association, Uganda. pp. 507-511.

Kesaulya, H., Baharuddin, Zakaria, B., and Syaiful, S. A. (2015). Morphological Characteristics of Potato (*Solanum tuberosum* L.) Variety Hartapel Origin South Buru-Moluccas. *Int. J. Curr. Res. Biosci. Plant Biol.*, **2** (2): 15-21.

Khatun, M. (1995). A study on the performance of seventeen Dutch Potato Varieties in Bangladesh. An M.Sc.(Ag.) Thesis. Bangladesh Agricultural University, Mymensigh.

Kumar, S. and Chauchan B. P. S. (1979). Association analysis in the segregating potato progeny. Indian. *Journal of Agronomy*, **24**(4): 501-504.

Kumbhar, M. B., Larik, A. S. and Hafiz, H. M. I. (1980). Biometrical association of yield and yield components in durum and bread wheat Information Service. **54**: 35 37.

Kushwah, V. S. and Singh, S. P. (2008). Effect of intra-row spacing and date of haulm cutting on production of small size tubers. *J. Potato*. **35** (1/2): 88-90.

Leclerc, Y. and Donnelly. D. J. (1990). Seasonal differences in the field performance of micropropagated potato under a short growing season in Quebec. *Ame. Potato J*. **67**: 507-516.

Levy, D. (1985). Propagation of potato by direct transfer of in vitro proliferated shoot cuttings into the field. *Scientia Hortic*. **26**:105-109.

Levy, D. (1986). Potato propagation through the use of in vitro proliferated cuttings transferred directly into the field. *Amer. Potato J*. **63**: 439.

Levy, D. (1988). Propagation of potato by the transfer of transplants of in vitro proliferated shoot cuttings into the field. *Scientia Hortic*. **36**:165-171.

Lommen, W. J. M. (1994). Effect of weight of potato minitubers on sprout growth, emergence and plant characteristics at emergence. *Potato Res.* **37**: 315-322.

Mahmood, S. (2005). A study of planting method and spacing on the yield of potato using TPS. *Asian J. Plant Sci***. 4**: 102-105.

McDonald, J. G. (1987). Comparative levels of potato virus's S and Y infection of micro-plants and tuber-propagated plants in the field. *Ame. Potato J.* **64**:517-521.

Mehdi, M., Saleem, T., Rai, H. K., Mir, M. S. and Rai. G. (2008). Effect of nitrogen and FYM interaction on yield and yield traits of potato germplasm under Ladakh condition. *Potato J.* **35** (3& 4): 126-129.

Meris, B. (1969). Study on maturity, yield under water weight and some other characters of potato progenies. *Euphytica*, **18**:297-319.

Mihovilovich, E., Carli, C., De Mendiburu, F., Hualla, V. and Bonierbale, M. (2014). Tuber bulking maturity assessment of elite and advanced potato clones protocol. Lima (Peru). International Potato Center. p. 43.

Mohammad, A., Mohammad, N., Safarzadeh, V., Peyman, S. and Ali, S. (2013). Effect of plant density, date and depth of cultivation on yield and yield components of potato planting in the chabahar. *Intl J. Agron. and plant production*. vol., **4** (8), 1890-1897.

Onder, M., and Babaoglu, M. (2001). Interactions among grain variables in various dwarf dry bean (*Phaseolus vulgaris* L.) cultivars. *J. Agron. and Crop Sci*. **187**:10-23.

Onder, M., and Babaoglu, M., (2001). Interactions among grain variables in various dwarf dry bean (*Phaseolus vulgaris* L.) cultivars. *Journal of Agronomy and Crop Science,* **187**:10-23.

Pandey, S. K., Gour, P. C., Singh, V. P. and Kumar, D. (2002). Potential of processing quality potato varieties in different agro climatic region. *In*: Potato Global Research and Development.

Pandey, S. K., Singh, S.V., Marwaha, R.S. and Pattanayak, D. (2009). Indian potato processing varieties: Their impact and future priorities. Potato J. 36(3-4): 95-114.

Pankhrust, R. (1964). Notes for a history of Ethiopian agriculture. Ethiopian Observer **7**: 210-240.

Patel, C. K., Patel, P. T. and Chaudhari, S. M. (2008). Effect of physiological age and seed size on seed production of potato in North Gujarat. Potato J. **35** (1&2): 85-87.

