PERFORMANCE OF MINI SEEDLING TUBERS DERIVED FROM TRUE POTATO SEED AS INFLUENCED BY ITS SIZE AND CLUMP PLANTING

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CERTIFICATE

This is to certify that the thesis entitled, "**PERFORMANCE OF MINI SEEDLING TUBERS DERIVED FROM TRUE POTATO SEED AS INFLUENCED BY ITS SIZE AND CLUMP PLANTING**" 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 HORTICULTURE**, embodies the result of a piece of *bona fide* research work carried out by **ROJOBI NAHAR ROJONI**, Registration No. **04-01245** 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, 2011
Place: Dhaka, Bangladesh

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The

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ABSTRACT

An experiment was conducted at the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from November 2010 to March 2011 to study the performance of mini seedling tubers derived from true potato seed as influenced by its size and clump planting. The experiment was laid out in a Randomized Complete Block Design with three replications and includes four levels of seedling tuber size, *viz*. 6-<7 g (S_1), 7-<8 g (S_2), 8-<9 g (S_3) and, 9-≤10 g (S_4) and three levels of seedling tuber hill^{-1}, *viz*. 1 hill^{-1} (N_1), 2 hill^{-1} (N_2) and 3 hill^{-1}l (N_3). The highest tubers hill^{-1} (6.30), tubers weight hill^{-1} (128.90 g) and gross tuber yield (25.78 tha^{-1}) were found from S_4 while the lowest from S_1. On the other hand, the highest tubers hill^{-1} (5.66), tubers weight hill^{-1} (123.95 g) and gross tuber yield (24.79 tha^{-1}) were found from N_3 while the lowest from N_1. The highest tubers hill^{-1} (6.36), tubers weight hill^{-1} (138.35 g) and gross tuber yield (27.67 tha^{-1}) were found from S_4N_3 and the lowest gross tuber yield (12.83 tha^{-1}) from S_1N_1. The highest benefit cost ratio (1.96) was found from S_4N_1. So, it can be concluded that, 9-≤10 g seedling tuber size with 1 seedling tuber hill^{-1} were found suitable for potato production.

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LIST OF ACRONYMS

ABBREVIATIONS	ELABORATIONS
%	Percent
@	At the rate
°C	Degree centigrade
AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
CGR	Crop Growth Rate
CIP	International Potato Center
CV	Coefficient of Variation
DAP	Days After Planting
DMRT	Duncan’s Multiple Range Test
et al.	And others
etc.	Etcetera
FAO	Food and Agriculture Organization
LA	Leaf Area
LAI	Leaf Area Index
LSD	Least Significant Difference
MOA	Ministry of Agriculture
MSTAT	Michigan State University Statistical Package for Data Analysis
NSB	National Seed Board
pH	Hydrogen ion concentration
RARS	Regional Agriculture Research Station
RCBD	Randomized Complete Block Design
SRDI	Soil Resource Development Institute
TCRC	Tuber Crop Research Centre
TDM	Total Dry Matter
TPS	True Potato Seed
UNDP	United Nations Development Program

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) belonging to the family Solanaceae is the 4th important food crop of the world. It provides essential vitamins, minerals and trace elements to the human in diet (Horton, 1987). In Bangladesh, potato is one of the major crops next to rice and wheat and covers an area of about 403.4 thousand hectare of land producing 5.95 million tons of potato with 14.74 tons of average yield per hectare (MOA, 2009). Potato has acquired great importance in rural economy in Bangladesh. It is considered as a vegetable crop and contributes as much 55 % of the total vegetable production in Bangladesh (BBS, 2009).

Bangladesh has a great agro-ecological potential of growing potato. The area and production of potato in Bangladesh has been increasing from the last decades but the yield per unit area remains more or less static. The national average yield in Bangladesh is much lower compare to many potato growing countries of the world like Belgium, the Netherlands, UK, Germany and USA where the average yield ranges between 38.4 to 49.0 t ha^{-1} (FAO, 1999). This low yield of potato in Bangladesh might be due to lack of quality seed tuber, environmental limitations, unavailability and uneven distribution of certified seeds and use of indigenous cultivars (Roy, 2009; Roy *et al*. 2005; Wiersema, 1986).

The total requirement of seed potatoes in Bangladesh is about 5.86 lac tons, whereas, the public and private sectors supplied about 10-12% of the total requirement (BBS, 2007). The rest is covered by the farmer's own poor quality seed tuber. Therefore, the high cost and inadequate availability of healthy seed tubers are the major constraints in the production and productivity of potato in Bangladesh (Roy, 2009; Siddique and Roy *et al*. 1999). To overcome this, an alternative technology of True Potato Seed (TPS) for potato production has shown great promise for producing both disease free and cheaper seed tuber and thereby, reducing the cost of cultivation and to help the farmers to be less dependent on conventional seed sources (Upadhya *et al*. 2003; Pallais, 1994; Malagamba, 1988; Acatino and Malagamba, 1983).

Potato production in Bangladesh may be increased by improving cultural practices among which optimization of manure and fertilizer, planting time, spacing and use of optimal size seed tubers which influences the yield of potato (Divis and Barta, 2001). Development of true potato seed (TPS) technology has opened a new era in potato cultivation. Tuber Crop Research Centre (TCRC), BARI showed that a good TPS progeny may produce 500 to 800 seedling tubers in a meter of land when planted at 10 cm × 10 cm spacing (TCRC, 2004). These seedling tubers can be planted as good quality seed tubers for ware potato production (Wiersema, 1984). Wiersema (1984) stated that these seedling tubers have higher yield potentiality and the yields from these seedling tubers can be as high as that of large seed tubers when optimum plant spacing is used.

In nursery bed, TPS are planted in close spacing in order to produce small sized seedling tubers. The seedling tubers size ranged from 1g to 40g, though 40g tuber seldom produced. Depending on progeny and plant spacing, about 20 to 25 % tuber belongs to <10g sized grade (Roy *et al.* 2005). In Bangladesh, mini seedling tubers (≈10g) are usually neglected both in terms of ware potato and seedling tuber. The genetical constitution of each of the mini seedling tuber is more or less similar to that of standard one (Upadhya *et al*. 2003).

Some of the mini seedling tubers may be planted together in a hill, which is known as clump planting, which could behave equally seed of its requirement to single normal tuber. Seedling tuber size and clump planting may consider very important factors for the production of potato. Unlike other crops, potato needs high investment in seed which is nearly 40% of the total cost (Verma *et al*. 2007). Khalafalla (2001) reported that the smaller the seedling tuber size, higher the profit in potato cultivation. In traditional method of potato production, seedling tuber size and plant population per hill have been found to influence the yield and economic return (Hossain, 2004). Only a few studies have been done considering size of seedling tubers and clump planting on the growth and yield of potato in Bangladesh.

In order to develop a technically sound and economically feasible standard method for production and utilization of TPS seedling tubers, the present study were undertaken with the following objectives:

i. To study the growth and yield performance of true potato seed seedling tuber
ii. To find out suitable method for utilization of seedling tubers for potato production
iii. To identify the suitable clump planting technique

CHAPTER II

REVIEW OF LITERATURE

Potato is one of the important food crops of the world but in Bangladesh it is mainly used as a vegetable. The average yield of potato in Bangladesh is much lower compared to many potato growing countries of the world. The main limiting factor for potato production and its low yield in Bangladesh is the unavailability of good quality seed tuber. True potato seed can be used successfully for raising seed potato in order to mitigate the acute seed problem of Bangladesh. A good number of experiments have been conducted around the world in order to improve the production technology of TPS seedling tubers but under Bangladesh condition research are inadequate and inconclusive. However, the research findings and information related to the present study, so far collected from different relevant publications and sources have been reviewed below:

2.1 Production and importance of potato in Bangladesh

In Bangladesh potato is mainly used as vegetable and is available in the market throughout the year with reasonable price as compared to other vegetables. According to Kadly (1972), the potato ranks first in biological value, which is an index of the protein of absorbed nitrogen retained in body for growth or maintenance or both, is 73 for potato compared to 54 for maize and 53 for wheat flour. Potato contributes appreciable quantity of energy as well as substantial amounts of high quality protein and essential vitamins, minerals and trace elements to human diet (Horton, 1987).

2.2 History of the use of true potato seed (TPS)

In China, potato production using TPS has been practiced successfully since 1967 in many communes and state farms in Inner Mongolia, Yunnan, Sichuan, Heilongjiang and Anhwei provinces (Li, 1983). In 1979, seedling tubers derived from TPS were planted on 21660 hectares of land in China with an average yield of 29-155% (Li and Shen, 1979). In India, studies with TPS were carried out in late forties (Upadhya, 1979) while in the United Kingdom, potatoes were produced from directly sown TPS in the nineteen-sixties (Gray, 1979).

Potato has been propagated traditionally from tubers and rarely from true seed. In the center of origin of the potato, South American Indians used TPS to rejuvenate their potato stocks from time to time (Salaman, 1949). A good number of Andean cultivars, presently being maintained at the International Potato Center (CIP, 1981 & 1982), may have resulted from selection of plants from TPS by ancient farmers (Wiersema, 1984). Haan (1953) reported that in Europe, during the year 1845 when the late blight epidemics wiped out most of the potato crops in the Netherlands, the country imported TPS from abroad.

The International Potato Center (CIP) has initiated research work on TPS in 1977 and since then most potato producing countries are experimenting with TPS technology (Accatino, 1979; Malagamba, 1988). In Bangladesh, research on TPS technology did initiate in 1980-81 at Bangladesh Agricultural Research Institute (BARI) in collaboration with CIP.

2.3 Role of TPS technology in potato production around the world

According to Hussain (2000), in Bangladesh major breakthrough in disease free seed potato production has taken place by the efforts of private sector companies through adopting i) Tissue culture technique and ii) True potato seed technology. If these technologies are fully exploited, cost of seed tuber will be reduced at the farmer's level. Elias *et al*. (1997) suggested that under Bangladesh condition only 40-45 g of TPS is needed to sow 200 m^2 of nursery bed area which will produce sufficient amount of seedling tubers enough to plant one hectare of land in the next year to produce seed tuber or ware potato.

Based on the on-station and on-farm results conducted in Bangladesh, Upadhya (1995) made a future projection of potato production from TPS in Bangladesh. He pointed that if one-third potato area of Bangladesh could be planted by TPS derived planting material, there will be a saving of 2734 hectares of land for other crop and at the same time there will be a saving of 35,000 t of tuber for human consumption. Siddique (1998) also made a future projection, where it has been shown that nearly 32% of the potato area under modern varieties in Bangladesh could be covered by high quality seed tubers produced from TPS within a period of only 3 years. He also mentioned that, the starting point would be sowing of only about 6.0 kg TPS in 5 hectares of land for the production of seedling tubers in the first year, which will lead to marketing of about 45,000 MT (6,000 × 5) seed tubers at the end of 3rd year and this will cover nearly 40% of the deficit of high quality seed tubers of modern varieties.

Chilver *et al.* (1999) reported that the on-farm profitability of TPS related technologies was assessed in several agro-ecologies in Egypt, India, Indonesia and

Peru based on results of on-farm research conducted in the mid 1990s. TPS technology was found substantially more profitable than clonal propagation. TPS seedling tubers gave higher yields compared to standard cultivars. They also suggested that prospects for TPS technologies were reasonably good when the cost of planting material in the conventional system exceeds 22% of the value of production.

Commercial potato production traditionally has been based on using tubers for propagation especially in developing countries. This is a major limiting factor in potato production because of high cost and unavailability of good quality seed tuber for planting and rapid degeneration of seed tuber stocks due to pathological and physiological reasons (Accatino and Malagamba, 1983; Wiersema, 1984). Among the various means of reducing the cost of production of potato and way of getting good quality seed, the use of true potato seed (TPS) has recently been emerged as a new technology (Malagamba, 1988; CIP, 1992; Rashid *et al*. 1993a and Singh, 1999).

Research on true potato seed at International Potato Center (CIP), Lima, Peru as well as in New Zealand, India, Korea and Egypt by few seed producing companies in USA demonstrated the potentiality of using true seed as planting material, especially in developing countries (Sadik, 1983). The TPS technology has been well established in China and extensive adoption of this technology seemed likely in India, Bangladesh, Indonesia, Egypt, Nicaragua, Nepal, Srilanka, Paraguay and Vietnam (CIP, 1992 and Pallais, 1994). In Egypt, much progress has been made on the development of a seed system based on TPS seedling tubers (El-Bedewy *et al*. 1994).

Seedling tubers derived from TPS offer a promise of getting healthy planting material at low cost for the poor farmers in their own environment (Brown, 1987). Again TPS seedling tubers produce higher or equivalent yield with that of standard potato varieties and can maintain better yield potential for at least 2-3 successive clonal generations of tuber production without much reduction in yield (Pande *et al*. 1990; Hossain *et al*. 1992; Hossain *et al*. 1994 and Anonymous, 2001).

The Bangladesh Agricultural Research Institute (BARI) has released two hybrid TPS varieties, namely BARI TPS-1 and BARI TPS-2 (Razzaque *et al*. 2000). True potato seed can be used for potato production in three different methods (Sadik, 1983; Chaudhury *et al*. 1987; Upadhya *et al*. 1990 and Kadian *et al*. 1992): i) Direct field sowing of TPS, ii) Transplanting of seedling raised in beds to the field and iii) Production of seedling tubers through material in the subsequent years either for seed potato production or for ware potato production.

True potato seeds are formed in small fruits produced on potato plants and the fruits are termed as berries. Singh (1999) reported that depending on genotype and environment, a single potato plant may have 50-100 berries; single berry contains 150-200 seeds and 1g TPS may contain 1500-200 seeds. He also mentioned that TPS technology is labour-intensive and requires less initial capital for raising a potato crop. This combination suits to small and marginal farmers of developing countries who have generally plenty of family laboures and less capital. Kadian *et al*. (1987) pointed out that in the developing countries TPS technology can successfully be adopted by the farmers in those areas where i) seed tuber cost is very high, ii) yields are very poor due to non-availability of good quality seed and iii) cheap labour is easily available.

Wiersema (1983) reported that based on the results of CIP, it was calculated that without multiplication, about 100 m^2 nursery bed would be required to produce sufficien seedling tubers for one hectare, with one field multiplication this area could be reduced to about 30 m^2 and two field multiplication to about 3 m^2. Only 100 g of TPS can replace 2-3 t of seed tubers required to plant one hectare of land and thus diverting it for use as food (Sadik, 1983 and Singh, 1999).

2.4 Utilization of TPS seedling tubers for potato production

A field study was carried out by Hossain (2004) at BARI, Gazipur and BAU, Mymensingh during 1998-99 to 2000-2001 seasons to evaluate and compare the production and utilization of seedling tubers (<1 g, 1-<2 g, 2-<3 g, 3-<4 and 4-<5 g) derived from true potato seed (TPS). Days to emergence, plant height, foliage number, stems plant^{-1}, number of tubers plant^{-1}, marketable and total yields were significantly increased with the increase in seedling tubers weight and number of seedling tuber per hill. He reported that 4-<5 g size seedling tubers with 3 seedling tubers per hill gave the highest tuber yield and can be successfully used for potato production.

An experiment was carried out in Sudan by Amin *et al*. (1996) with three types of true potato seed (TPS) for producing seedling tubers raised in a seedbed with mixture of clay, sand and dry leaves. About 3.1 kg of seedling tubers m^{-2} in the growing season of 1988-89 and between 4.3 and 5.1 kg m^{-2} in 1989/90 were produced. The seedling tubers were stored and used as seed tubers subsequently compared with the locally popular variety Alpha. The mean tuber yields of the hybrids ranged between 9.4 and 11 tha^{-1} in 1990-91 and between 21.9 and 22.9 tha^{-1} in 1991-92. Mean tuber yields of cultivar Alpha were 14.3 tha^{-1} in 1990-91 and 24.1 tha^{-1} in 1991-92, showing that tuber yields comparable to those of imported seed tubers could be obtained from seedling tubers of TPS origin.

An experiment was conducted by Ahmed *et al*. (2001) in Pakistan to evaluate the performance of seedling tubers of potato cultivars 'TPS-9601', 'TPS-9602', 'TPS-9603', 'TPS-9604', 'TPS-9605', 'TPS-9606', 'TPS-9607', 'TPS-9608' and 'TPS-9609' raised from true seed in second generation compared with the tubers of local cultivars Diamant and Desiree. TPS progenies performed significantly better than the control for all the yield parameters i.e. number and weight of large, medium and small tubers. TPS-9606 remained highest for the number and weight of large tubers $plant^{-1}$. The number and weight of medium tubers and number of small tubers were highest in TPS-9605. Desiree (control) gave the minimum number of large and medium tubers, and the lowest weight of medium tubers.

An experiment were conducted at RARS, Jessore where two TPS progenies (HPS-1I/67 and HPS-7/67) were evaluated using small (<5 g) seedling tubers under different (nine) planting systems (Anonymous, 1997). Progeny FIPS-H/67 showed superiority in performance to HPS-7/67 regarding all the characters except stem $hill^{-1}$. The yield of progeny HPS-l1/67 was significantly higher (31.75 tha^{-1}) compared to progeny l-IPS-7/67. The yield of clump planting varied from 27.81 to 33.58 tha^{-1} which was statistically non-significant. This present study revealed that small tubers (<5g) derived from TPS were useful for seed tubers.

Four true potato seed (TPS) hybrids were evaluated for tuber yield with a standard variety (Diamont) at Naltar Seed Valley Northern Areas, Gilgit by Nizamuddin *et al*. (2010). Various agronomic parameters like number of stems plant^{-1}, seedling vigor, number of tubers m^{-2}, yield of tubers ha^{-1} and grading weight (%) were assessed. The TPS hybrids Atzimba × TPS-67 and LT-8 × TPS-67 gave higher tuber yield (43 tha^{-1}) than the standard variety Diamont. Diamont and the TPS hybrid MF-I × TPS-67 did not significantly differ for tuber yield ha^{-1} whereas the TPS hybrid MF-II × TPS-67 produced the lowest number of tubers plant^{-1}, number of tubers m^{-2}, and yield ha^{-1} (29.2 t). On the basis of this study, it is concluded that TPS parent TPS-67 (male parent) has a better combining ability with TPS parents LT-8 and Atzimba, hence true potato seed (TPS) of these hybrids are recommended for general cultivation in Northern Areas of Pakistan.

In a study conducted by Roy *et al.* (2005) involving ten true potato seed progenies, the average yields obtained in the 1st (F_1C_0), 2st (F_1C_1), and 3rd (F_1C_2) generations were 65.9, 29.5, and 26.4 tha^{-1}, respectively. The mean yield reduction from F_1C_0 to F_1C_1 was 55.24% (range 50.57% - 60.42%) and that from F_1C_1 and F_1C_2 was 10.51% (range 6.57% - 16.67%). Percent yield reduction from 1st to 3rd generation was the highest (65.06) in HPS-1/13 and lower (56.56%) in HPS 11/13. Significant variations were observed among the progenies in respect of yield and other characters providing a basis for selection of superior progenies. However, the degree of yield reduction due to degeneration could not be ascertained from this study.

Seedling tubers are normally produced in raised beds under high planting density and a considerable success has been achieved in this regard under the agro-ecological conditions of Bangladesh (Sikka, 1987; Hossain *et al*. 1994; Chaudhury and Rasul, 1995; Maleque, 1997; Choudhury, 1997 and Alam, 1999). In high density, seedling tubers of different sizes ranging from <1 g to >20 g are produced in nursery beds. Research results indicate that, seedling tubers of all sizes are potentially high quality planting material and can be used effectively in seed potato production (Rashid *et al*. 1993a; Anonymous, 1997; Kamaly, 1997 and Roy *et al*. 1997). Seedling tubers derived from TPS produce higher or equivalent yield with that of standard potato varieties and can maintain better yield potential for at least 2-3 successive clonal generation of potato production without much reduction in yield (Pande *et al*. 1990 and Hossain *et al*. 1992).

2.5 Effect of tuber size and plant population on the yield of potato

A field experiment was carried out by Patel *et al.* (2002) during 2000 and 2001 in Kargil, Jammu and Kashmir, India, to investigate the effect of seed size [medium (25-50 g), big (50-75 g) and large (75-100 g)] and intra row spacing (20, 25 and 30 cm) on the yield of potato cv. Kufari Chandramukhi. The authors reported that growth, total yield, tubers plant^{-1} and average weight of individual tuber were greatly affected by seed size and spacing. Tuber yield (30.52 tha^{-1}) and the number of tuber plant^{-1} (10.40) were significantly highest with big seed size and 25 cm intra-row spacing, while average weight of individual tuber (53.93 g) was highest with large seed size and 30 cm intra-row spacing.

A field experiment was conducted by Tohin (2010) at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from 10 November 2009 to 10 March 2010 to investigate the effect of seed tuber weight and plant spacing on morpho-physiological characters, yield attributes and yield of potato. The experiment comprised of four different weight of seed tubers *viz*., 40 ± 2, 30 ± 2, 20 ± 2 and 10 ± 2 g and three plant spacing *viz*., 60 cm × 25 cm, 60 cm × 20 cm and 60 cm × 15 cm. Plant height, stems hill^{-1}, LA plant^{-1} and LAI, TDM plant^{-1} and TDM m^{-2} and CGR increased with increasing seed tuber weight but yield attributes and yield increased upto 30 ± 2 g tuber weight. The highest tuber yield tha^{-1} (both gross and marketable) was recorded in the tuber weight of 30 ± 2 g due to increased number of tubers hill^{-1} and tuber yield hill^{-1}. The lowest tuber yield tha^{-1} both gross and marketable was recorded in the seed tuber weight of 10 ± 2 g.

A field study was carried out by Adhikari (2005) at Khumaltar, Lalitpur, during 2002-2004 to evaluate and compare the performance of different sizes of seedling tubers (1-5 g, 5-10 g, 10-20 g and 20-40 g) of true potato seed (TPS) with whole and half cut seed tubers of Desiree of 20-40 g size at 60-25 cm spacing. Percent emergence, plant height, leaves number plant^{-1}, stems plant^{-1}, number of tubers plant^{-1}, marketable and total yields were significantly increased with the increase in seedling tubers weight as compared to whole and half cut seed tubers of Desiree. Late blight

(*Phytophthora infestans*) disease was quite low in the TPS crops than Desiree. Both whole and half cut seed tubers of Desiree produced significantly higher average individual tuber weight. Uniformity of the tubers harvested from different sizes of seedling tubers was statistically similar and tubers from Desiree were statistically uniform as compared to seedling tubers. He suggests that more than 1 g size seedling tubers can be successfully used for potato production as from the seed tubers of any standard variety.

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

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

A trial with four different sizes of seedling tubers (5, 5-10, 10-15 and 15-20 g) combined with four spacings (60 × 10, 60 × 15, 60 × 20, and 60 × 25 cm) was conducted by Islam (1992) at BAU, Mymensingh. Plant vigour and foliage coverage was significantly higher at early stage of plant growth when large seeds were planted at closer spacing. However, at the later stage no significant variation was observed. The number of tuber hill^{-1} and yield increased when larger seeds and closer spacings were used. The multiplication rate on the basis of unit weight of seed was higher in smaller seeds than larger ones. From a field trial at BAU, Mymensingh, Kamaly (1997) also reported that the yield of potato increased with the increase in seedling tuber size and the multiplication rate on the basis of unit weight of seed was higher in smaller seeds than larger ones.

According to Singh *et al*. (1998) four nitrogen doses (100, 150, 200 and 250 kg Nha^{-1}) and three different seed sizes (<10 g, 10-20 g and 20-30 g) were studied for potato production from seedling tuber with a spacing of 60 × 20 cm and they obtained highest tuber yield from large (20-30 g) sized seeds and lowest yield from small (<10 g) seeds.

Ahmed and Quasem (1968) reported that large seed tubers play a vital role in producing higher yield. Karim and Hossain (1980) observed that the larger seed had yield advantages over smaller ones. Kumar and Baijal (1979) observed that the larger seed tubers were superior to smaller ones in producing better plant growth, development and higher tuber yield. Siddique *et al*. (1987) reported that the tuber yields produced from large seed tubers were higher compared to small tubers. Hussain (1985) concluded that tuber yield increased with the increases in seed size and it was primarily due to high food reserve in large seed.

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

An experiment was conducted by Verma *et al.* (2007) at Muzaffarpur, Bihar, India, during rabi 2001-02 with 15 treatment combinations which included five seed tuberlet sizes (<10, 10-20, 20-30, 30-40 and >40 g) and three true potato seed (TPS) cultivars (92-PT-27, TPS C-3 and HPS 1/13). They reported that the seed tuberlet size of 30-40 g resulted in significantly superior tuber yield, which was at par with the tuber yield obtained from 10-20 and >40 g seed tubers in all the three TPS cultivars.

An experiment were conducted by Khan *et al*. (2010) to determine the suitable planting geometry for better yield from TPS mini tubers during autumn 2006-2007 and 2007-2008. It was revealed that small size (5-20 g and 20-30 g) tubers planted at closer row and plant spacing (60 × 15 cm and 70 × 15 cm) produced 31.0%, 31.33%, 28.33% and 32.33% medium size tubers (35-55 mm size). Whereas wider spacing (70 cm × 20 cm and 50 cm × 20 cm) produced relatively higher number of large size tubers.

An experiment were conducted by Mukhopadhyay (2001) to study the effects of tuber size (2-5, 6-10 and 11-15 g) and NPK (50, 100 and 150% of the recommended rate) on potato TPS families (HPS-1/13, TPSA-C3 and MST-1) were investigated in West Bengal, India during 1995-96 and 1996-97. The emergence of crops ranged from 76.6-94.0% at 30 days after planting. Although the TPS families did not vary significantly, seedling tubers of 11-15 g recorded higher percentage of emergence irrespective of NPK rates. The tuber yield increased with the increase in tuber size and NPK rate. However, similar yield increase was obtained at 100% N. The highest net return was recorded for 2-5 g tuber size for all TPS families irrespective of the NPK rate. However, the cost benefit ratio was highest when tubers of similar size were fertilized with 50% of the recommended rate.

An experiment were conducted by Roy *et al*. (2009) by using three True Potato Seed progenies (BARI TPS-1, BARI TPS-2 and P-364 × TPS-67) were evaluated using mini seedling tuber (~5 g) under different clump planting methods (1, 2, 3, 4 and 5 seedling tuber hill^{-1}, respectively) at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during 2007 to 2008. Both progeny and clump planting method had significant effects on most of the growth and yield parameters. Progeny, P-364 × TPS-67 showed superiority in performance to BARI TPS-2 and BARI TPS-1 regarding all the characters. Maximum values for tuber yield and seed tuber yield were obtained in case of 3 seedling tubers planted hill^{-1}, the values decreasing with increasing number of seedling tubers planted hill^{-1}. Out of 15 treatment combinations, P-364 × TPS-67 and 3 seedling tubers hill^{-1} was the best for commercial potato as well as seed tuber production. The benefit cost ratio was also the highest for 3 seedling tubers hill^{-1}, which gave the maximum quantity of marketable tubers from the hybrid TPS progeny P-364 × TPS-67.

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

Bishop and Wright (1959) observed that the size of tubers produce was related to the plant spacing. Kamal and Khan (1973) reported that increased spacing decreased the yield of potato and closest spacing gave the highest yield. Eddowes (1975) observed that higher total yield was always associated with closer spacing and higher seed weight ha^{-1}.

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

Carputo *et al*. (1996) carried out an experiment in Italy to find out the effect of varying plant population on the production of tubers from potato seedlings by using three different plant densities: 35, 70 and 100 plants m^{-2}. Increasing the plant population significantly increased the number of tubers produced, but no significant difference was found between the plant densities of 70 and 100 plants m^{-2}. The seedling tubers produced in nursery beds were tested in the field for ware potato production using different sized tubers. The best performances were obtained using tubers 30-40 mm.

Chaudhury and Rasul (1995) reported that small (<20 mm), medium (20-28 mm) and large (>28 mm) sized seedling tubers were studied at 60 × 10, 60 × 15 and 60 × 20 cm spacing respectively and irrespective of seed size the yield was found to be increased with the increase of plant population. Four sizes of seedling tubers (5.0, 7.5, 12.5 and 17.5 g) and four depth of planting (surface level, 2.5, 5.0 and 7.5 cm) was studied at BAU, Mymensingh by Sultana (1998) for potato production from seedling tubers. Seedling tuber size significantly influenced the growth and yield of potato. The yield was found to increase with the increase of seedling tuber size and the maximum yield (39.34 t/ha) was obtained from the large seeds.

Cloete and Els (1982) reported that a positive correlation was found between number of stems plant^{-1} and yield. As the number of stem increased by planting large tubers or by closer spacing the total yield increased. Singh (1992) reported that with common seed rate in three seed sizes, small seed size (25 g) gave 21.1 and 46% higher yield than medium (50 g) and large (100 g) seed. The multiplication rate decreased with increase in seed size. Planting the small seed fetched the highest net income. Wiersema (1984) reported that the advantage of small tubers specially small seedling tubers over larger ones would seem to be their high multiplication rate. The high multiplication rate of small tubers and their tendency to produce small tubers would make them particularly suitable for the production of seed potato rather than ware potato production.

Engels *et al*. (1993a) reported that the rate of field emergence was faster with large (>5 g) than small (<5 g) seedling tubers but the final emergence was about 90% regardless of size. Initial foliage development was faster from large than small seedling tubers. The number of above ground stems increased with increasing seedling tuber size. However, on a per weight basis, 1-5 g tubers were about five times more effective in producing stems than tubers of >20 g. In another experiment, Engels *et al*. (1993b) found that tuber yields from small seedling tubers were increased at higher planting densities. The potential of seedling tubers to produce tubers of marketable weight decreased with decreasing seedling tuber size.

Experimental work was carried out by Carputo *et al.* (1994) in order to select the best parental lines and to evaluate the appropriate breeding schemes for the use of seedling tubers in southern Italy. 48 true potato seed (TPS) families with different genetic backgrounds were tested for seedling tuber production. The seedling tuber families were tested for tuber production by subdividing them in two size classes: 25-35 mm and 35-45 mm. The highest yield was attained by 4X × 2X families and indicated significant differences with regard to tuber size and TPS families for both total and marketable tuber yield.

Four sizes of seedling tubers (5, 10, 20 and 30 g) in combination with four interplant spacings (10, 15, 20 and 25 cm) were studied for potato production by Rashid *et al*. (1993b). Closer planting as well as larger seedling tubers increased tuber yield significantly. Closer spacing produced a higher proportion of small tubers while larger seedling tubers produced more large tubers. In case of multiplication rate, when the seed weight was considered, smaller seeds yielded much higher than larger ones. The multiplication rate was 31.3 and 8.3 times for 5 g and 30 g seeds, and 14.6 and 19.0 times for 60 × 15 cm and 60 × 30 cm spacing respectively.
From an experiment on seedling tuber size Hoang *et al*. (1988) stated that yield increased markedly with the increase of seedling tuber size. 2-5 g sized seedling tubers yielded 17.6 tha^{-1} whereas 10-15 g sized seedling tubers yielded 29.3 tha^{-1}. From another trial, comparison between the local cultivar and TPS seedling tubers they found that the TPS progeny had superior resistance to *Phytophthora infestans*, lower virus infection and higher yield at harvest.

Gojski (1979) conducted a trial with various seed sizes and the materials were planted at 10, 20, 30 and 40 cm spacing. He observed that haulm mass increased due to increased spacing and larger seed tubers. Wiersema (1984) reported that plants in small sized (1-5 g) seedling tubers develop more slowly and produce a larger proportion of tubers smaller than 45 mm larger tubers. It would, therefore, appear that the management of relatively small seedling tubers should aim at promoting early plant growth by close plant spacing. He also stated that small tubers tend to produce small tubers, a tendency likely to be more pronounced in a shorter growing period.

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

In field experiments conducted in Egypt by Engels *et al*. (1993a) to evaluate the performance of seedling tubers derived from true potato seed was investigated under conditions of decreasing and increasing day length and temperature. Field emergence and haulm development were compared in crops from seedling tubers ranging in weight from 5 to 35 g at different planting densities. The number of eyes tuber^{-1} increased with the seedling tuber size but the number of eyes g^{-1} tuber was more than 7 times higher in small (1–5 g) seedling tubers than in large (>20 g) ones. Despite these large differences in the number of eyes, sprout weight g^{-1} tuber weight after storage in a non-cooled store was similar in tubers from different size grades. He also found that, initial foliage development was much faster from large than from small tubers. Plants grown from small tubers at low planting density developed more and larger axillary branches and tended to senesce later than plants from large tubers.

Khurana (1990) reported that seedling tubers of nine TPS were tested against two seed sizes (10 g and 20 g). Seedling tubers of 10 g were planted at 60 × 12 cm and 20 g at 60 × 20 cm spacing. The crop raised from 10 g tubers gave lower yield than that raised from 20 g tubers. Major difference in yield was due to a reduction in proportion of large size tubers. The mean tuber weight of the crop raised from 10 g tubers were also lower than that the crop raised from 20 g tubers. According to Nankar (1990) nearly 50% of the seedling tubers produced in nursery beds was of below 5 g size. To assess the possibility of using <5 g seedling tubers as planting material one, two and three seedling tubers hill^{-1} were planted in the inter cropping system. Three seedling tubers hill^{-1} gave the highest yield. To evaluate the potential of seedling tubers of TPS families for commercial potato production. Seedling tubers of 15-35 mm size were tested by Kadian *et al*. (1992). In comparison to smaller tuber size, the larger tubers gave better performance for yield. Marketable yield and tuber size declined marginally with decreasing seedling tuber size.

Mandala and Arora (1987) conducted an experiment with 15, 25 and 35 cm plant spacing and 45 cm row spacing and observed that the lowest spacing gave the highest yield. Ahmad *et al*. (1976) observed that lower yield plant^{-1} at closer plant spacing can be compensated by increasing the number of hills per unit area. Bashar (1976) reported that wider spacing increased tuber yield per hill but the highest yield per unit area was obtained from the closest spacing. Singh and Chhabaria (1980) reported that the tuber yield decreased with increased spacing within each seed size used. Closer spacing gave the highest yield of total as well as seed grade tubers.

Optimizing plant density and seed size are the most important subjects of potato production systems due to their effects on seed cost, plant development, yield and quality of the crop. In this relations an experiment was conducted by Gulluoglu and Aroglu (2009) to know the effects of different in row spacing (20, 25, 30 and 35 cm) and seed size (small, medium and large) treatments on yield components and tuber yield of potato. The authors observed that closer spacing reduced tubers hill^{-1}, average tuber weight, tuber yield hill^{-1} and percentages of large and medium weight tubers. Total yields increased as increasing planting density up to 20 cm spacing. The authors reported that seed size should be considered during recommendation for planting density in potato production.

Patel *et al*. (2008) conducted an experiment to evaluate the effects of physiological age (200, 375, 750 and 1125 degree days) and seed size (31-59 g and 51-70 g) on the growth (percent emergence, percent ground cover and number of stems hill^{-1}) and tuber yield of potato on loamy sand soils and observed that better growth and yield could be achieved by planting 51-70 g seed tubers with a physiological age of 375 degree days.

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

Rashid *et al*. (1979) found that the small seed tubers (28-35 mm) produced higher tuber yield than the larger ones (35-45 mm). But Popova (1979) reported that there was no significant difference in tuber yield of potatoes with different size of seed tubers viz. small (30 g), medium (50-80 g) and large (80-100 g). Wiersema (1984) stated that the number of above ground stems increase with increasing tuber size.

These stems were either main stems originating from one of the buds in the eyes, or secondary stems developing from axillary buds. Since both type of stems are capable of producing tubers (Allen and Wurr, 1973), these additional stems are likely to have contributed to the higher yield.

Rashid *et al*. (1993b) reported that in general, small seedling tubers are superior to small tubers or cut tubers of the standard varieties of the same size as they are likely to be virus free and do not decay as easily as cut tubers once planted.

Shingrup *et al.* (2003) investigated the effect of row spacing (45 and 60 cm) and tuber size (6-25 g and 26-45 g) on growth, yield and yield components of potato cv. Kufri Jyoti and reported that plant growth and development increased with increased tuber size. The tuber size of 26-45 g recorded significantly higher yield but average weight of tuber was higher in 6-25 g tuber size. Upadhya and Cabello (2001) studied the influence of seed size and density on the performance of direct seedling transplants from hybrid true potato seed and reported that seed size and density strongly suggest a high correlation between seed size and yield.

Singh *et al*. (1999) reported that four sizes of seedling tubers (5-10, 10-20, 20-40 and >40 g) in addition to 40-60 g size seed tubers of Kufri Badsha were compared for tuber yield. The total tuber yield as well as marketable tuber yield increased with increase in seedling tuber size. However, seedling tuber sizes 10-20, 20-40 and >40 g were not significantly different. Yield of Kufri Badsha was statistically as per with the yield of 5-10 g size seedling tubers.

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

The effect of tuber size (25-30, 30-55, 55-75 and 75-85 mm) on potato growth and yield was determined by Divis and Barta (2001) in Czech Republic in 1996-98. The authors reported that increasing seed tuber size produced an increase in emergence percentage. Larger tubers produced higher stems plant^{-1}, crop growth rate and higher yield compared to small ones.

The size of seed tuber influences the production of potato. The growth of young plant is directly related to the size of seed used and generally large seed tubers exhibit earlier sprout emergence, faster growth and development, more stems as well as tubers, earlier maturity and higher tuber yield than small seed (Grewal *et al*. 1992). Use of large seed generally results increased seed rate.

The yield of plants grown from small (5-20 g) seedling tubers was similar to that of plants grown from clonal seed tubers when planted at equivalent weight rates (CIP, 1982). The main difference between plants grown from small and large seedling tubers was the comparatively slower growth rate of those from small tubers. Karle *et al*. (1997) reported that with same spacing large seedling tubers (5-10 g) produced significantly higher yield over small seed size (up to 5 g). The multiplication rate and benefit cost ratio was highest in small sized seeds. Thus planting small sized seedling tubers seems to be an attractive low investment technology for potato production, provide healthy tubers. Batra *et al*. (1992) reported that percent emergence, plant height, tubers number hill^{-1} and tuber yield increased with increase in seedling tuber size. Kadian *et al*. (1988) stated that the seedling tubers below 20 g size can successfully be used as seed tuber for next season, which gave the same potential yield as from seed tubers (30-50 g) of standard cultivars.

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

Three sizes of seedling tubers (<15 mm planted at 60 × 10 cm spacing, 15-20 mm planted at 60 × 15 cm spacing and 21-28 mm planted at 60 × 20 cm spacing) were studied by Roy *et al*. (1997) and found that number and weight of tubers hill^{-1} increased with the increase in seedling tuber size but significantly higher yields of total and seed grade tubers were obtained from small seedling tubers, particularly due to closer spacing.

Wiersema (1982) suggested that the production of ware potato from seedling tuber of 1-5 g size the spacing should be 50 cm × 10-15 cm. He also found that the multiplication rate (yield/planting rate) for small (1-5 g) seedling tubers was the highest (22) compared to 10-20 g sized (23) and 40-60 g sized (10) seedling tubers. To find out an optimum planting density of seedling tubers two spacings (50 × 20 cm and 50 × 10 cm) were studied by Saikia and Rajkhowa (1998) and found that total marketable yields were higher in closer spacing (50 × 10 cm) over the spacing of 50 × 20 cm.

Wiersema and Cabello (1986) found that final emergence of plants derived from different sized seedling tubers was similar but plants from 1-5 g seedling tubers required an average of 4 days more to reach 90% emergence than plants from larger seedling tubers. They also concluded that 1-5 g tubers are more suitable for seed tuber (28-45 mm) production than the production of ware sized tubers.

Wiersema and Cabello (1986) were conducted an experiment to evaluate the growth and yield of plants from different-sized seed tubers derived from true potato seed. In single-sprout tubers, dry weight of haulm stem^{-1} at 47 days after planting was greater in the 40-60 g tubers when compared with that in the 5-10 g or the 10-20 g tubers. They also found that, different rates of planting, 1-5 g seed tubers produced smaller tubers than 5-10 g or 10-20 g seed tubers. Increased rate of planting resulted in non-significant yield increases per unit area in plots planted with 1-5 g seed tubers. The yield increases were significant when 5-10 g and 10-20 g seed tubers were planted at higher rates. The number of main stems per unit of seed tuber weight was five times greater in 1-5 g tubers compared with that in 40-60 g tubers.

Wilson and Murphy (1969) reported that emergence of plants was early with 70.0 g seed tubers compared to 42.5 g seeds of similar type. Rashid (1987) conducted a trial at TCRC, BARI, Joydebpur and observed increased plant emergence with larger seed tubers but the effect was not significant. Tabibullah *et al*. (1982) reported that in whole seed potato the germination period was shorter than that of cut halves. Beukema and Zaag (1979) stated that the size of seed tubers influenced the number of sprouts. Larger tubers produced more sprouts than the smaller ones.

CHAPTER III

MATERIALS AND METHODS

This chapter describes the materials and methods which were used in the field to conduct the experiment during the period from 28 November 2010 to 28 March 2011. It comprises a short description of experimental site, soil and climate, variety, growing of the crops, experimental design and treatments and collection of data presented under the following headings:

3.1 Experimental site

The study was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. Geographically the experimental area is located at $23^{0}41$ N latitude and $90^{0}22$ E longitudes at the elevation of 8.6 m above the sea level (FAO, 1988). The map showing the experimental site under study in Appendix III.