Radovan, M., (1992). Path-coefficient analysis of some yield components of sunflower (*Helianthus annuus* L.).1 *Euphytica* **60**:210-205.

Rahman, M. M. (2014). Assessment of potato varieties for processing industry in Bangladesh. M. S. Thesis, SAU, Dhaka, Bangladesh.

Rasui, M. G., Islam, M. A., Nahar, M. S. and Rashid M. M. (1995). Heritability, Variability and correlation in the first tuber let progenies derived from true potato seed Bangladesh Journal of Science., **30**:161-170.

Ravikant and Chandha, S. (2009). Effect of planting season and fertility regimes on different potato cultivars. *Potato J.* **36**(1-2): 68-71.

Rojoni, R. N., Islam, N., Roy, T. S., Sarkar, M. D. and Kabir, K. (2014). Yield potentiality of true potato seed seedling tubers as influenced by its size and clump planting. App. Sci. Report**. 6**(2): 41-46.

Roy, T. S., Nishizawa, T., Islam, M. S., Razzaque, M. A. and Hasanuzzaman, M. (2009). Potentiality of small seedling tuber derived from true potato seed (*Solanum tuberosum* L.) and its economic return as affected by progeny and clump planting. *Int. J. Agric. Environ. Biotec***., 2**: 385-392.

Rytel, E. (2004). The effect of edible potato maturity on its after-cooking consistency (in Polish). Zesz. Probl. Post. NaukRol. **500**: 465-473.

Sandhu, S. K. and Kang, G. S. (1998). Genetic analysis in andigena potatoes (*Solanum tuberosum* L) *Indian journal of Genetics and plant Breeding*, **25**:181-185.

Sattar, M. A., N. Sultana, M. M. Hossain, M. H. Rashidand A. K. M. A., (2007). Genetic variability, correlation and path analysis in potato (*Solanum tuberosum* L.). *Bangladesh J. Pl. Breed. Genet*. **20**(1): 33-38.

Sharma, J. R. (1998). Statistical and biometrical techniques in plant breeding.

Sharma, O. P. (2001). Hill's Economic Botany, Tata McGraw. Hill publishing company limited. New Delhi, India. pp. 482-485.

Sharma, Y. K. 1999. Studies on genetic variability and performance of potato seed, *Indian journal of science*. 18:412-418.

Singh, B. D. (1983). Plant breeding principles and methods. New Delhi. P. 458.

Sinha, N. K., Cash, J. N. and Chase, R. W. (1992). Differences in sugar, chip color, specific gravity and yield of selected potato cultivars grown in Michigan. *Amer. Potato J.* **69**: 385-389.

Smith, O. P. and R. H. Storch. (1984). Prediction of potato leafroll virus disease in Maine from thermal unit accumulation and an estimate of primary inoculum. *Plant Dis.* **68**:863-865.

Sohail, M., Khan, R. U., Afridi, S. R., Imad, M. and Mehrin, B. (2013). Preparation and quality evaluation of sweet potato ready to drink beverage. ARPN J. *Agric. Biol. Sci*. **8**: 279-282.

Spooner, D. M. (2009). DNA barcoding will frequently fail in complicated groups: An example in wild potatoes. *American J. of Bot.* **96**: 1177 – 1189.

Tesfaye A., Shermarl, W., Thunya, T. and Oranuch, L. (2012). Dry matter content, starch content and starch yield variability and stability of potato parieties in Amhara Region of Ethiopia. *Kasetsart J*. (Nat. Sci.) **46**: 671 – 683.

Thornton, M. K. and K. W. Knutson. (1986). Effect of transplant container volume and growing season length on field performance of micropropagated potatoes. *Amer. Potato J*. **63**:399-410.

UNDP-FAO. (1988). Land resources appraisal of Bangladesh for agricultural development. Report to Agro-ecological regions of Bangladesh. UNDP-FAO, BGD/81/ 035 Technical Report 2. p. 570.

Uyen, N. V. and Zaag, P. V. (1985). Potato production using tissue culture in Vietnam: The status after four years. *Ame. Potato J*. **62**: 237-241.

Waterer, D. (2002). Management of common scab of potato using planting and harvesting dates. *Canadian J. Plant Sci*. **82**: 185–189.

Wattimena, G., B. McCown and G. Weis. (1983). Comparative field performance of potatoes from micro-culture. *Ame. Potato J.* **60**:27-33.

William H. B. and Steven B. J. (2010). Commercial Potato Production in North America.