3.2 Characteristics of soil

Soil of the experimental field was silty loam in texture. The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under the AEZ No. 28. Soil sample of the experimental plot was collected from a depth of 0-30 cm before conducting the experiment and analyzed in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix I.

3.3 Climate and weather

The climate of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October (Edris *et al*. 1979). Details of the meteorological data during the period of the experiment was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix II.

3.4 Plating material

In this research work, TPS seedling tubers of the variety BARI TPS-1 were collected from the Tuber Research Centre, Bangladesh Agriculture Research Institute, Gazipur and were used as planting material. The variety is a hybrid between female parent MF-II and male parent TPS-67 was released by the National Seed Board (NSB) during 1997. Plants of the variety are medium with spreading habit; tubers are round oval, shining creamy skin with light yellow flesh (Razzaque *et al*. 2000).

3.5 Treatment of the experiment

The experiment consisted of two factors *viz*., seedling tuber size and clump planting. Clump planting is the technique of planting per hill where more than one tuber are planted and the plant per hill as counted as single plant.

Factor A: Four levels of seedling tuber size

i) S_1 = 6-<7 g

ii) S_2 = 7-<8 g

iii) S_3 = 8-<9 g

iv) S_4 = 9-≤10 g

Factor B: Clump planting: Three levels of seedling tuber per hill

i) N_1 = 1 per hill

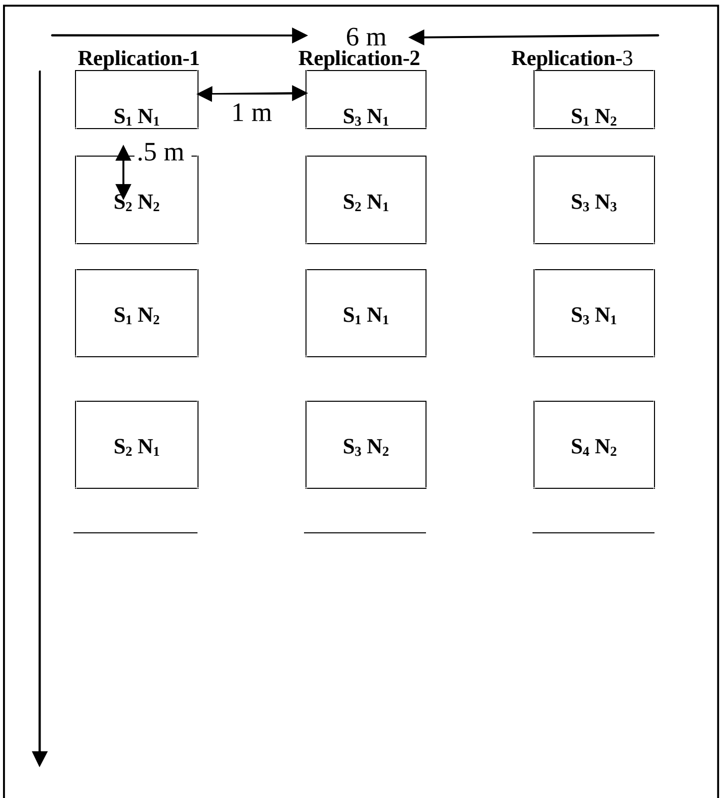
ii) N_2 = 2 per hill

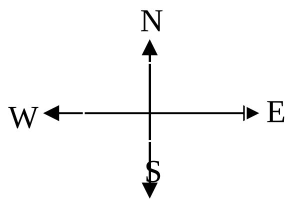
iii) N_3 = 3 per hill

There were 12 (4 × 3) treatments combination such as S_1N_1, S_1N_2, S_1N_3, S_2N_1, S_2N_2, S_2N_3, S_3N_1, S_3N_2, S_3N_3, S_4N_1, S_4N_2 and S_4N_3.

3.6 Design and layout of the experiment

The two factors experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 108 m^2 with length 18 m and width 6 m. The total area was divided into three equal blocks. Each block was divided into 12 plots where 12 treatments combination were distributed randomly. There were 36 unit plots altogether in the experiment. The size of the each plot was 1 m × 1 m. The distance maintained between two blocks and two plots were 1 m and 0.5 m, respectively. The plots were raised up to 10 cm. In the plot with maintaining distance between row to row and plant to plant were 50 cm and 10 cm, respectively. The layout of the experiment is given below:





Plot size: 1 m x 1 m
Spacing: 50 cm x 10 cm
Spacing between plots: 50 cm
Spacing between replication: 1 m

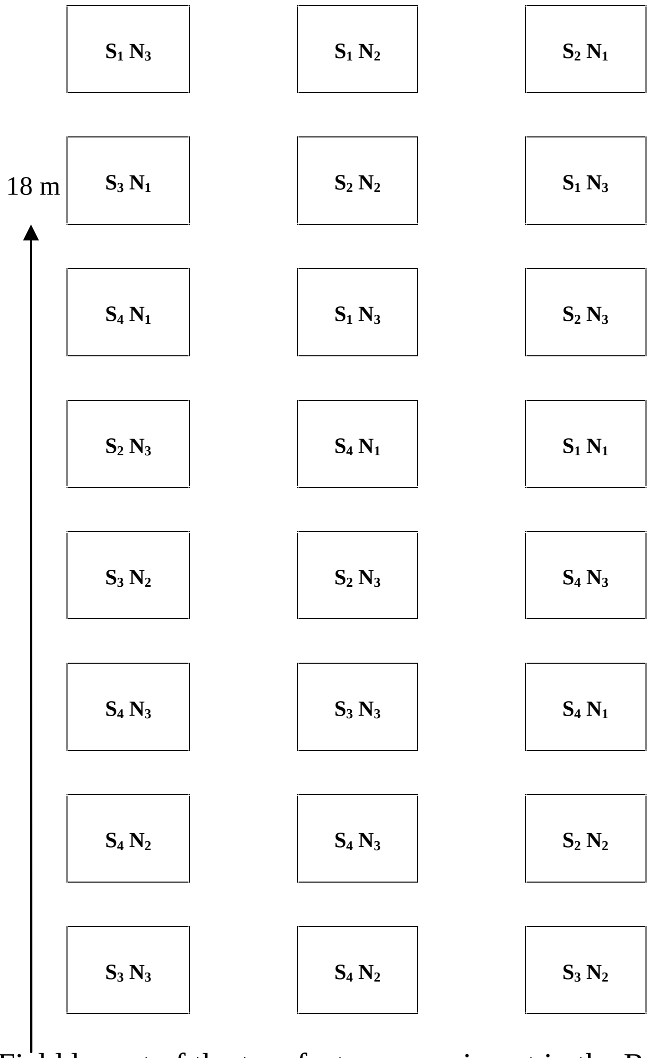
Factor A:
Four levels of seedling tuber size

i) S_1 = 6-<7 g

iii) S_2 = 7-<8 g

v) S_3 = 8-<9 g

vii) S_4 = 9-≤10 g



Factor B:
Three levels of seedling tuber per hill

i) N_1 = 1 per hill

ii) N_2 = 2 per hill

iii) N_3 = 3 per hill

Field layout of the two factors experiment in the Randomized complete Block Design

3.7 Land preparation

The plot selected for conducting the experiment was opened in the 2nd week of November 2010 with a power tiller and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil was obtained for sowing of seedling tubers. In order to avoid water logging due to rainfall during the study period, drainage channels were made around the land. The soil was treated with Furadan 5G @ 15 kg ha^{-1} when the plot was finally ploughed to protect the young seedlings from the attack of cut worm.

3.8 Application of manure and fertilizers

The crop was fertilized as per recommendation of TCRC (2004). Urea, triple superphosphate (TSP), muriate of potash (MP), zypsum, zinc oxide and boric acid were used as sources of nitrogen, phosphorus, potassium, sulphur, zinc and boron, respectively. The doses of fertilizers were 300, 220, 250, 100, 25, 15 and 10000 kg ha^{-1} for urea, TSP, MP, gypsum, Zinc sulphate, boric acid and cowdung respectively. Cowdung was applied 10 days before final land preparation. Total amount of TSP, gypsum, ZnO, boric acid and half of urea and MP were applied at basal doses during final land preparation. The remaining 50% urea and MP were side dressed in two equal splits at 25 and 45 days after planting (DAP) during first and second earthing up.

3.9 Seed preparation and sowing

The seedling tubers were taken out of the cold store about three weeks before planting. The tubers were graded according to the size 6-<7 g, 7-<8 g, 8-<9 g and 9-≤10 g (Appendix V) and kept under diffuse light conditions to have healthy and good sprouts. Planting was done on November 28, 2010. The well sprouted seedling tubers were planted at a depth of 5-7 cm in furrow made 50 cm apart. After planting, the seedling tubers were covered with soil.

3.10 Intercultural operation

After planting of seedlings tubers various intercultural operations were furnished for proper growth and development of the crop.

3.10.1 Weeding

First weeding was done two weeks after emergence. Another weeding was done before 2nd top dressing of urea. It was also done as and when required to keep the crop free from weeds and to keep the soil loose for proper aeration and development of tubers.

3.10.2 Earthing-up

After proper weeding of the crop, earthing-up was done at 25 days after planting, just after side dressing of fertilizers and second earthing up was done after 20 days of first earthing up. Earting-up was done with a narrow spade to provide more space for the development of tubers.

3.10.3 Irrigation

Three irrigations were provided throughout the growing period in controlled way. The first irrigation was given at 25 DAP. Subsequently, another two irrigations were given at 45 and 65 DAP. Top dressing of fertilizers was followed by irrigation for proper utilization of fertilizers.

3.10.4 Plant protection

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

3.10.5 De-haulming

Haulm cutting was done before 7 days of harvesting.

3.10.6 General observation

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

3.10.7 Harvesting

The crops were harvested at 100 DAP. The harvested plants were tagged separately plot wise. Ten plants were randomly selected from each plot and tagged for recording necessary data and then tubers were harvested from the entire field. The maturity of plant was indicated by the plants showing 80 to 90% of leaf senescence and the top started drying. Haulm cutting was done before 7 days of harvesting. The yield of tuber was taken plot wise and converted into tons per hectare. Care was taken to avoid injury in potatoes during harvesting.

3.11 Data collection

Ten plants were randomly selected from each unit plot for the collection of data. Data were collected in respect of the following parameters:

3.11.1 Days to first emergence

Days to first emergence of plants was recorded on the basis of first emergence of plants in hill out of total hills planted per plot.

3.11.2 Days to 80% emergence

The period required for 80% emergence of plants was recorded on the basis of emergence of plants in 80% hills out of total hills planted per plot.

3.11.3 Plant height

Plant height was measured from sample plants in centimeter (cm) from the ground level to the tip of the growing point. Plant height was recorded at 40, 55, 70 and 100 days after planting as the average of 5 selected plants to observe the growth rate of plants.

3.11.4 Number of leaves per plant

The total number of leaves per plant was counted as the number of leaves per hill. Total number of leaves per plant was recorded at 40, 55, 70 and 100 days after planting as the average of 5 selected plants.

3.11.5 Leaf area per plant

Leaf area per plant was recorded in centimeter (cm) with the help of perimeter. Data were recorded at 40, 55, 70 and 100 days after planting. During the period of data recording a single plant was uprooted from each plot.

3.11.6 Leaf area index (LAI)

It is the ratio of Leaf area to unit land area. Data were recorded at 40, 55, 70 and 100 days after planting. Leaf area index of plant was recorded with the help of following formula.

$$LAI = \frac{\text{Leaf area}}{\text{Unit land area}}$$

Where, Unit land area = Spacing of plant to plant and row to row (10 × 50 cm)

3.11.7 Total fresh mass per plant

Fresh mass of plant was taken by using a balance from the plant which was uprooted for taking data on leaf area from each plot and data recorded in gram (g). It was calculated from summation of leaves, stem, tuber and roots weights. Data were recorded at 40, 55, 70 and 100 days after planting.

3.11.8 Total dry mass per plant

The total dry mass was recorded in gram (g) by drying parts (80 ^{0}C ± 2) for 72 hours and then transferred into desiccators and allowed to cool down to the room temperature. It was calculated from summation of leaves, stem, tuber and roots weights was taken in an electronic balance. Data were recorded at 40, 55, 70 and 100 days after planting.

3.11.9 Total dry mass per m^2

The total dry mass per plant was converted to per m^2 multiplied by 20 numbers of plants. Data were recorded in gram (g) at 40, 55, 70 and 100 days after planting.

3.11.10 Crop growth rate (CGR)

Crop growth rate is the rate of dry matter production of a plant per unit of time and area. Data were recorded at 40-55, 55-70 and 70-100 days after planting with the help of following formula.

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} \quad g\ m^{-2}\ day^{-1}$$

Where, W_2 and W_1 are the dry mass at time T_2 and T_1 respectively.

3.11.11. Number of tubers per hill

The average number of tubers hill^{-1} was recorded from the average of 10 plants selected from each unit plot.

3.11.12 Tubers weight per hill

The average weight of tuber per hill was calculated in gram (g) from 10 plants from each unit plot at harvest.

3.11.13 Gross yield of tubers per hectare

The gross yield tubers (marketable, non-marketable, seed and non-seed tuber) per hectare was calculated from the per m^2 yield data and was recorded in tones. Yield is categorized into marketable (>20 g) and non-marketable (<20 g) and recorded with t ha^{-1} with their percent amount.

3.11.14 Grade of tubers

After harvest, the tubers were graded in different size. Grading was done manually with the help of a grader. The potatoes from seedling tubers were graded in four grade, viz. <28 mm, 28-45 mm, 46-55 mm and >55 mm diameter size. The percentage of tubers in each grade was calculated. Among these four grades, <28 mm size tubers were considered as non grade, 28-45 mm and 46-55 mm size tubers were considered as seed tubers while the tuber size >55 mm were considered as non-seed tubers. The yield of seed and non-seed tubers was calculated in tones per hectare.

3.12 Economic analysis

The cost of production was analyzed with a view to finding out the most profitable treatment combination. In this case, all the non-material and material input costs were considered for calculating the cost of production. Analyses were done according to the procedure determining by Alam *et al.* (1989). The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit-cost ratio} = \frac{\text{Gross return}}{\text{Total cost of production}}$$

3.13 Statistical analysis

The data collected on various parameters of potato plant were statistically analyzed to find out the statistical significance of the treatment effect. The mean values of all the treatments were calculated and analyses of variance for all the characters were performed by the F-test (variance ratio). The significance of the difference among the treatment combinations of means was estimated by least significance difference (LSD) at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

During the study, four levels of seedling tuber size (6-<7 g, 7-<8 g, 8-<9 g and 9-≤10 g) and clump planting (1 seedling tuber hill^{-1}, 2 seedling tubers hill^{-1} and 3 seedling tubers hill^{-1}) were included in the study. The results of the study regarding the effect of seedling tuber size and clump planting on growth characters yield and yield related traits of potato have been presented and possible interpretations have been made in this chapter which is given below:

4.1 Days to first emergence

The duration required for first emergence of plants was influenced significantly due to size of seedling tubers. Seedling tubers (8-<9 g and 9-≤10 g) required minimum duration (7.56 days), whereas seedling tubers (7-<8 g) required comparatively maximum duration (8.67 days) for first emergence of plants but it was statistically similar to 6-<7 g seedling tubers (Table 1 and Appendix VI).

The duration required for first emergence of plants was not influenced significantly by the clump planting (Table 2 and Appendix VI).

The duration required for first emergence of plants was not influenced significantly by the treatment combination of seedling tuber size and clump planting. Among the treatment combinations, duration required for first emergence of plants ranged between 7.00 to 9.33 days. The seedling tubers of 9-≤10 g size (S_4) in combination with 1 seedling tuber per hill (N_1) required the minimum duration for first emergence of plants (Table 3 and Appendix VI).

4.2 Days to 80% emergence

The duration required for 80% emergence of plants was influenced significantly due to seedling tuber size. Seedling tubers (8-<9 g and 9-≤10 g) required minimum duration (10.78 days), whereas seedling tubers (6-<7 g) required maximum duration (12.33 days) for 80% emergence of plants (Table 1 and Appendix VI). The results indicate that duration required for 80% emergence of plants decreased gradually with the increase in seedling tuber size. The early emergence from large seedling tubers was probably due to more reserve food material. This result is in agreement with the findings of several workers (Wilson and Murphy, 1669; Rashid, 1987; Wiersema, 1984; Hossain, 2004 and Engels *et al*. 1993a) where the authors reported that emergence was faster in larger tubers compare to smaller ones.

The duration required for 80% emergence of plants was influenced significantly by the clump planting. Three seedling tubers per hill required minimum duration (10.92 days) compared to 1 or 2 seedling tubers per hill for 80% emergence of plants (Table 2 and Appendix VI).

Significant variation was recorded among the treatment combination of seedling tubers size and clump planting in duration required for 80% emergence of plants. Among the treatment combinations, duration required for 80% emergence of plants ranged between 10.33 to 13.33 days. The seedling tubers of 9-≤10 g size (S_4) in combination with 3 seedling tubers per hill (N_3) required the minimum duration for 80% emergence of plants (Table 3 and Appendix VI). This result is in agreement with the findings of Hossain (2004) where the author reported that emergence was faster in larger seedling tubers with higher number of seedling tubers per hill.

4.3 Plant height

Plant height was significantly influenced by seedling tuber size at 40, 55, 70 and 100 DAP of potato (Table 1 and Appendix VI). Result showed that, increasing size of seedling tuber significantly increased the plant height. The tallest plant at 40 DAP (55.51cm), 55 DAP (65.00 cm), 70 DAP (72.84 cm) and 100 DAP (82.17 cm) were recorded in 9-≤10 g seedling tuber size (S_4). Whereas, the shortest plant height at 40 DAP (39.14 cm), 55 DAP (47.12 cm), 70 DAP (55.49 cm) and 100 DAP (65.99 cm) were found in the treatment 6-<7 g seedling tuber size (S_1). The plant height was higher in larger seedling tubers because of larger seedling tuber had huge stored food material that supported increased vegetative growth of the plants. This result is consistent with many scientists (Garg *et al*. 2000; Khalafalla, 2001; Reust, 2002; Hossain, 2004 and Tohin, 2010) in potato who reported that plant height of potato increased with increasing seed tuber size.

Table 1. Effect of seedling tuber size on the emergence and plant height of potato

Treatments	Days to 1st emergence	Days to 80% emergence	Plant height (cm) at			
			40 DAP	55 DAP	70 DAP	100 DAP
S_1	8.11 ab	12.33 a	39.14 d	47.12 d	55.49 d	65.99 d
S_2	8.67 a	11.56 ab	44.48 c	51.69 c	60.48 c	69.46 c
S_3	7.56 b	11.11 b	50.47 b	58.38 b	67.23 b	74.37 b
S_4	7.56 b	10.78 b	55.51 a	65.00 a	72.84 a	82.17 a
LSD $_{(0.05)}$	0.81	0.89	1.33	1.57	1.19	0.87
F-test	*	*	**	**	**	**
CV%	10.45	8.04	2.86	2.90	1.90	1.22

** = Significant at 1% probability, * = Significant at 5% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g and S_4= 9-≤10 g

The plant height was influenced significantly by the clump planting and increased gradually with the increase in seedling tubers per hill. The tallest plant at 40 DAP (48.96 cm), 55 DAP (57.52 cm), 70 DAP (66.19 cm) and 100 DAP (74.91 cm) were found in 3 seedling tubers per hill (N_3). Whereas, the shortest plant height at 40 DAP (46.04 cm), 55 DAP (54.23 cm) and 70 DAP (62.78 cm) were found in 1 seedling tuber per hill (N_1) while at 100 DAP (71.98 cm) from N_2 but it was statistically similar to the number of seedling tuber 1 per hill. The highest plant grown from 3 seedling tubers per hill was obtained probably due to more inter-plant competition for sun light (Table 2 and Appendix VI). This result is in agreement with the findings of Hossain (2004).

Table 2. Effect of clump planting on the emergence and plant height of potato

Treatments	Days to 1st	Days to	Plant height (cm) at

	emergence	80% emergence	40 DAP	55 DAP	70 DAP	100 DAP
N_1	8.00	12.00 a	46.07 b	54.23 b	62.78 b	72.10 b
N_2	8.08	11.42 ab	47.17 b	54.89 b	63.06 b	71.98 b
N_3	7.83	10.92 b	48.96 a	57.52 a	66.19 a	74.91 a
$LSD_{(0.05)}$	0.71	0.78	1.15	1.36	1.03	0.76
F-test	ns	*	**	**	**	**
CV%	10.45	8.04	2.86	2.90	1.90	1.22

ns = Non-significant, ** = Significant at 1% probability, * = Significant at 5% probability, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

The plant height was influenced significantly by the treatment combinations of seedling tubers size and clump planting at 40 DAP and 100 DAP (Table 2 and Appendix VI). The tallest plant at 40 DAP (56.13 cm) and 100 DAP (85.09 cm) from 9-≤10 g seedling tuber size with 3 seedling tubers per hill (S_4N_3). On the other hand, the shortest plant height 40 DAP (37.87 cm) from 6-<7 g seedling tuber size with 1 seedling tuber per hill (S_1N_1) and at 100 DAP (64.30 cm) from 6-<7 g seedling tuber size with 2 seedling tubers per hill (S_1N_2).