Yildirim, M. B., C. F., Çalikan, Ö., Çaylak and Budak, (1997). Multivariate relationships in potatoes. Second Turkish Field Crops Symposium, 22-25 September. Samsun, Turkey.

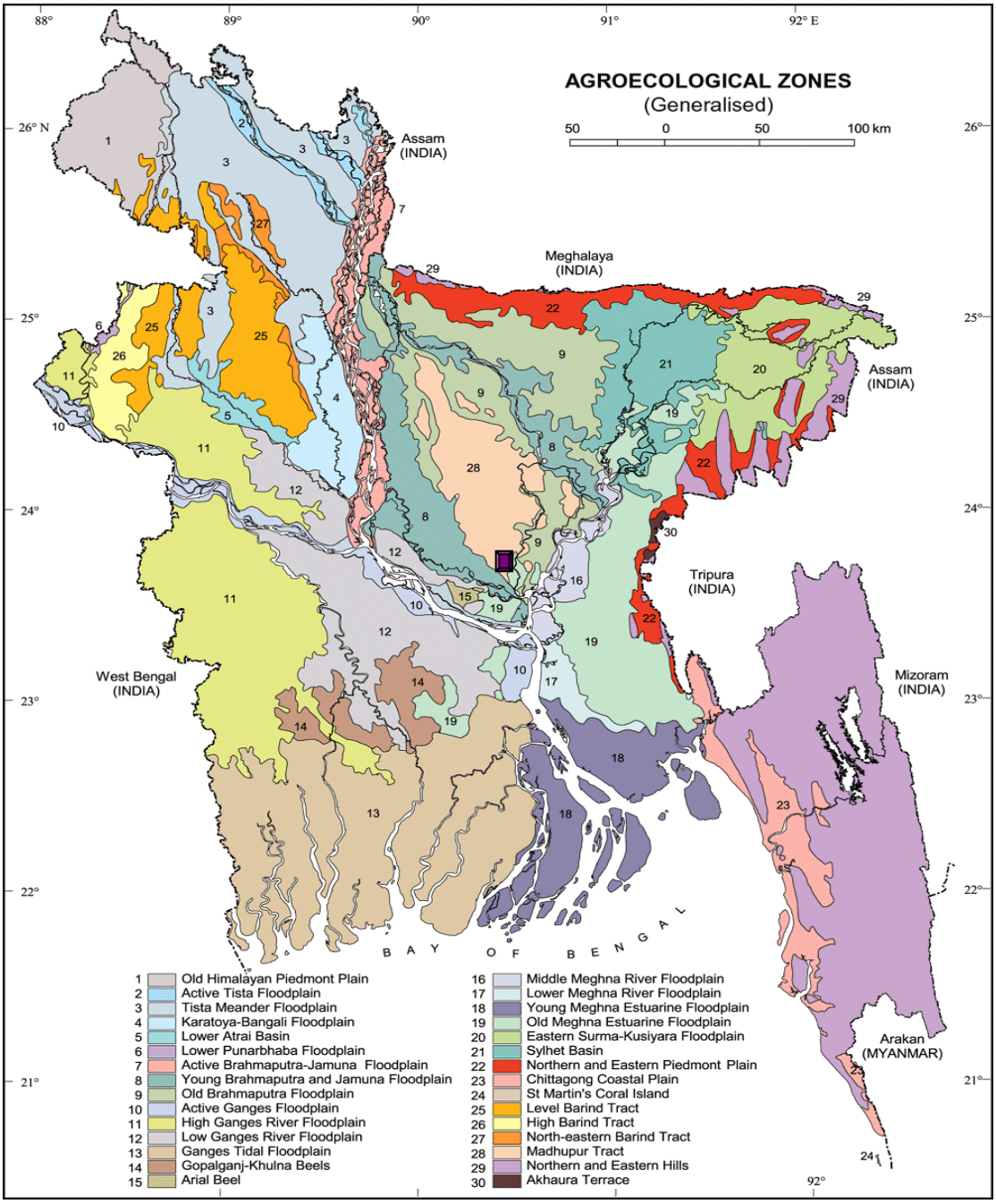
Yucel, D. O., A. E. Anlarsal and C. Yucel (2006). Genetic variability, correlation and path analysis of yield and yield Components in chickpea (*Cicer arictinum* L.). *Turk J. Agric*. *For*. **30**:183-188.

Zaag, D. E. van der (1990). The implication of micropropagation for the future of seed potato production system in Europe. *In* Proc. 11th Triennial Conference EAPR, Ekinburgh, 28-45.

APPENDICES

APPENDICES

Appendix I. Map showing the experimental site under the study



The experimental site under study

Appendix II. Monthly average Temperature, relative humidity and total rainfall and sunshine of the experimental site during the period from December 2015 to March 2016.

Month	Air temperature (°C)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (h)
	Maximum	Minimum			
December 2015	34.8	18.0	77	227	5.8
January 2016	32.3	16.3	69	0	7.9
February 2016	29.0	13.0	79	0	3.9
March 2016	28.1	11.1	72	1	5.7

Source: Weather station, SAU, Dhaka-1207

Appendix III: Morphological, physical and chemical characteristics of initial soil (0-15 cm depth) of the experimental site

A. Physical composition of the soil

Soil separates	%
Sand	36.90
Silt	26.40
Clay	36.66
Texture class	Clay loam

B. Chemical composition of the soil

Sl. No.	Soil characteristics	Analytical data
1	Organic carbon (%)	0.82
2	Total N (kg/ha)	1790.00
3	Total S (ppm)	225.00
4	Total P (ppm)	840.00
5	Available N (kg/ha)	54.00
6	Available P (kg/ha)	69.00
7	Exchangeable K (kg/ha)	89.50
8	Available S (ppm)	16.00
9	pH (1:2.5 soil to water)	5.55
10	CEC	11.23

Source: Soil Department, Sher-e-Bangla Agricultural University, Dhaka-1207

Appendix IV. Analysis of variance of the data on plant height of different potato germplasm

Plant height (cm)					
Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Rep	2	4.1053	2.0526	0.39	0.6795
Var	18	5426.561	301.4756	57.35**	0.00
Error	36	189.2281	5.2563		
Total	56	5619.895			

'**' indicates significant at 1% level of probability

Appendix V. Analysis of variance of the data on tuber yield per plot (kg) of different potato germplasm

Yield per plot (Kg)					
Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Rep	2	1.1799	0.5899	13.71	0.512
Var	18	17.1715	0.954	22.17**	0.00
Error	36	1.549	0.043		
Total	56	19.9004			

'**' indicates significant at 1% level of probability

Appendix VI. Analysis of variance of the data on tuber yield ton per hectare of different potato germplasm

Yield ton (ha)					
Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Rep	2	241.0421	120.521	13.69	0.493
Var	18	3508.813	194.9341	22.15**	0.00
Error	36	316.8559	8.8016		
Total	56	4066.711			

'**' indicates significant at 1% level of probability

Appendix VII. Analysis of variance of the data on number of leaves of different Potato germplasm

Number of leaves plant^{-1}					
Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Rep	2	9.0877	4.5439	0.74	0.485
Var	18	1472.211	81.7895	13.29**	0.00
Error	36	221.5789	6.155		
Total	56	1702.877			

'**' indicates significant at 1% level of probability

Appendix VIII. Analysis of variance of the data on chlorophyll content of different potato germplasm

Chlorophyll content					
Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Rep	2	10.0501	5.025	1.22	0.3071
Var	18	556.4776	30.9154	7.51**	0.00
Error	36	148.2816	4.1189		
Total	56	714.8093			

'**' indicates significant at 1% level of probability

Appendix IX. Analysis of variance of the data on number of plantlets of different potato germplasm

Number of plantlets plant^{-1}					
Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Rep	2	13.0526	6.5263	12.85	0.232
Var	18	783.9298	43.5517	85.77**	0.00
Error	36	18.2807	0.5078		
Total	56	815.2632			

'**' indicates significant at 1% level of probability

Appendix x. Analysis of variance of the data on number of tuber per plant of different Potato germplasm

Number of tuber per plant					
Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Rep	2	1.2425	0.6212	1.52	0.2315
Var	18	528.0018	29.3334	71.98**	0.00
Error	36	14.6709	0.4075		
Total	56	543.9151			

'**' indicates significant at 1% level of probability

Appendix XI. Analysis of variance of the data on individual tuber weight of different potato germplasm

Individual tuber weight					
Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Rep	2	3.473	1.7365	0.29	0.752
Var	18	23451.47	1302.86	215.55**	0.00
Error	36	217.6001	6.0444		
Total	56	23672.55			

'**' indicates significant at 1% level of probability