Table 3. Combined effect of seedling tuber size and clump planting on the emergence and plant height of potato

Treatments	Days to 1st emergence	Days to 80% emergence	Plant height (cm) at			
			40 DAP	55 DAP	70 DAP	100 DAP
S_1 N_1	8.33	13.00 ab	37.87 i	47.00	55.03	66.01 i
S_1 N_2	8.00	13.00 ab	38.80 hi	46.27	54.13	64.30 j
S_1 N_3	8.00	11.00 c	40.75 gh	48.10	57.32	67.67 h
S_2 N_1	9.33	13.33 a	44.40 ef	51.47	59.97	69.35 fg

$S_2 N_2$	8.67	10.67 c	43.00 fg	50.40	59.03	68.66 gh
$S_2 N_3$	8.00	10.67 c	46.03 de	53.20	62.45	70.36 f
$S_3 N_1$	7.33	11.00 c	47.53 d	56.10	65.53	73.20 e
$S_3 N_2$	8.00	10.67 c	50.95 c	57.97	67.25	73.40 e
$S_3 N_3$	7.33	11.67 bc	52.93 bc	61.07	68.90	76.52 d
$S_4 N_1$	7.00	10.67 c	54.47 ab	62.37	70.57	79.85 c
$S_4 N_2$	7.67	11.33 c	55.93 a	64.93	71.83	81.57 b
$S_4 N_3$	8.00	10.33 c	56.13 a	67.70	76.11	85.09 a
LSD $_{(0.05)}$	1.41	1.56	2.30	2.73	2.06	1.51
F-test	ns	*	*	ns	ns	**
CV%	10.45	8.04	2.86	2.90	1.90	1.22

ns = Non-significant, ** = Significant at 1% probability, * = Significant at 5% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

4.4 Number of leaves per plant

The foliage coverage of plants was influenced significantly at all dates of observations due to variation in seedling tuber size. The highest number of leaves plant^{-1} at 40 DAP (46.87), 55 DAP (55.68), 70 DAP (69.11) and 100 DAP (83.30) were found in 9-≤10 g seedling tuber size (S_4) while the lowest number of leaves plant^{-1} at 40 DAP (28.12), 55 DAP (36.32), 70 DAP (50.26) and 100 DAP (62.84) were found in 6-<7 g seedling tuber size (S_1). The result revealed that the number of leaves increased gradually with the increase in seedling tuber size (Fig. 1 and Appendix VII). This trend of the present results was agreed to that of (Wiersema, 1984; Batra *et al*. 1992; Islam, 1992 and Engels *et al*. 1993a, Gulluoglu and Aroglu, 2009 and Hossain, 2004) in potato and reported that leaf number in potato decreased with decreasing tuber weight.

The clump planting significantly influenced the number of leaves plant^{-1}. The maximum number of leaves plant^{-1} at 40 DAP (39.44), 55 DAP (49.00), 70 DAP (61.41) and 100 DAP (74.45) were recorded in 3 seedling tubers plant^{-1}. On the other hand the minimum number of leaves plant^{-1} at 40 DAP (36.56), 55 DAP (43.56), 70 DAP (57.47) and 100 DAP (70.61) were found in 1 seedling tuber plant^{-1} (N_1). The results indicated that the number of leaves plant^{-1} were directly proportional to the clump planting (Fig. 2 and Appendix VII). This result is in agreement with the findings of Hossain (2004).

There was significant variation among the treatment combinations of seedling tubers size and clump planting. The highest number of leaves plant^{-1} at 40 DAP (50.17), 55 DAP (59.77), 70 DAP (72.87) and 100 DAP (87.97) were found in 9-≤10 g seedling tuber size with 1 seedling tuber per hill (S_4N_1) whereas, the lowest number of leaves plant^{-1} at 40 DAP (27.07) from 6-<7 g seedling tuber size with 2 seedling tubers per hill (S_1N_2) but it was statistically similar to 6-<7 g seedling tuber size with 1 seedling tuber per hill (S_1N_1). At 55 and 70 DAP, the lowest number of leaves plant^{-1} (34.77 and 49.23) were recorded from 6-<7 g seedling tuber size with 1 and 2 seedling tubers per hill respectively while at100 DAP the lowest number of leaves plant^{-1} (61.90) was found in 6-<7 g seedling tuber size with 2 seedling tuber per hill (S_1N_2) but it was statistically similar to 6-<7 g seedling tuber size with 1 and 2 seedling tubers per hill respectively. (Table 4 and Appendix VII). This result is in agreement with the findings of Hossain (2004).

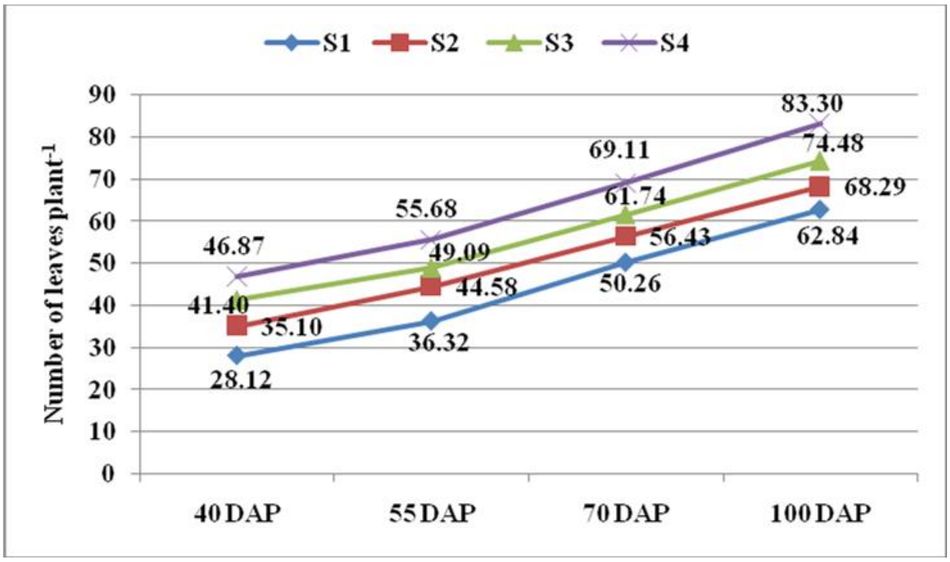


Fig. 1 Effect of seedling tuber size on the number of leaves plant^{-1}

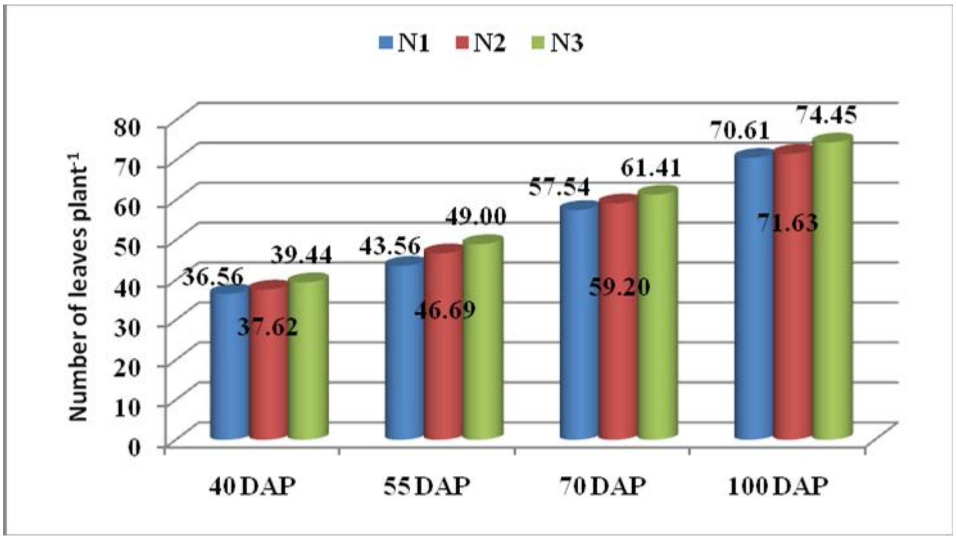


Fig. 2 Effect of clump planting on the number of leaves plant^{-1}

Table 4. Combined effect of seedling tuber size and clump planting on the number of leaves plant^{-1}

Treatment	Number of leaves plant^{-1} at			
	40 DAP	**55 DAP**	**70 DAP**	**100 DAP**
S_1 N_1	28.20 g	34.77 g	51.80 fg	63.30 h
S_1 N_2	27.07 g	35.20 g	49.23 h	61.90 h
S_1 N_3	29.10 g	39.00 f	49.73 gh	63.33 h
S_2 N_1	32.73 f	40.97 f	53.77 f	67.03 g
S_2 N_2	34.83 f	45.20 e	56.40 e	67.67 g
S_2 N_3	37.73 e	47.57 de	59.13 d	70.17 f
S_3 N_1	40.50 d	46.70 e	58.38 de	73.07 e
S_3 N_2	42.93 cd	50.90 c	62.93 c	74.03 e
S_3 N_3	40.77 d	49.67 cd	63.90 c	76.33 d
S_4 N_1	44.80 bc	51.80 c	66.23 b	79.03 c
S_4 N_2	45.63 b	55.47 b	68.23 b	82.90 b
S_4 N_3	50.17 a	59.77 a	72.87 a	87.97 a
LSD $_{(0.05)}$	2.64	2.90	2.28	2.07

F-test	**	*	**	**
CV%	4.12	3.69	2.27	1.69

** = Significant at 1% probability, * = Significant at 5% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

4.5 Leaf area per plant

Leaf area plant^{-1} showed statistically significant variation due to the seedling tuber size. Maximum leaf area at 40 DAP (2078 cm^2), 55 DAP (2401 cm^2), 70 DAP (2923 cm^2) and 100 DAP (3113 cm^2) were recorded from 9-≤10 g seedling tuber (S_4). Minimum leaf area at 40 DAP (1212 cm^2), 55 DAP (1362 cm^2), 70 DAP (1888 cm^2) and 100 DAP (2149 cm^2) were recorded from 6-<7 g seedling tuber (Fig. 3 and Appendix VIII). The variation in leaf area might occur due to the variation in stems plant^{-1} as well as leaves. The results are also supported by the result of Gulluoglu and Aroglu (2009) in potato.

Leaf area plant^{-1} was influenced significantly due to the clump planting. Maximum leaf area plant^{-1} at 40 DAP (1748 cm^2), 55 DAP (2000 cm^2), 70 DAP (2468 cm^2) and 100 DAP (2705 cm^2) were recorded from 3 seedling tubers per hill (N_3). Minimum leaf area plant^{-1} at 40 DAP (1553 cm^2), 55 DAP (1662 cm^2), 70 DAP (2217 cm^2) and 100 DAP (2486 cm^2) were recorded from 1 seedling tuber per hill (Fig. 4 and Appendix VIII).

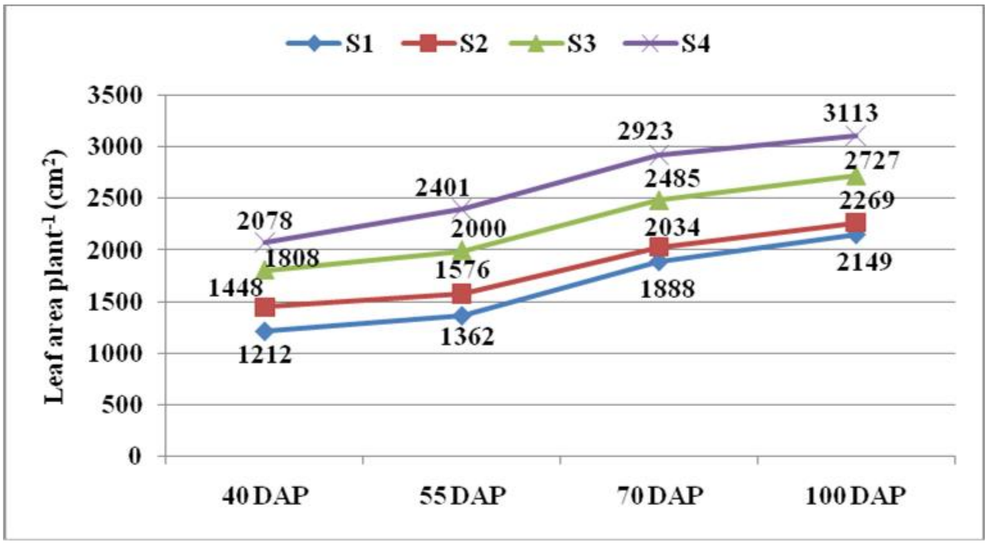


Fig. 3 Effect of seedling tuber size on the leaf area plant^{-1} (cm^2)

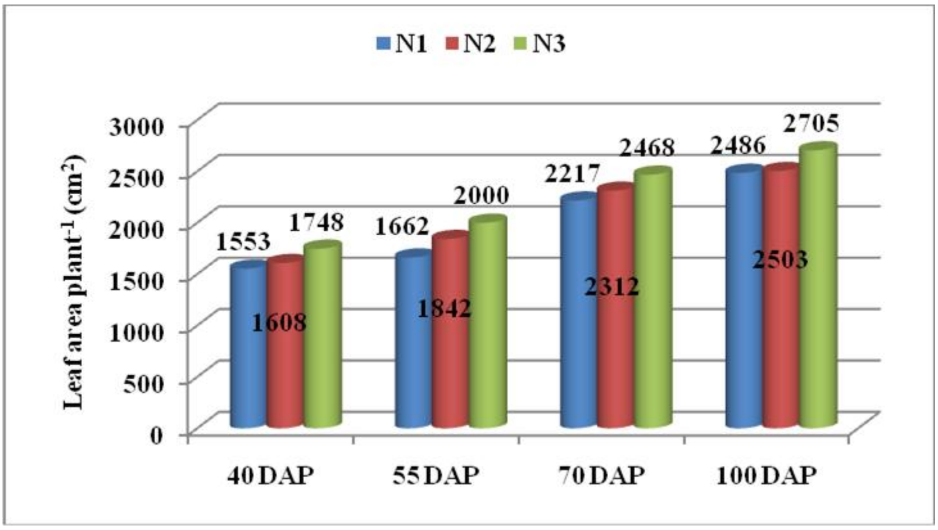


Fig. 4 Effect of clump planting on the leaf area plant^{-1} (cm^2)

Table 5. Combined effect of seedling tuber size and clump planting on the leaf area plant^{-1}

Treatments	Leaf area plant^{-1} (cm^2) at			
	40 DAP	**55 DAP**	**70 DAP**	**100 DAP**
S_1 N_1	1161	1106	1946 efg	2227 e
S_1 N_2	1177	1448	1806 g	2022 f
S_1 N_3	1299	1531	1911 fg	2200 ef
S_2 N_1	1405	1523	1946 efg	2240 e
S_2 N_2	1409	1559	2033 ef	2221 ef
S_2 N_3	1529	1647	2121 e	2346 e
S_3 N_1	1676	1813	2315 d	2572 d
S_3 N_2	1790	1989	2464 d	2657 d
S_3 N_3	1957	2198	2677 c	2952 bc
S_4 N_1	1971	2207	2659 c	2907 c
S_4 N_2	2056	2373	2946 b	3113 b
S_4 N_3	2208	2623	3164 a	3321 a
LSD $_{(0.05)}$	93.82	414.5	193.0	203.0
F-test	ns	ns	*	*
CV%	3.39	13.34	4.89	4.67

ns = Non-significant, * = Significant at 5% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

At 70 and 100 DAP there were significant variation among the treatment combinations of seedling tubers size and clump planting while leaf area per plant were influenced insignificantly at 40 and 50 DAP. Maximum leaf area plant^{-1} at 70 DAP (3164 cm^2) and 100 DAP (3321 cm^2) were recorded from the treatment combinations of 9-≤10 g seedling tubers size and 3 seedling tubers per hill (S_3N_3) whereas, minimum leaf area plant^{-1} at 70 DAP (1806 cm^2) and 100 DAP (2022 cm^2) were recorded from 6-<7 g seedling tubers size and 2 seedling tubers per hill S_1N_2 (Table 5 and Appendix VIII).

4.6 Leaf area index

The effect of seedling tuber size on leaf area index (LAI) was significant at 40, 55, 70 and 100 DAP (Fig. 5 and Appendix IX). Results showed that LAI increased with increasing tuber size. The highest LAI was recorded in 9-≤10 g seedling tuber (S_4) at 40 DAP (4.16), 55 DAP (3.99), 70 DAP (5.85) and 100 DAP (6.23). The lowest LAI was recorded in 6-<7 g seedling tuber at 40 DAP (2.40), 55 DAP (2.72), 70 DAP (3.77) and 100 DAP (4.30) were recorded in 6-<7 g seedling tuber (S_1). The variation in LAI might occur due to the variation in leaf area plant^{-1}. This result is supported by Verma *et al.* (2007) in potato.

The LAI was significantly influenced by clump planting at 40, 55, 70 and 100 DAP (Fig. 6 and Appendix IX). Result showed that LAI increased with increasing number of seedling tuber per hill. The highest LAI was recorded in 3 seedling tubers per hill (3.49, 3.10, 4.93 and 5.41 at 40, 55, 70 and 100 DAP respectively). The lowest LAI was recorded in 1 seedling tuber per hill (3.1, 3.32, 4.43 and 4.97 at 40, 55, 70 and 100 DAP, respectively).

The interaction effect of seedling tuber size and clump planting had significant effect on LAI at 70 and 100 DAP while leaf area index was influenced insignificantly at 40 and 55 DAP (Table 6 and Appendix IX). The highest LAI was recorded in 9-≤10 g seedling tuber with 3 seedling tubers per hill (6.33 and 6.64 at 70 and 100 DAP respectively). The lowest LAI was recorded in the

treatment combination of 6-<7 g seedling tuber with 2 seedling tubers per hill (3.61 and 4.04 at 70 and 100 DAP, respectively).

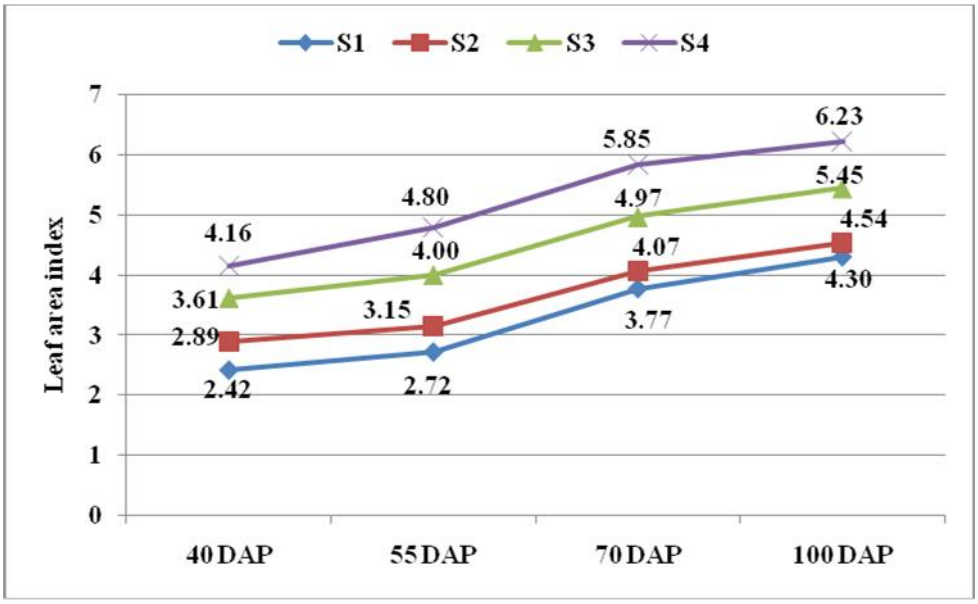


Fig. 5 Effect of seedling tuber size on the leaf area index of potato

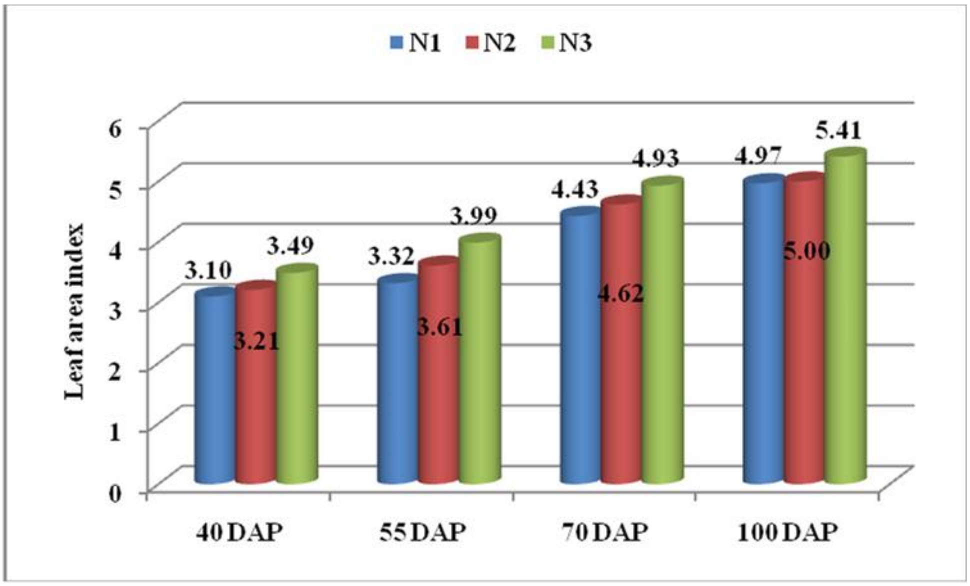


Fig. 6 Effect of clump planting on the leaf area index of potato

Table 6. Combined effect of seedling tuber size and clump planting on the leaf area index of potato

Treatments	Leaf area index at			
	40 DAP	55 DAP	70 DAP	100 DAP
S_1 N_1	2.32	2.21	3.89 efg	4.45 e
S_1 N_2	2.35	2.59	3.61 g	4.04 f
S_1 N_3	2.60	3.06	3.82 fg	4.40 ef
S_2 N_1	2.81	3.04	3.89 efg	4.48 e
S_2 N_2	2.82	3.12	4.06 ef	4.44 ef
S_2 N_3	3.06	3.29	4.24 e	4.69 e
S_3 N_1	3.35	3.62	4.63 d	5.14 d
S_3 N_2	3.58	3.98	4.93 d	5.31 d
S_3 N_3	3.91	4.39	5.35 c	5.90 bc
S_4 N_1	3.94	4.41	5.32 c	5.81 c
S_4 N_2	4.11	4.75	5.89 b	6.22 b
S_4 N_3	4.41	5.25	6.33 a	6.64 a
LSD $_{(0.05)}$	0.19	0.87	0.39	0.41
F-test	ns	ns	*	*
CV%	3.38	14.11	4.88	4.68

ns = Non-significant, * = Significant at 5% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

4.7 Fresh mass production per plant

Fresh mass production per plant showed statistically significant due to seedling tuber size. The highest fresh mass plant^{-1} at 40 DAP (212.50 g), 55 DAP (268.30 g), 70 DAP (337.50 g) and 100 DAP (456.00 g) were recorded from 9-≤10 g seedling tuber (S_4). The lowest fresh mass plant^{-1} at 40 DAP (46.22 g), 55 DAP (98.78 g), 70 DAP (157.50 g) and 100 DAP (233.20 g) were recorded from 6-<7 g seedling tuber (Fig. 7 and Appendix X). Result showed that total fresh mass plant^{-1} increased with increasing seedling tuber size.

Fresh mass production per plant was influenced significantly due to the clump planting. The highest fresh mass plant^{-1} at 40 DAP (144.80 g), 55 DAP (196.90 g), 70

DAP (258.30 g) and 100 DAP (358.00 g) were recorded from 3 seedling tubers per hill (N_3). The lowest fresh mass plant^{-1} at 40 DAP (103.90 g), 55 DAP (151.80 g), 70 DAP (211.50 g) and 100 DAP (284.90 g) were recorded from 1 seedling tuber per hill (Fig. 8 and Appendix X). Result showed that total fresh mass plant^{-1} increased with increasing number of seedling tuber per hill that increased the number of stem per plant.

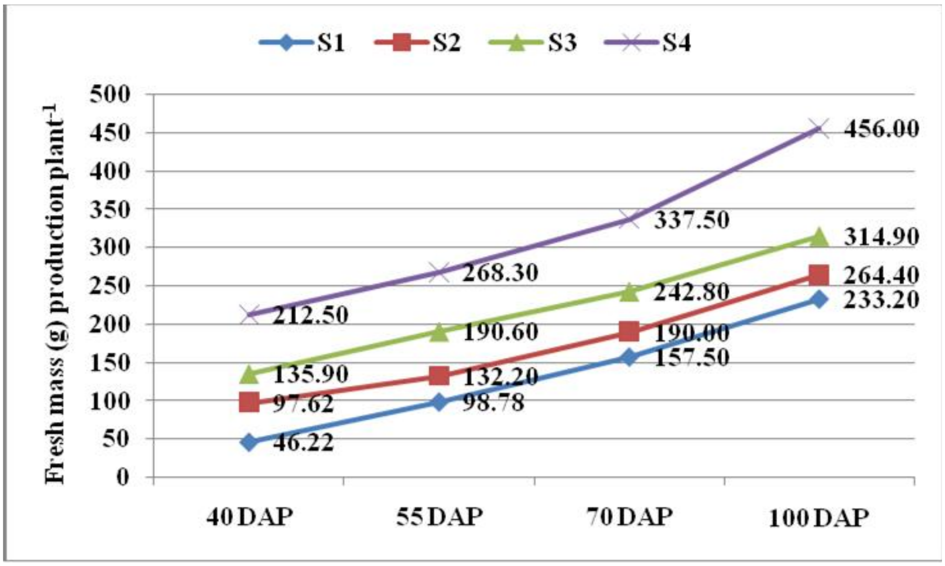


Fig. 7 Effect of seedling tuber size on fresh mass (g) production plant^{-1}

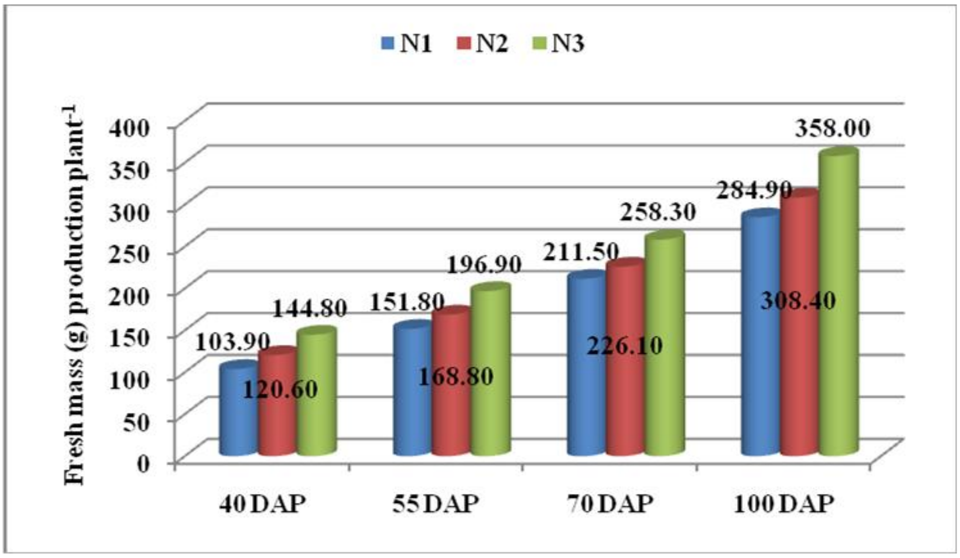


Fig. 8 Effect of clump planting on fresh mass (g) production plant^{-1}

Table 7. Combined effect of seedling tuber size and clump planting on fresh mass production plant^{-1}

Treatments	Fresh mass (g) production plant^{-1} at

	40 DAP	**55 DAP**	**70 DAP**	**100 DAP**
$S_1 N_1$	33.17 j	85.73 j	150.80 j	220.30 i
$S_1 N_2$	49.33 i	107.10 i	163.90 i	245.30 gh
$S_1 N_3$	56.17 i	103.50 i	157.80 ij	234.00 hi
$S_2 N_1$	78.83 h	121.30 h	182.20 h	248.50 fg
$S_2 N_2$	94.67 g	127.90 h	182.10 h	259.40 f
$S_2 N_3$	119.40 ef	147.50 g	205.70 g	285.40 e
$S_3 N_1$	114.20 f	162.50 f	217.10 f	282.70 e
$S_3 N_2$	126.50 e	185.10 e	229.80 e	290.20 e
$S_3 N_3$	167.20 d	224.20 d	281.60 d	371.70 d
$S_4 N_1$	189.30 c	237.60 c	295.70 c	388.20 c
$S_4 N_2$	211.90 b	255.10 b	328.50 b	438.70 b
$S_4 N_3$	236.30 a	312.30 a	388.10 a	541.00 a
LSD $_{(0.05)}$	7.25	9.22	8.51	13.99
F-test	**	**	**	**
CV%	3.48	3.16	2.17	2.60

** = Significant at 1% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

There was significant variation among the treatment combinations of seedling tubers size and clump planting. The highest fresh mass plant^{-1} at 40 DAP (236.30 g), 55 DAP (312.30 g), 70 DAP (388.10 g) and 100 DAP (541.00 g) were recorded from 9-≤10 g seedling tuber size with 3 seedling tubers per hill (S_4N_3). The lowest fresh mass plant^{-1} at 40 DAP (33.17 g), 55 DAP (85.73 g), 70 DAP (150.80 g) and 100 DAP (220.30 g) were recorded from 6-<7 g seedling tuber size and 1 seedling tuber per hill (Table 7 and Appendix X).

4.8 Dry mass production per plant

Dry mass production per plant showed statistically significant variation due to the seedling tuber size. The highest dry mass per plant at 40 DAP (39.19 g), 55 DAP (49.55 g), 70 DAP (66.17 g) and 100 DAP (90.23 g) were recorded from 9-≤10 g seedling tuber size (S_4). The lowest dry mass per plant at 40 DAP (9.91 g), 55 DAP (20.17 g), 70 DAP (32.71 g) and 100 DAP (49.74 g) were recorded from 6-<7 g seedling tuber size (Fig. 9 and Appendix XI). Total dry mass was higher in larger tubers because of larger seedling tuber had huge stored food material than smaller ones and promoted increased vegetative growth of the plants. This result is consistent with many workers (Garg *et al*. 2000; Khalafalla, 2001; Reust, 2002 and Tohin, 2010) in potato and reported that TDM increased with increasing seed tuber weight.

Total dry mass per plant was influenced significantly 40, 55, 70 and 100 DAP due to the clump planting. Maximum dry mass per plant at 40 DAP (27.55 g), 55 DAP (38.18 g), 70 DAP (51.20 g) and 100 DAP (71.63 g) were recorded from 3 seedling tubers per hill (N_3). Minimum dry mass per plant at 40 DAP (19.52 g), 55 DAP (29.73 g), 70 DAP (41.41 g) and 100 DAP (58.79 g) were recorded from 1 seedling tuber per hill (Fig. 10 and Appendix XI).

There was significant variation among the treatment combinations of seedling tubers size and clump planting. The highest dry mass per plant at 40 DAP (45.30 g), 55 DAP (58.44 g), 70 DAP (75.92 g) and 100 DAP (102.60 g) were recorded from 9-≤10 g seedling tuber size with 3 seedling tubers per hill (S_4N_3). The lowest dry mass per plant at 40 DAP (6.96 g), 55 DAP (17.66 g), 70 DAP (30.82 g) and 100 DAP (47.71 g) were recorded from 6-<7 g seedling tuber size with 1 seedling tuber per hill (Table 8 and Appendix XI).

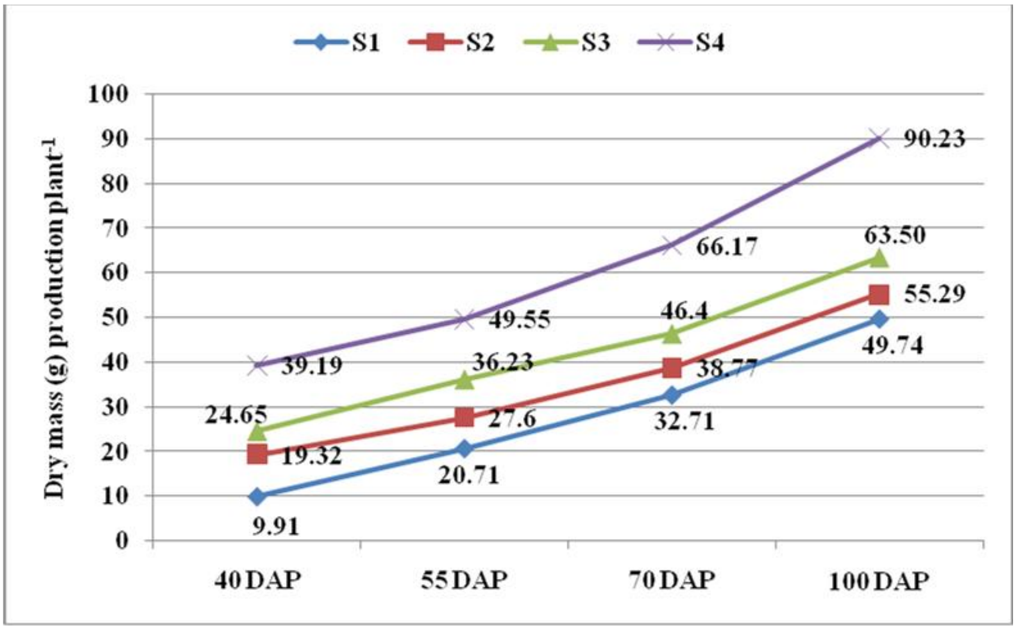


Fig. 9 Effect of seedling tuber size on dry mass production plant^{-1}

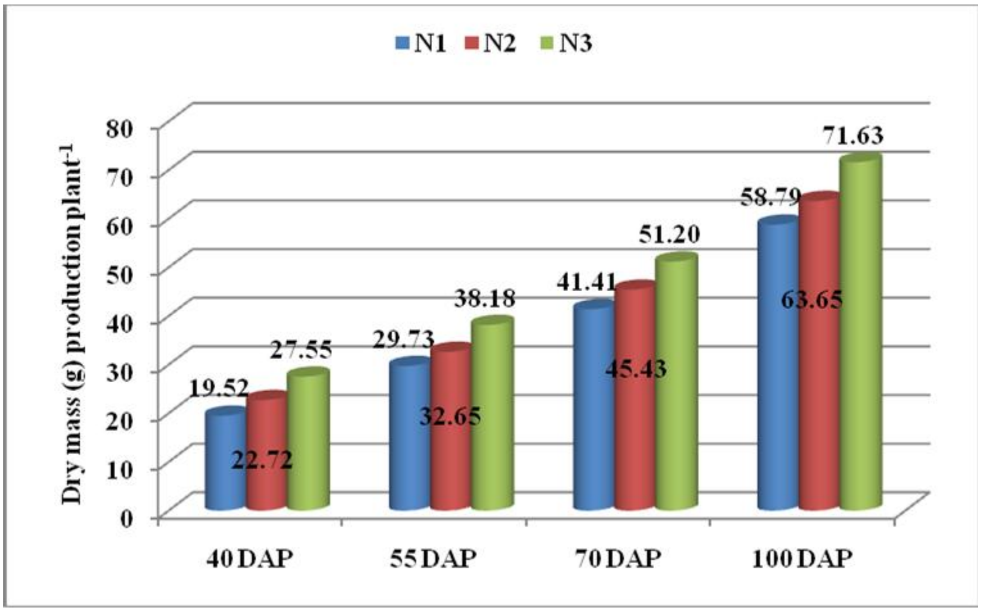


Fig. 10 Effect of clump planting on dry mass production plant^{-1}

Table 8. Combined effect of seedling tuber size and clump planting on dry mass production plant^{-1}

Treatments	Dry mass production plant^{-1} (g) at			
	40 DAP	55 DAP	70 DAP	100 DAP
$S_1 N_1$	6.96	17.66 h	30.82 i	47.71 g
$S_1 N_2$	10.44	22.31 g	33.47 hi	50.59 fg
$S_1 N_3$	12.33	22.16 g	33.85 hi	50.91 fg
$S_2 N_1$	15.62	25.57 f	35.71 gh	52.49 efg
$S_2 N_2$	19.36	26.40 f	38.56 fg	55.19 def
$S_2 N_3$	22.97	30.82 e	42.05 ef	58.17 d
$S_3 N_1$	20.92	32.25 de	40.92 ef	56.50 de
$S_3 N_2$	23.41	35.13 d	45.29 e	59.17 d
$S_3 N_3$	29.61	41.31 c	52.99 d	74.82 c
$S_4 N_1$	34.58	43.43 c	58.18 c	78.45 c
$S_4 N_2$	37.68	46.77 b	64.40 b	89.65 b

$S_4 N_3$	45.30	58.44 a	75.92 a	102.60 a
LSD (0.05)	2.79	3.17	4.52	4.89
F-test	ns	**	**	**
CV%	7.08	5.59	5.80	4.46

ns = Non-significant, ** = Significant at 1% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

4.9 Total dry mass production of plant per m^2

There was a significant variation in total dry mass (TDM) production of plant m^{-2} at 40, 55, 70 and 100 DAP due to seedling tuber size (Fig. 11 and Appendix XII). Result showed that total dry mass m^{-2} increased with increasing seedling tuber size. The highest TDM m^{-2} was recorded in 9-≤10 g seedling tuber size (783.70, 990.90, 1323.00 and 1805.00 g m^{-2} at 40, 55, 70 and 100 DAP, respectively). In contrast, the seedling tuber size of 6-<7 g had the lowest TDM m^{-2} at all growth stages (198.20, 414.20, 654.30 and 994.80 g m^{-2} at 40, 55, 70 and 100 DAP, respectively). This result is consistent with Tohin (2010).

The effect of clump planting on TDM production m^{-2} was influenced significantly at all growth stages (Fig. 12 and Appendix XII). Result showed that total TDM production m^{-2} increased with increasing number of seedling tubers per hill. The highest TDM m^{-2} was recorded in 3 seedling tubers per hill (551.10, 763.70, 1024.00 and 1433.00 g m^{-2} at 40, 55, 70 and 100 DAP respectively) and the lowest TDM m^{-2} was recorded in 1 seedling tuber per hill (390.40, 594.50, 828.20 and 1176 g m^{-2} at 40, 55, 70 and 100 DAP, respectively).

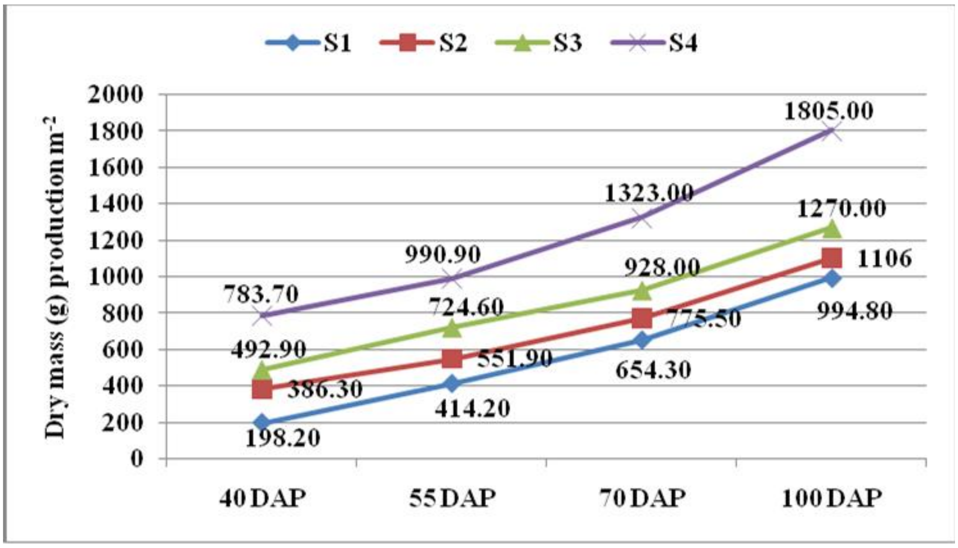


Fig. 11 Effect of seedling tuber size on dry mass production of plant m^{-2} (g)

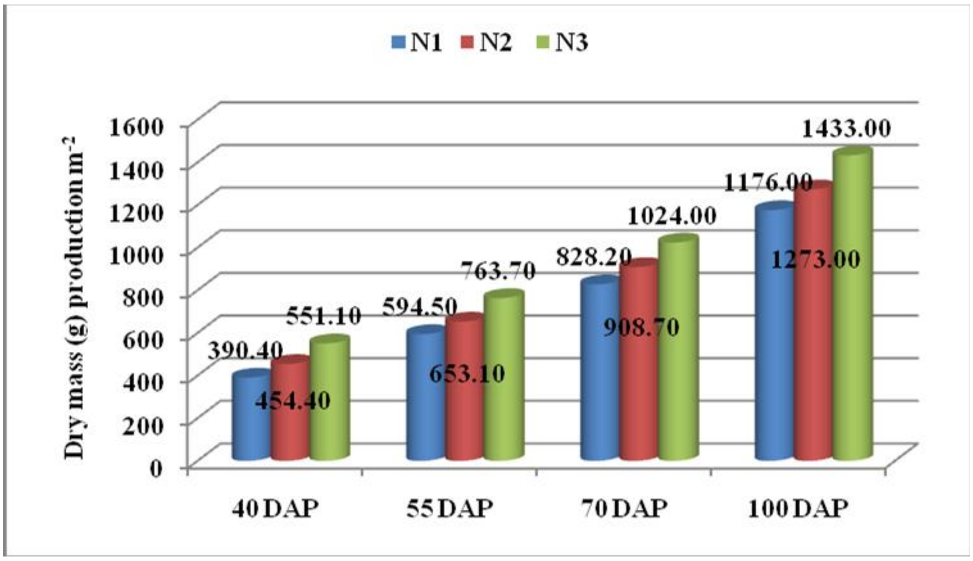


Fig. 12 Effect of clump planting on dry mass production of plant m^{-2} (g)

Table 9. Combined effect of seedling tuber size and clump planting on dry mass production of plant m^{-2}

Treatments	Dry mass (g) production m^{-2} at			
	40 DAP	55 DAP	70 DAP	100 DAP
S_1 N_1	139.10	353.10 h	616.40 i	1176.00 bc
S_1 N_2	208.90	446.30 g	669.50 hi	1273.00 b
S_1 N_3	246.70	443.30 g	677.00 hi	1433.00 a
S_2 N_1	312.50	511.30 f	714.30 gh	1016.00 e

$S_2 N_2$	387.20	528.00 f	771.30 fg	1012.00 e
$S_2 N_3$	459.30	616.40 e	840.90 ef	1018.00 e
$S_3 N_1$	418.40	644.90 de	818.40 ef	1050.00 de
$S_3 N_2$	468.10	702.60 d	905.90 e	1104.00 cde
$S_3 N_3$	592.30	826.20 c	1060.00 d	1163.00 c
$S_4 N_1$	691.50	868.60 c	1164.00 c	1130.00 cd
$S_4 N_2$	753.50	935.50 b	1288.00 b	1183.00 bc
$S_4 N_3$	906.10	1169.00 a	1518.00 a	1496.00 a
LSD $_{(0.05)}$	55.81	63.49	90.42	97.73
F-test	ns	**	**	**
CV%	7.08	5.59	5.80	4.46

ns = Non-significant, ** = Significant at 1% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

The interaction effect of seedling tuber size and clump planting had significant effect on TDM m^{-2} at 55, 70 and 100 DAP (Table 9 and Appendix XII). The highest TDM m^{-2} was recorded in the treatment combination of 9-≤10 g seedling tuber with 3 seedling tubers per hill (1169.00, 1518.00 and 1496.00 g m^{-2} at 55, 70 and 100 DAP, respectively). The lowest TDM m^{-2} was recorded in the treatment combination of 6-<7 g seedling tuber size with 1 seedling tuber per hill (353.10 and 616.40 g m^{-2} at 55 and 70 DAP respectively) except at 100 DAP while it was minimum (1012.00 g m^{-2}) in S_2N_2.

4.10 Crop growth rate

Crop growth rate (CGR) was significantly influenced by seedling tuber size at 40-55, 55-70 and 70-100 DAP (Fig. 13 and Appendix XIII). Results showed that, the CGR increased with increasing seedling tuber size. At 55-70 DAP, plant showed the highest CGR than at 40-55 and 70-100 DAP. At 55-70 DAP, CGR was higher in 8-<9 g seedling tuber size (15.44 g m^{-2} day^{-1}) followed by the 9-≤10 g seedling tuber size (13.81 g m^{-2} day^{-1}) with same statistical rank. In contrast, the lowest CGR both at 40-55 and 70-100 DAP was recorded in seedling tuber size of 7-<8 g (11.04 and 11.01 g m^{-2} day^{-1}, respectively while it was minimum in 8-<9 g seedling tuber size at 55-70 DAP). The CGR was higher in larger seedling tuber might be due to increased TDM plant^{-1}. This result is consistent with (Divis and Barta, 2001 and Tohin, 2010) in potato and reported that larger tuber produced higher number of stems plant^{-1}, crop growth rate and yield as compared to small ones.

The effect of clump planting on CGR was not influenced significantly (Fig. 14 and Appendix XIII). However, 3 seedling tubers per hill showed highest growth rate (17.36 g m^{-2} day^{-1} at 55-70 DAP) and the lowest growth rate was recorded in 1 seedling tuber per hill (11.59 g m^{-2} day^{-1} at 70-100 DAP).

The interaction effect of seedling tuber size and clump planting on CGR was significant at 40-55 DAP (Table 10 and Appendix XIII). The highest CGR was recorded in the treatment combination of 9-≤10 g seedling tuber size with 3 seedling tubers per hill (17.51 g m^{-2} day^{-1}) and the lowest CGR was recorded in 7-<8 g seedling tuber size with 2 seedling tubers per hill (9.34 g m^{-2} day^{-1}), respectively.

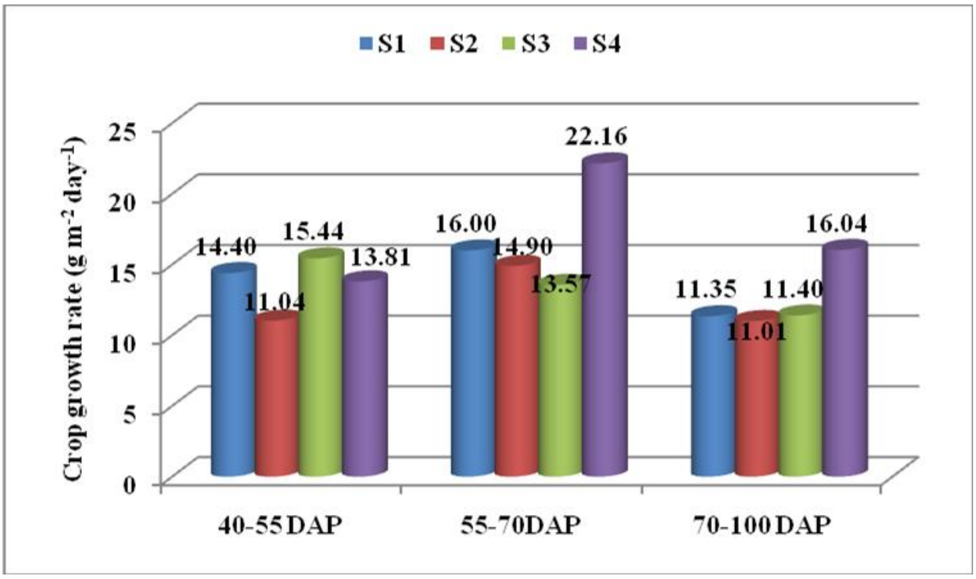


Fig. 13 Effect of seedling tuber size on the growth rate of plant (g m^{-2} day^{-1})

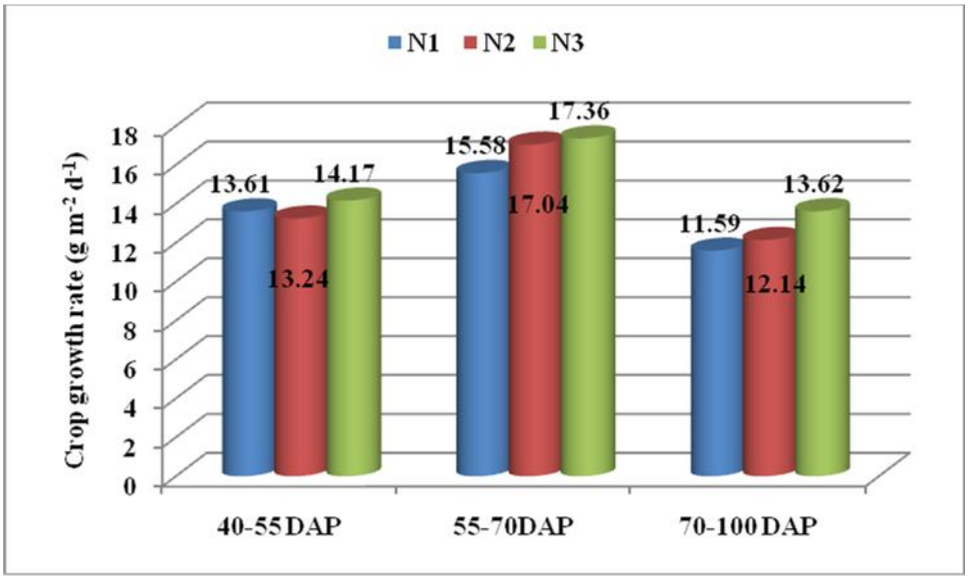


Fig. 14 Effect of clump planting on the growth rate of plant (g m^{-2} day^{-1})

Table 10. Combined effect of seedling tuber size and clump planting on the growth rate

Treatments	**Crop growth rate at (g m^{-2} d^{-1})**		
	40-55 DAP	**55-70DAP**	**70-100 DAP**
S_1 N_1	14.27 abc	17.55	11.26
S_1 N_2	15.83 ab	14.88	11.41
S_1 N_3	13.11 bcd	15.58	11.37
S_2 N_1	13.26 bcd	13.53	11.19
S_2 N_2	9.39 e	16.22	11.08
S_2 N_3	10.47 de	14.97	10.75
S_3 N_1	15.10 abc	11.57	10.39
S_3 N_2	15.63 ab	13.55	9.26
S_3 N_3	15.59 ab	15.58	14.55
S_4 N_1	11.80 cde	19.67	13.51
S_4 N_2	12.13 cde	23.51	16.83
S_4 N_3	17.51 a	23.31	17.79
LSD $_{(0.05)}$	3.31	7.46	3.85
F-test	**	ns	ns

CV%	14.30	26.43	18.24

ns = Non-significant, ** = Significant at 1% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

4.11 Tubers per hill

The effect of seedling tuber size on number of tubers hill^{-1} was statistically significant (Table 11 and Appendix XIV). Result revealed that number of tubers produced hill^{-1} increased gradually with the increase in seedling tuber size till 8-<9 g seedling tuber size and thereafter further increase seedling tuber size did not increase tubers hill^{-1}. The maximum number of tubers hill^{-1} was recorded in 8-<9 g seedling tuber size (6.66) that was statistically similar to 9-≤10 g seedling tuber size (6.30). In contrast, the lowest tubers hill^{-1} was recorded in seedling tuber size of 6-<7 g (3.41). Reduction in the tubers hill^{-1} under smaller seedling tuber size might be due to lesser stems hill^{-1}. Number of tubers hill $^{-1}$ increased gradually with the increase in seedling tuber size. This result is consistent with many workers (Cloete and Els 1982; Wiersema, 1984; Rashid, 1987; Batra *et al*. 1992; Islam, 1992; Rashid *et al*. 1993b; Roy, 1997; Sultana, 1998; Garg *et al*. 2000; Bong Kyoon *et al*. 2001; Khalafalla, 2001; Shingrup *et al.* 2003; Verma *et al.* 2007; Hossain, 2004 and Tohin, 2010) reported that tuber number hill^{-1} increased with increasing tuber weight till 55 g seed tuber.

Number of tubers hill^{-1} influenced significantly by the clump planting (Table 12 and Appendix XIV). Result showed that tuber number hill^{-1} increased with increasing number of seedling tubers per hill. The highest tubers hill^{-1} (5.66) was recorded in 3 seedling tubers per hill. The lowest tubers hill^{-1} was recorded in 1 seedling tuber per hill (4.91).

The interaction of seedling tuber size and clump planting had significant effect on number of tubers hill^{-1} (Table 13 and Appendix XIV). The highest tubers hill^{-1} was recorded in 8-<9 g seedling tuber size with 3 seedling tubers per hill (7.23) followed by the treatment combination of 9-≤10 g seedling tuber size with 2 seedling tubers per hill (6.71) with same statistical rank. The lowest tubers hill^{-1} was recorded in the treatment combination of 6-<7 g seedling tuber size with 1 seedling tuber per hill (3.06).

4.12 Tuber weight per hill

The effect of seedling tuber size on tuber weight hill^{-1} was significant (Table 11 and Appendix XIV). Result revealed that tuber weight hill^{-1} increased with increasing seedling tuber size. The highest tuber weight hill^{-1} was recorded in 9-≤10 g seedling tuber size (128.9 g). Whereas, the lowest tuber weight hill^{-1} was recorded in 6-<7 g seedling tuber size (85.85 g). The lesser tuber weight in smaller sized seed tuber might be due to fewer tubers hill^{-1} and smaller weight tuber. This result is supported by many workers (Gregoriou, 2000; Khalafalla, 2001; Reust, 2002; Malik *et al*. 2002; Shingrup *et al.* 2003; Sonawane and Dhoble, 2004; Verma *et al.* 2007; Gulluoglu and Aroglu, 2009; Tohin, 2010) reported that tuber yield decreased with decreasing seed tuber weight.

There was a significant variation in tuber weight hill^{-1} due to clump planting (Table 12 and Appendix XIV). Results showed that tuber weight decreased with decreasing number of seedling tubers per hill. The highest tuber weight hill^{-1} was recorded in 3 seedling tubers per hill (123.95 g). The lowest tuber yield hill^{-1} was recorded in 1 seedling tuber per hill (98.55 g).

The interaction effect of seedling tuber size and clump planting on tuber weight hill^{-1} was significant (Table 13 and Appendix XIV). The highest tuber weight hill^{-1} was recorded in the treatment combination of 9-≤10 g seedling tuber size with 3 seedling tubers per hill (138.35 g) but it was statistically similar to S_3N_2, S_3N_3 and S_4N_1. The lowest tuber weight hill^{-1} was recorded in the treatment combination of 6-<7 g seedling tuber size with 1 seedling tuber per hill (64.15 g hill^{-1}) that was statistically similar to 6-<7 g seedling tuber size with 2 seedling tubers per hill (71.65 g).

4.13 Gross yield of tuber

The gross tuber yield was significantly influenced by seedling tuber size (Table 11 and Appendix XIV). Result revealed that gross tuber yield increased with increasing seedling tuber size. The highest gross tuber yield was recorded in 9-≤10 g seedling tuber size (25.78 tha^{-1}). In contrast, the lowest gross tuber yield was recorded in 6-<7 g seedling tuber size (17.17 tha $^{-1}$). The gross tuber yield

was lower in smaller seedling tuber size because of producing minimum tuber weight hill^{-1}. The yield of total tuber also increased gradually with increasing seedling tuber size. This result is supported by many workers (Gojski, 1979; Karim and Hossain, 1980; Hussain, 1985; and Siddique *et al*. 1987; Khurana, 1990; Kadian *et al*. 1992; Rashid *et al*. 1993b; Karle *et al*. 1997; Kamaly 1997; Roy, 1997; Sultana 1998; Gregoriou, 2000; Khalafalla, 2001; Reust, 2002; Malik *et al*. 2002; Shingrup *et al.* 2003; Hossain, 2004; Sonawane and Dhoble, 2004; Verma *et al.* 2007; Gulluoglu and Aroglu, 2009 and Tohin, 2010) reported that tuber yield decreased with decreasing seed tuber weight. But the present result do not agree with the finding of Popova (1979) where the author reported that there was no significant difference in tuber yield of potato with different sizes of seed tubers, viz. small (30 g), medium (50-80 g) and large (80-100 g).

The clump planting also significantly influenced the gross tuber yield in potato (Table 12 and Appendix XIV). The gross tuber yield increased with increasing clump planting. The highest gross tuber yield was recorded in 3 seedling tubers per hill (24.79 tha^{-1}). The lowest tuber yield was recorded in 1 seedling tuber per hill (19.71 tha^{-1}) but it was statically similar to 2 seedling tubers per hill. The higher tuber yield always associated with higher plant population. The results are in agreement with the earlier findings of several workers (Bashar 1976; Singh and Chhabaria 1980; Cloete and Els 1982; Mandala and Arora 1987; Rashid *et al*. 1993b and Hossain, 2004) to assess the possibility of using <5 g seedling tubers as planting material. Nankar (1990) planted one, two and three seedling tubers per hill in inter cropping system and found that three seedling tuber per hill gave the highest yield.

Significant variation was recorded by the treatment combinations of seedling tuber size with clump planting on gross tuber yield (Table 13 and Appendix XIV). Results revealed that gross tuber yield increased with increasing seedling tuber per hill in the seedling tuber size of 9-≤10 g where as reverse trend was recorded in case of seedling tuber size of 6-<7 g. The highest gross tuber yield ha^{-1} was recorded in the treatment combination of seedling tuber size of 9-≤10 g with 3 seedling tubers per hill (27.67 tha^{-1}) that was statistically similar to the

treatment combination of seedling tuber size of 8-<9 and 9-≤10 g with 2, 3 and 1 seedling tubers per hill (14.33 tha^{-1}) respectively. The lowest gross tuber yield tha^{-1} was recorded in the treatment combination of seedling tuber size of 6-<7 g with 1 seedling tuber per hill (12.83 tha^{-1}) that was statistically similar to the treatment combination of 6-<7 g with 2 seedling tubers per hill (14.33 tha^{-1}). This result is in agreement with the earlier findings of Hossain (2004).

Table 11. Effects of seedling tuber size on yield attributes and gross yield of tuber

Treatments	**Number of tubers hill^{-1}**	**Tubers weight (g hill^{-1})**	**Gross yield of tuber (t ha^{-1})**
S_1	3.41 c	85.85 d	17.17 d
S_2	5.07 b	100.30 c	20.06 c
S_3	6.66 a	120.00 b	24.00 b
S_4	6.30 a	128.90 a	25.78 a
$LSD_{(0.05)}$	0.37	8.52	1.70
F-test	**	**	**
CV%	7.09	8.01	8.01

** = Significant at 1% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g and S_4= 9-≤10 g

Table 12. Effect of clump planting on yield attributes and gross yield of tuber

Treatments	**Number of tubers hill^{-1}**	**Tubers weight (g hill^{-1})**	**Gross yield of tuber (t ha^{-1})**

N_1	4.91 b	98.55 b	19.71 b
N_2	5.51 a	103.75 b	20.75 b
N_3	5.66 a	123.95 a	24.79 a
$LSD_{(0.05)}$	0.32	7.38	1.48
F-test	**	**	**
CV%	7.09	8.01	8.01

** = Significant at 1% probability, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

Table 13. Combined effect of seedling tuber size and clump planting on yield attributes and gross yield of tuber

Treatments	Number of tubers hill^{-1}	Tubers weight (g hill^{-1})	Gross yield of tuber (t ha^{-1})
S_1 N_1	3.06 f	64.15 f	12.83 f
S_1 N_2	3.53 f	71.65 f	14.33 f
S_1 N_3	3.61 f	121.65 bc	24.33 bc
S_2 N_1	4.26 e	103.35 de	20.67 de
S_2 N_2	5.50 d	90.00 e	18.00 e
S_2 N_3	5.40 d	107.50 cd	21.50 cd
S_3 N_1	6.48 b	98.35 de	19.67 de
S_3 N_2	6.26 bc	133.35 ab	26.67 ab
S_3 N_3	7.23 a	128.35 ab	25.67 ab
S_4 N_1	5.81 cd	128.35 ab	25.67 ab
S_4 N_2	6.71 ab	120.00 bc	24.00 bc
S_4 N_3	6.36 bc	138.35 a	27.67 a
$LSD_{(0.05)}$	0.64	14.75	2.95
F-test	*	**	**
CV%	7.09	8.01	8.01

** = Significant at 1% probability, * = Significant at 5% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

4.14 Marketable yield of tuber

Result revealed that marketable tuber yield increased with increasing seedling tuber size (Fig. 15 and Appendix XV). The highest marketable yield of tubers 18.69 tha^{-1} (35.45% by number) was recorded in 9-≤10 g seedling tuber size followed by the seedling tuber size of 8-<9 g (17.97 tha^{-1}) with same statistical rank. It was primarily due to high food reserves in large seed tubers which ultimately contributed to produce higher yield through increase vegetative growth of plants and rapid development of tubers. The lowest marketable tuber yield 13.56 tha $^{-1}$ (41.46% by number) was recorded in the seedling tuber size of 6-<7 g. The marketable tuber yield was lower in smaller seedling tuber because of producing lower tuber weight hill^{-1}. This result is supported by many workers (Malik *et al*. 2002; Shingrup *et al.* 2003; Sonawane and Dhoble, 2004; Verma *et al.* 2007; Gulluoglu and Aroglu, 2009 and, Tohin, 2010) repoted that marketable tuber yield decreased with decreasing seed tuber weight.

The effect of clump planting was influenced significantly on marketable tuber yield in potato (Fig. 16 and Appendix XV). The highest marketable tuber yield 18.99 tha^{-1} was recorded in 3 seedling tubers per hill (37.39% by number). The lowest marketable tuber yield 13.96 tha^{-1} was recorded in 1 seedling tuber per hill (38.28% by number).

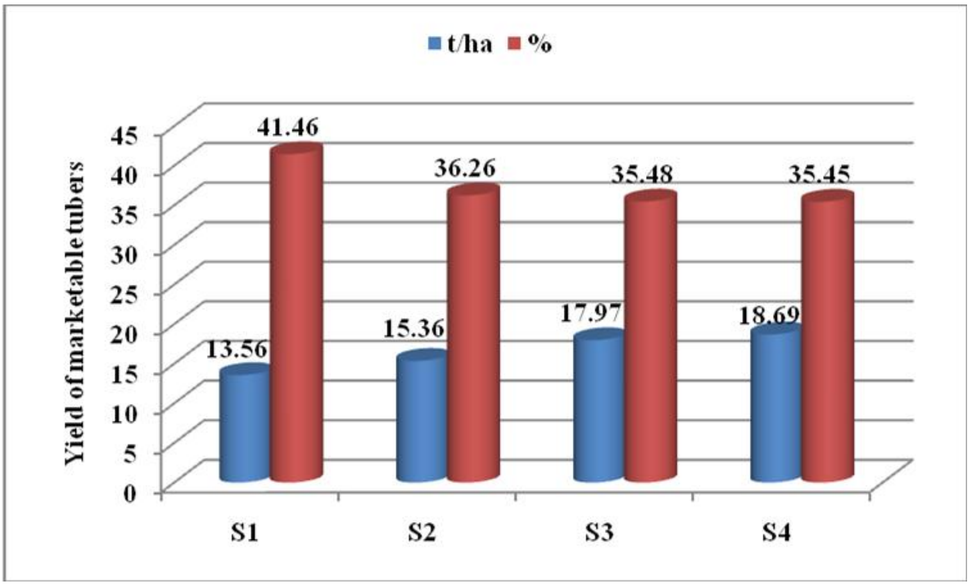


Fig. 15 Effect of seedling tuber size on marketable yield of tubers

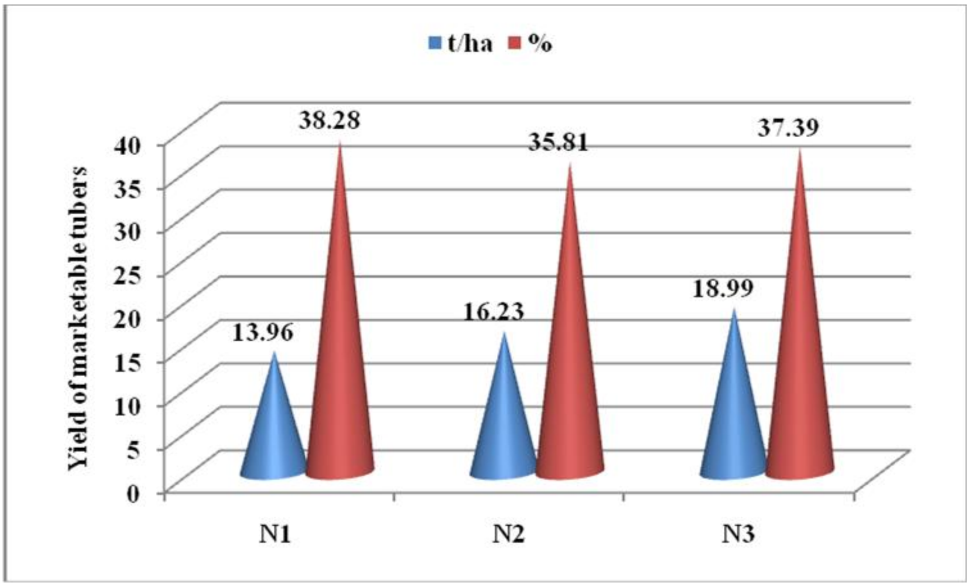


Fig. 16 Effect of clump planting on marketable yield of tubers

Table 14. Combined effect of seedling tuber size and clump planting on marketable yield of tubers

Treatments	Marketable (> 20 g) yield of tubers (t ha^{-1})	Marketable tubers (%) by number
S_1 N_1	9.17 g	35.36 de
S_1 N_2	11.83 fg	40.12 bc
S_1 N_3	19.67 abc	48.90 a
S_2 N_1	15.50 de	42.17 b

$S_2 N_2$	13.67 ef	32.68 e
$S_2 N_3$	16.90 cd	33.92 e
$S_3 N_1$	13.50 ef	39.75 bc
$S_3 N_2$	22.07 a	38.07 cd
$S_3 N_3$	18.33 bcd	28.52 f
$S_4 N_1$	17.67 cd	35.84 de
$S_4 N_2$	17.33 cd	32.28 e
$S_4 N_3$	21.07 ab	38.22 cd
$LSD_{(0.05)}$	2.91	3.59
F-test	**	**
CV%	10.49	5.71

** = Significant at 1% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

The interaction effect of seedling tuber size and clump planting on marketable tuber yield tha^{-1} was significant (Table 14 and Appendix XV). The highest marketable tuber yield 22.07 tha^{-1} (38.17% by number) was recorded in the treatment combination of 8-<9 g seedling tuber size with 2 seedling tubers per hill followed 21.07 tha^{-1} by the treatment combination of 9-≤10 g seedling tuber size with 3 seedling tubers per hill (38.22% by number) with similar rank. The lowest marketable tuber yield 9.17 tha^{-1} was recorded in the treatment combination of 6-<7 g seedling tuber size with 1 seedling tuber per hill (35.36% by number).

4.15 Non-marketable yield of tuber

There was a significant difference in non-marketable yield of tubers due to seedling tuber size (Fig. 17 and Appendix XV). The highest non-marketable yield of tubers 7.09 tha^{-1} (64.55% by number) was recorded in the seedling tuber size of 9-≤10 g followed 6.14 tha^{-1} by the seedling tuber size of 8-<9 g (64.52% by number). The lowest non-marketable tuber yield 3.61 tha^{-1} was recorded in the seedling tuber size of 6-<7 g (58.54% by number).

Non-marketable tuber yield in potato was significantly influenced by clump planting (Fig. 18 and Appendix XV). The highest non-marketable tuber yield 5.80 tha^{-1} was recorded in the seedling tubers 3 per hill (62.61% by number) followed 5.75 tha^{-1} by the 1 seedling tuber per hill (61.72% by number) that was statistically similar rank. The lowest non-marketable tuber yield 4.61 tha^{-1} was recorded in 2 seedling tubers per hill (64.18% by number).

The interaction effect of seedling tuber size and clump planting on non-marketable tuber yield was insignificant (Table 15 and Appendix XV). The highest non-marketable tuber yield 8.00 tha^{-1} was recorded in the treatment combination of 9-≤10 g seedling tuber size with 1 seedling tuber per hill (64.16% by number). The lowest non-marketable tuber yield 2.50 tha^{-1} was recorded in the treatment combination of 6-<7 g seedling tuber size with 2 seedling tubers per hill (59.88% by number).

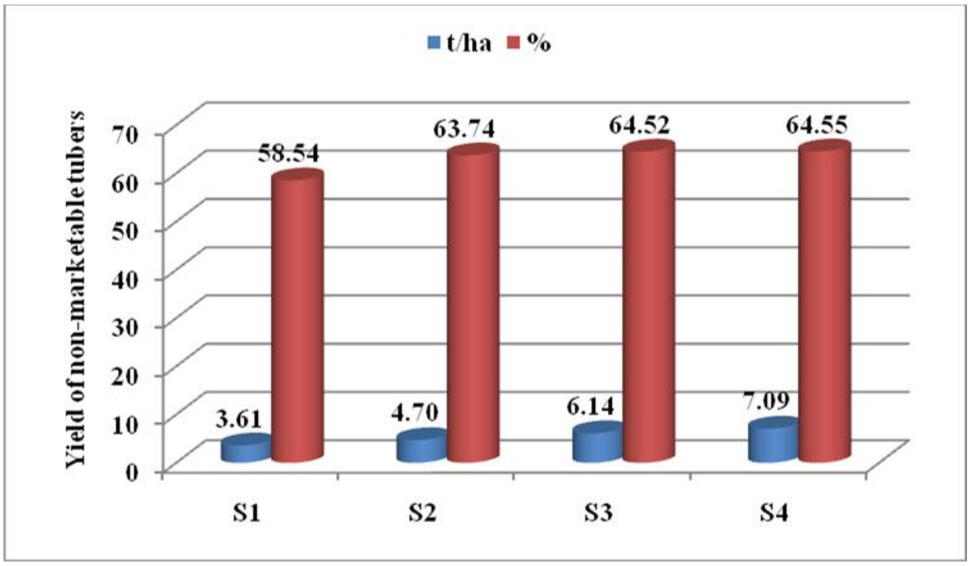


Fig. 17 Effect of seedling tuber size on non-marketable yield of tubers

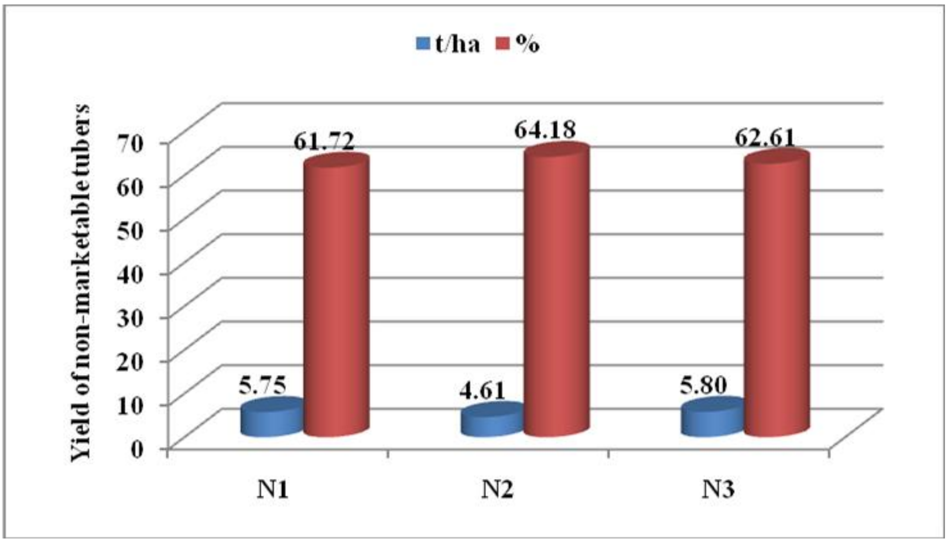


Fig. 18 Effect of clump planting on non-marketable yield of tubers

Table 15. Combined effect of seedling tuber size and clump planting on non-marketable yield of tubers

Treatments	Non-marketable (<20 g) yield of tubers (t ha^{-1})	Non-marketable tubers (%) by number
S_1 N_1	3.67	64.64 bc
S_1 N_2	2.50	59.88 de
S_1 N_3	4.67	51.10 f
S_2 N_1	5.17	57.83 e
S_2 N_2	4.33	67.32 b
S_2 N_3	4.60	66.08 b
S_3 N_1	6.17	60.25 de
S_3 N_2	4.60	61.83 cd
S_3 N_3	7.33	71.48 a
S_4 N_1	8.00	64.16 bc
S_4 N_2	6.67	67.72 b
S_4 N_3	6.60	61.78 cd
$LSD_{(0.05)}$	2.37	3.59
F-test	ns	**
CV%	19.54	3.38

ns = Non-significant, ** = Significant at 1% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber $hill^{-1}$, N_2= 2 seedling tubers $hill^{-1}$ and N_3= 3 seedling tubers $hill^{-1}$

4.16 Grade size distribution of tubers

The harvested tubers were categorized into four grades according to size, *viz*. Grade A-tuber >55 mm size, Grade B-tubers in between 46-55 mm in size, Grade C- tubers in between 28-45 mm in size and Grade D- tubers <28 mm. It was recorded that there was significant variation in grade size of tubers due to different seedling tuber size except Grade A (Table 16 and Appendix XI). The highest number of Grade-B and Grade-C tuber was recorded in the seedling tuber size of 6-<7 g (34.30% and 6.37% respectively) followed by seedling tuber size of 7-<8 g and 8-<9 g (5.37% and 5.10% for Grade-B respectively) was statistically similar rank. The highest number of Grade-D tuber was recorded in the seedling tuber size of 8-<9 g (65.59%) followed by seedling tuber size of 7-<8 g and 9-≤10 g (64.71% and 64.56% for Grade-D respectively) was statistically similar rank. The lowest numbers of Grade-B tubers were recorded in the seed tuber size of 9-≤10 g (4.17%). The lowest number of Grade-C tubers was recorded in the seedling tuber size of 8-<9 g (29.23%) followed by seedling tuber size of 7-<8 g and 9-≤10 g (29.56% and 31.01% respectively) was statistically similar rank while the lowest number of Grade-D was recorded in the seedling tuber size 6-<7 g (59.01%).

The effect of clump planting on tuber grade was insignificant except Grade-B (Table 17 and Appendix XI). The highest number of Grade-B was produced in 3 seedling tubers per hill (6.06%) followed by the seedling tuber 1 per hill that was statistically similar rank (5.07%). In contrast, the lowest number of Grade-B tuber was produced in 2 seedling tubers per hill (4.63%).

The interaction effect of seedling tuber size and clump planting on tuber grade was significant except Grade-A and Grade-B (Table 18 and Appendix XI). The highest number of Grade-C and Grade-D tuber was recorded in 6-<7 g and 8-<9 g seedling tuber size with 3 seedling tubers per hill (40.530% and 71.48% for Grade-C and Grade-D respectively). However, the lowest number of Grade-C and Grade-D tuber was recorded in 8-<9 g and 6-<7 g seedling tuber size with 3 seedling tubers per hill (22.71% and 51.10% for grade-C and grade-D, respectively).

Table 16. Effect of seedling tuber size on the grade of tubers

Treatments	Grade of tubers (%) by number			
	< 28 mm (Grade-D)	28-45 mm (Grade-C)	46-55 mm (Grade-B)	> 55 mm (Grade-A)
S_1	59.01 b	34.30 a	6.372 a	0.32
S_2	64.71 a	29.56 b	5.371 ab	0.36
S_3	65.59 a	29.23 b	5.09 ab	0.08
S_4	64.56 a	31.01 b	4.17 b	0.26
LSD $_{(0.05)}$	3.02	3.27	1.31	0.69
F-test	**	**	*	ns
CV%	4.87	10.78	25.54	275.46

ns = Non-significant, ** = Significant at 1% probability, * = Significant at 5% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g and S_4= 9-≤10 g

Table 17. Effect of clump planting on the grade of tubers

Treatments	Grade of tubers (%) by number			
	< 28 mm (Grade-D)	28-45 mm (Grade-C)	46-55 mm (Grade-B)	> 55 mm (Grade-A)
N_1	63.02	31.65	5.07 ab	0.27
N_2	64.54	30.57	4.64 b	0.26
N_3	62.85	30.85	6.06 a	0.24
LSD $_{(0.05)}$	2.62	2.83	1.14	0.59
F-test	ns	ns	*	ns
CV%	4.87	10.78	25.54	275.46

ns = Non-significant, * = Significant at 5% probability, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

Table 18. Combined effect of seedling tuber size and clump planting on the grade of tubers

Treatments	Grade of tubers (%) by number			
	< 28 mm (Grade-D)	28-45 mm (Grade-C)	46-55 mm (Grade-B)	> 55 mm (Grade-A)
$S_1 N_1$	64.64 bcd	29.85 bcd	5.51	0.00
$S_1 N_2$	61.29 d	32.51 bc	6.20	0.00
$S_1 N_3$	51.10 e	40.53 a	7.41	0.97
$S_2 N_1$	59.79 d	33.18 bc	6.24	0.78
$S_2 N_2$	67.32 ab	29.34 bcd	3.06	0.28
$S_2 N_3$	67.03 abc	26.15 de	6.81	0.00
$S_3 N_1$	63.47 bcd	32.61 bc	3.92	0.00
$S_3 N_2$	61.83 cd	32.36 bc	5.57	0.25
$S_3 N_3$	71.48 a	22.71 e	5.81	0.00
$S_4 N_1$	64.17 bcd	30.95 bcd	4.61	0.28
$S_4 N_2$	67.72 ab	28.07 cde	3.72	0.50
$S_4 N_3$	61.78 d	34.02 b	4.19	0.00
$LSD_{(0.05)}$	5.23	5.66	2.27	1.19
F-test	**	**	ns	ns
CV%	4.87	10.78	25.54	275.46

ns = Non-significant, ** = Significant at 1% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

4.17 Yield of seed and non-seed tubers

There was a significant difference on the yield of seed and non-seed tubers due to seedling tuber size (Table 19 and Appendix XVII). The highest yield of seed and non-seed tubers 18.71 tha^{-1} and 7.02 tha^{-1} were recorded in the seedling tuber size of 9-≤10 g followed 18.30 tha^{-1} and 5.70 tha^{-1} by the seedling tuber size of 8-<9 g respectively. The lowest yield of seed and non-seed tubers 12.83 tha^{-1} and 4.33 tha^{-1} was recorded in the seedling tuber size of 6-<7 g. The seed and non-seed tubers increased gradually with the increase in seedling tuber size. This result is in agreement with the findings of Hossain (2004).

Seed tubers yield in potato was significantly influenced but non-seed tuber yield was insignificant by clump planting (Table 20 and Appendix XVII). The highest seed tuber yield 18.99 tha^{-1} was recorded in the seedling tubers 3 per hill. The lowest seed tuber yield 14.64 tha^{-1} was recorded in 1 seedling tuber per hill but it was statistically similar to seedling tubers 2 per hill (15.12 tha^{-1}). The seed tubers increased gradually with the increase in seedling tubers per hill. This result is in agreement with the findings of Hossain (2004).

Table 19. Effect of seedling tuber size on the yield of seed and non-seed tubers

Treatments	Seed tubers (t ha^{-1})	Non-seed tubers (t ha^{-1})
S_1	12.83 c	4.33 b
S_2	15.12 b	4.93 b
S_3	18.30 a	5.70 ab
S_4	18.74 a	7.03 a
LSD$_{(0.05)}$	2.22	1.49
F-test	**	**
CV%	13.94	27.70

** = Significant at 1% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g and S_4= 9-≤10 g

Table 20. Effect of clump planting on the yield of seed and non-seed tubers

Treatments	Seed tubers (t ha^{-1})	Non-seed tubers (t ha^{-1})
N_1	14.64 b	5.07
N_2	15.12 b	5.63
N_3	18.99 a	5.80
LSD$_{(0.05)}$	1.92	1.29
F-test	**	ns
CV%	13.94	27.70

ns = Non-significant, ** = Significant at 1% probability, N_1= 1 seedling tuber hill^{-1}, N_2= 2 seedling tubers hill^{-1} and N_3= 3 seedling tubers hill^{-1}

Table 21. Combined effect of seedling tuber size and clump planting on the yield of seed and non-seed tubers

Treatments	Seed tubers (t ha^{-1})	Non-seed tubers (t ha^{-1})
S_1 N_1	9.67 d	3.17
S_1 N_2	11.00 d	3.33
S_1 N_3	17.83 ab	6.50
S_2 N_1	15.17 bc	5.50
S_2 N_2	12.57 cd	5.43
S_2 N_3	17.63 ab	3.87
S_3 N_1	15.00 bc	4.67
S_3 N_2	19.57 a	7.10
S_3 N_3	20.33 a	5.33
S_4 N_1	18.73 ab	6.93
S_4 N_2	17.33 ab	6.67
S_4 N_3	20.17 a	7.50
$LSD_{(0.05)}$	3.84	2.60
F-test	*	ns
CV%	13.94	27.70

ns = Non-significant, ** = Significant at 5% probability, S_1= 6-<7 g, S_2= 7-<8 g, S_3= 8-<9 g, S_4= 9-≤10 g, N_1= 1 seedling tuber $hill^{-1}$, N_2= 2 seedling tubers $hill^{-1}$ and N_3= 3 seedling tubers $hill^{-1}$

The interaction effect of seedling tuber size and clump planting on seed tuber yield was significant but on non-seed tuber yield was insignificant (Table 20 and Appendix XVII). The highest seed tuber yield 20.33 t ha^{-1} was recorded in the seedling tubers 3 per hill with 8-<9 g seedling tuber size but it was statistically similar to seedling tubers 3 per hill with 9-≤10 g seedling tuber size (20.17 t ha^{-1}). The lowest seed tuber yield 9.67 t ha^{-1} was recorded in 6-<7 g seedling tuber size with 1 seedling tuber per hill.

4.18 Economic analysis

Economic analysis was done with a view to observing the comparative cost and benefit under different treatment combinations of seedling tuber size and clump planting. For this purpose, the input cost for land preparation, seed tuber, planting, manure and fertilizer, intercultural operation and manpower required for all the operations including tubers were recorded against each treatment, which were then enumerated into cost per hectare. The details economic analysis has been presented in Appendix XVIII and XIX.

Variation in cost of production was noticed due to the cost of seedling tuber and clump planting (Table 22). The total cost of cultivation ranged between 168400 and 352400 Tk.ha^{-1}. The cultivation cost increased with increasing seedling tuber size and increasing seedling tubers per hill. The highest cost of production was involved when used 9-≤10 g seedling tuber size with 3 seedling tubers per hill (Tk 352400 ha^{-1}). The lowest cost of production was involved when used 6-<7 g seedling tuber size with 1 seedling tuber per hill (Tk 168400 ha^{-1}). The highest gross return was obtained from the treatment combination of 8-<9 g seedling tuber size with 2 seedling tubers per hill (Tk 464400 ha^{-1}) while the lowest gross return was found from the treatment combination of 6-<7 g seedling tuber with 1 seedling tuber per hill (Tk 201700 ha^{-1}). However, the highest net profit was obtained from the treatment combination of 8-<9 g seedling tuber size with 2 seedling tubers per hill (Tk 212000 ha^{-1}). The maximum benefit-cost ratio was recorded in the treatment combination of 9-≤10 g seedling tuber size with 1 seedling tuber per hill (1.96) that was apparently similar to the treatment combination of 7-<8 g seedling tuber size with 1 seedling tuber per hill (1.90). The lowest benefit-cost ratio was recorded in the treatment combination of 6-<7 g seedling tuber with 2 seedling tubers per hill (1.17). From economic point of view, the seed tuber size of 9-≤10 g seedling tuber size with 1 seedling tuber per hill was more profitable than the other treatment combination.

Table 22. Economic analysis in potato production as influenced by seedling tuber size and clump planting

Treatment combinations		Seed rate (kg ha^{-1})	Total cost of production (Tk. ha^{-1})[a]	Yield of potato (kg/ha)	Gross return (Tk. ha^{-1})[b]	Net profit (Tk. ha^{-1})	Benefit cost ratio
Seedling tuber size	Clump planting						
6-<7 g	One	1100	168400	12830	201700	33300	1.20
	Two	2200	212400	14330	249100	36700	1.17
	Three	3300	256400	24330	416700	160300	1.63
7-<8 g	One	1300	176400	20670	335850	159450	1.90
	Two	2600	228400	18000	295050	66650	1.29
	Three	3900	280400	21500	361000	80600	1.29
8-<9 g	One	1600	188400	19670	300850	112450	1.60
	Two	3200	252400	26670	464400	212000	1.84
	Three	4800	316400	25670	403300	86900	1.27
9-≤10 g	One	1900	200400	25670	393400	193000	1.96
	Two	3800	276400	24000	379950	103550	1.37
	Three	5700	352400	27670	454400	102000	1.29

[a] Calculated on the basis of March 2011 market price.

[b] Considering Tk. 20 and 5 per kg of marketable (> 20 g) and non-marketable tubers (< 20 g), respectively at harvest.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the Horticulture research farm, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during the period from November 2010 to March 2011 to study the performance of mini seedling tubers derived from true potato seed as influenced by its size and clump planting. The experiment comprised of 4 levels of seedling tubers, viz. 6-<7 g (S_1), 7-<8 g (S_2), 8-<9 g (S_3) and, 9-≤10 g (S_4) and clump planting: three levels of seedling tuber per hill, *viz*. 1 per hill (N_1), 2 per hill (N_2) and 3 per hill (N_3). Thus there were twelve treatments and the experiment was laid out in randomized complete block design with three replications.

The morphological parameters such as days to first and 80% emergence, plant height, number of leaves plant^{-1}, leaf area (LA) plant^{-1} and leaf area index (LAI), fresh mass production plant^{-1}, total dry mass (TDM) plant^{-1} and TDM m^{-2} were significantly influenced by seedling tuber size at different growth stages in potato. The highest plant height, number of leaves hill^{-1}, LA plant^{-1} and LAI, fresh mass, TDM plant^{-1} and TDM m^{-2} increased significantly with increasing seedling tuber size of 9-≤10 g. In contrast, the shortest plant height, leaves plant^{-1}, LA plant^{-1}, LAI, fresh mass plant^{-1}, TDM plant^{-1} and TDM m^{-2} was recorded in the seedling tuber size of 6-<7 g. The effect of seedling tuber size on crop growth rate (CGR) was significant. Results showed that crop growth rate was greater in 55-70 DAP than in 40-55 DAP and 70-100 DAP.

The effect of seedling tuber size on yield attributes such as tubers hill^{-1}, tuber weight hill^{-1} and gross tuber yield was significant. Tubers hill^{-1}, tubers weight hill^{-1} and gross tuber yield tha^{-1} increased with increasing seedling tuber size of 9-≤10 g. In contrast, the lowest gross tuber yield was recorded in seedling tuber size of 6-<7 g. There was significant variation in grade size of tubers due to different seedling tuber size. The highest number of Grade-B and Grade-C tuber was recorded in the seedling tuber size of 6-<7 g (34.30% and 6.37% for Grade-B and Grade-C respectively). The highest number of Grade-D tuber was recorded in the seedling tuber size of 8-<9 g (65.59%). The lowest number of grade-C was recorded in the seedling tuber size of 8-<9 g (29.23%).

The highest plant height, number of leaves plant^{-1}, LA plant^{-1} and LAI, fresh mass, TDM plant^{-1} and TDM m^{-2} increased significantly with increasing number of seedling tuber per hill. In contrast, the shortest plant height, leaves plant^{-1}, LA plant^{-1}, LAI, fresh mass plant^{-1}, TDM plant^{-1} and TDM m^{-2} was recorded in the seedling tuber size of 6-<7 g. The effect of clump planting on crop growth rate (CGR) was insignificant.

The effect of clump planting on yield attributes such as tubers hill^{-1}, tuber weight and gross tuber yield was significant. The highest tubers hill^{-1}, tuber weight hill^{-1} and gross tuber yield ha^{-1} was increased with increasing the number of seedling tubers per hill. In contrast, the lowest tubers hill^{-1}, tuber weight hill^{-1} and gross tuber yield was recorded in 1 seedling tuber per hill. The highest number of Grade-B tuber was recorded in 3 seedling tubers per hill and the lowest number of grade-B was recorded in 2 seedling tubers per hill.

The highest plant height, number of leaves plant^{-1}, LA plant^{-1} and LAI, fresh mass, TDM plant^{-1} and TDM m^{-2} were recorded in 9-≤10 g seedling tuber size with 3 seedling tubers per hill. In contrast, the shortest plant height, leaves plant^{-1}, LA plant^{-1}, LAI, fresh mass plant^{-1}, TDM plant^{-1} and TDM m^{-2} was recorded in the treatment combination of 6-<7 g seedling tuber size with 1 seedling tuber per hill.

The highest tubers hill^{-1}, tuber weight hill^{-1} and gross tuber yield ha^{-1}were recorded in 9-≤10 g seedling tuber size with 3 seedling tubers per hill. In contrast, the lowest tubers per hill, tuber weight hill^{-1} and gross tuber yield ha^{-1} were recorded in 6-<7 g seedling tuber size with 1 seedling tuber per hill.

The highest number of Grade-C tuber was recorded in 6-<7 g seedling tuber size with 3 seedling tubers per hill and the lowest number of grade-C tuber was recorded in 8-<9 g seedling tuber size with 3 seedling tubers per hill.

The cultivation cost increased with increasing tuber size and number of seedling tuber per hill. The maximum benefit-cost ratio was recorded in the treatment combination of 9-≤10 g seedling tuber size with one seedling tuber hill (1.96) and it was lowest in the treatment combination of 6-<7 g seedling tuber size with 2

seedling tubers hill (1.17). So, it can be concluded that, treatment combination of 9-≤10 g seedling tuber size and 1 seedling tuber per hill were found suitable for potato production.

REFERENCES

Accatino, P. 1979. Agronomic management in the utilization of true potato seed, Preliminary results. In: CIP Report of the planning conference on the production of potatoes from true seed. Manila, Philippines. pp. 61-69.

Accatino, P. and Malagamba, P. 1983. Growing potatoes from TPS. Current agronomic knowledge and future prospects. In: Hooker, W. J. (ed.) "Research for the Potato in the Year 2000", International Potato Centre (CIP), Lima, Peru. pp. 61-62.

Adhikari, R. C. 2005. Performance of Different Size True Potato Seed Seedling Tubers at Khumaltar. *Nepal Agri. Res. J*., **6**: 1-7.

Ahmad, K. U., Abdullah, A. M. and Hossain, A. K. M. A. 1976. Efficiency of seed potato when planted at different rates. *Bangladesh Hort.,* **4** (2): 1-10.

Ahmed, C. M. S., Sajjad, S. and Abbasi, N. A. 2001. Performance of seedling potato tubers from true seed in second generation in comparison with local varieties. *Sarhad J. Agri.*, **17** (1): 69-73.

Ahmed, K. U. and M. A. Quasem. 1968. Study on the performance of the different size of cut seed potato when compared with whole seed potato. *Agric. Pakistan.* **13** (1): 9-16.

Alam, M. S. 1999. Growth and yield of TPS seedling tubers as influenced by cowdung manure and chemical fertilizers. An MS thesis, Department of Horticulture, BAU, Mymensingh. p. 63.

Alam, M. S., Iqbal, T. M. T., Amin, M. and Gaffar, M. A. 1989. Krishitattic Fasaler Utpadan O Unnayan (In Bengali). T. M. Jubair Bin Iqbal, Sirajganj. pp. 231-239.

Allen, E. J. and Wurr, D. C. E. 1973. A comparison of two methods of recording stem densities in the potato crop. *Potato Res*., **16**: 10-20.

Amin, S. M. B., Adam, E. V. and Pehu, E. 1996. Production of seedling tubers derived from true potato seed and their use as seed tubers in the Sudan. *Exp. Agri.*, **32** (4): 419-426.

Anonymous. 1997. Performance of small tubers derived from true potato seed with clump planting. Horticulture Research Paper, Bangladesh Research Publication.

Anonymous. 2001. Annual Research Report on Tuber Crops Improvement 2000-2001. Tuber Crops Research Centre, BARI, Joudebpur, Gazipur. pp. 4-5.

Bashar, M. A. 1976. The effect of spacing on the growth and yield of potato. An MS thesis, Department of Horticulture, BAU, Mymensingh. p. 86.

Batra, V. K., Malik, Y. S., Pandita, M. L. and Khurana, S. C. 1992. Effect of seedling tuber size, spacing and method of planting on potato production. *J. Indian Potato Assoc*., **19** (3-4): 166-170.

BBS. 2007. Bangladesh Bureau of Statistics. Monthly Statistical Bulletin. Ministry of Planning, Govt. People's Repub. Bangladesh. pp. 54-55.

BBS. 2009. Bangladesh Bureau of Statistics. Monthly statistical year book. Ministry of Planning, Govt. People's Repub. Bangladesh. p. 64.

Bedewy, R. C. C. and Cortbaoui, R. 1994. Egypts seed system based on true potato seed. CIP circular. **20** (1): 5-8.

Beukema, H. P. and Zaag, D. E. V. 1979. Potato Improvement: Some Factors and Facts. International Agriculture Centre, Wageningen, The Netherlands. p. 224.

Bishop, J. G. and Wright, D. N. 1959. The effect of size and spacing of seed piece on the yield and grades of White Rose Potatoes in Korn country, California. *American Potato J*., **36**: 235-240.

Bong Kyoon, K., Young Kil, K. and Mi Ra, K. 2001. Effect of seed potato size on plug seedling growth and field performance. *Korean J. Crop Sci*., 46 (2): 121-124.

Brown, K. J. 1987. Soil Resources Bangladesh. Soil Survey Project, UNDP-FAO, Rome, Italy. p. 211.

Carputo, D., Barone, A., Consoli, D. and Frusciante, L. 1994. Use of seedling tubers from TPS in southern Italy. *American J. Potato Res*., **71** (1): 29-38.

Carputo, D., Pentimalli, M. and Frusciante, L. 1996. Production and use of seedling tubers from true potato seed (TPS) for potato cultivation in Italy. *American J. Potato Res*., **39** (1): 3-9.

Chaudhury, E. H. and Rasul, M. G. 1995. True potato seed (TPS) research and development in Bangladesh. Proc. workshop on National Programme for true potato seed (TPS) in Bangladesh. BARC, Dhaka, pp. 28-37.

Chaudhury, E. H., Sarker, M. H. and Rashid, M. H. 1987. Agronomic management for potato production from true seed in Bangladesh. PRC, BARI, Joydebpur, Gazipur. pp. 18-27.

Chilver, A., Walker, T., Khatana, V., Fano, H., Suherman, R. and Rizk, A. 1999. On-farm profitability of true potato seed (TPS) utilization technologies. Working paper series, CIP. **99** (3): 41p.

Choudhury, M. Z. H. 1997. Effect of plant spacing on the production of potato seedling tubers. An MS thesis, Department of Horticulture, BAU, Mymensingh. 97p.

CIP. 1981. Annual Report 1981. International Potato Centre (CIP), Lima, Peru. 11p.

CIP. 1982. Annual Report 1982. International Potato Centre (CIP), Lima, Peru. 30p.

CIP. 1992. Annual Report 1992. International Potato Centre (CIP), Lima, Peru. 27p.

Cloete, G. S. and Els, D. L. 1982. The effect of seed size and within row spacing on seed tuber production of potato cultivar BP-1. *Agroplantae*. **14** (1): 1-4 [Cited from Potato Abst., **8** (4), 1983].

Divis, J. and Barta, J. 2001. Influence of the seed tuber size on yield and yield parameters in potatoes. *Rostlinna Vyroba*, **47** (6): 271-275. [Cited from AGRIS Abst., 2002].

Eddowes, M. 1975. Effect of seed size and spacing on total and marketable yield of main crop potatoes. In: Abstract of conference papers, 6th Triennial Conference of European Association for potato Research. Wageningen, The Netherlands. pp. 130-131.

Edris, K. M., Islam, A. T. M. T., Chowdhury, M. S. and Haque, A. K. M. M. 1979. Detailed Soil Survey of Bangladesh. Department Soil Survey, Govt. of the People's Republic of Bangladesh. p. 118.

El-Elias, S. M., Hossain, A. B. S., Akhter, M. I. and Islam, M. R. 1997. Production of potato from true potato seed (folder in Banla). TCRC, BARI, Joudebpur, Gazipur.

Engels, C., El-Bedewy, R. C. C. and Sattelmacher, B. 1993a. Effects of weight and planting density of tubers derived from true potato seed on growth and yield of potato crops in Egypt: 1. Sprout growth, field emergence and haulm development. *Filed Crops Res*., **35**: 129-170.

Engels, C., Bedewy, R. E. and Sattelmacher, B. 1993b. Effects of weight and planting density of tubers derived from true potato seed on growth and yield of potato crops in Egypt: 2. Tuber yield and tuber size. *Filed Crops Res*., **35**: 171-182.

Escribeno, I. F. 1992. The size of potato and seed piece. Inst. *Noc. Invest. Agron*., **41**: 207-16. [Cited from *Field Crop Abst*., **47**: 1964].

FAO. 1988. Production Year Book. Food and Agriculture Organization of the United Nations. Rome, Italy. **42**: 190-193.

Garg, V. K., Singh, S., Raj, D. and Kumar, A. 2000. Effect of physio-agronomical manipulations on the number and yield of seed tubers in breeders seed in the hills. Potato, global research and development: Proc. of the Global Conf. on Potato, Dec.6-11, 1999. Vol-**1**. New Delhi, India, pp. 413-418.

Gojski, B. 1979. The effect of planting density for seed potatoes of different sizes on the yield of potato cv. Krokus and Pierwiosunek. Bunletyn Instytutu Ziemniaka. **24**: 77-93. [Cited from *Field Crop Abst*. **36** (3), 1983].

Gray, D. 1979. Fluid drilling and other methods for sowing seeds with potential for the true potato seeds. In: CIP Report of the planning conference on the production of potatoes from true seed. Manil, the Philippines. pp. 117-131.

Gregoriou, S. 2000. The effect of row spacing on yield and tuber size distribution of the potato cv. Cara. Tech. Bull. *J. Cyprus Agri. Res. Ins*., **207**: 1-10.

Grewal, J. S., Sharma, R. C. and Saini, S. S. 1992. Agro-techniques for intensive potato cultivation in India. *Indian Council Agri. Res*., New Delhi. pp.26-28.

Gulluoglu, L. and Aroglu, H. 2009. Effects of seed size and row spacing on growth and yield of early potato in a mediterranean-type environment in Turkey. *African J. Agri. Res*., 4 (5): 535-541.

Haan, H. D. 1953. Potato breeding in the Netherlands. *Euphytica*, **2**: 113-121.

Hoang, V. T., Liem, P. X., Dan, V. B., Dam, N. D., Linh, N. X., Viet, N. V., Tung, P. X. and Zaag, P. V. 1988. True potato seed research and development in Vietnam. *American Potato J.,* **65**: 295-302.

Horton, D. 1987. Potatoes: Production, Marketing and Programs for Developing Countries. Westview Press, London. pp. 19-24.

Hossain, M. M. 2004. Production and utilization of seedling tubers derived from true potato seed. PhD thesis, Department of Horticulture, BAU, Mymensingh, pp. 202-205.

Hossain, M. M., Hossain, M. J., Habib, A. K. M. A. and Hossain, A. E. 1992. Studies on degeneration of seedling tubers derived from true potato seed. *Bangladesh Hort.,* **20** (1): 69-72.

Hossain, M. M., Sarker, P. K. and Mondal, M. A. A. 1994. Production and utilization of seedling tubers derived from true potato seed (TPS) in farmers field. *J. Bio. Sci.,* **2**: 83-88.

Hussain, M. M. 1985. Potato: Production, Storage and Utilization (In Bangla). Mrs. Meer Tasimum Ghoni, 85/5, Kakrail, Dhaka. 242 p.

Hussain, M. M. 2000. Export potential of potatoes from Bangladesh. Paper presented in the first conference of Bangladesh Potato Council (BPC) held at Bangladesh Agricultural Research Council (BARC), Dhaka.

Islam, F. 1992. Effect of seedling tuber size and plant spacing on the growth and yield of potato. An MS thesis, Department of Horticulture, BAU, Mymensingh, p. 43.

Kadian, M. S., Pande and Upadhya, M. D. 1992. Seedling tubers from true potato seed (TPS) as planting material for north-west Indo-Gangetic plains of India. *Crop Res*., **5** (3): 499-504.

Kadian, M. S., Patel, P. K., Thakur, K. C. and Upadhya, M. D. 1988. Comparative yield potential of seedlings and seedling tubers from true potato seed in Deesa (Gujrat). *J. Indian Potato Assoc*., **15** (1): 15-18.

Kadian, M. S., Patel, P. K., Upadhya, M. D. and Thakur, K. C. 1987. Evaluation of TPS progenies for the potato production in Deesa (Gujrat). *J. Indian Potato Assoc.,* **14** (1&2): 57-59.

Kadly, M. S. 1972. Protein yield of various crops as related to protein value. *Economic Bot*., **26**: 142-144.

Kamal, A. M. A. and Khan, I. H. 1973. Effect of variety and spacing on the yield of potato tubers. *Bangladesh Hort*., **1** (2): 52-56.

Kamaly, M. H. K. 1997. Effects of TPS seedling tuber size and plant spacing on growth and yield of potato. An MS thesis, Department of Horticulture, BAU, Mymensingh, p. 108.

Karim, S. M. R. and Hossain, S. M. A. 1980. Effects of cultivar, seed size and seed source on the yield and quality of potato. *Bangladesh Hort*., **8** (1): 25-28.

Karle, A. S., Quadir, S. J. and Dhoble, M. V. 1997. Effects of seedling tuber size and fertility levels on growth and yield of potato by TPS. *J. Maharashtra Agril. Univ.,* **22** (3): 362-363.

Khalafalla, A. M. 2001. Effect of plant density and seed size on growth and yield of solanum potato in Khartoum State, Sudan. *African J. Crop Sci.,* 9 (1): 77-82.

Khan, S. A., Jamaru, M. M. R. and Arain, M. Y. 2010. Determination of Suitable Planting Geometry for Dfferent True Potato Seed Tuberlet Grades. *Pakistan J. Agri. Res*., **23**: 1-2.

Khurana, S. C. 1990. Performance of TPS Populations at Hisar. (Gaur, P. C. edited) Commercial adoption of true potato seed Technology- Prospects and Problems. Central Potato Research Institute (CPRI), Shimla, India. pp. 54-61.

Kumar, P. and Baijal, B. D. 1979. Effect of seed size on growth pattern of potato. *Agril. Univ. J. Res. Sci*., **28** (2): 35-40.

Li, C. H. 1983. Prospects for the use of true seed to grow potato. In: Hooker, W. J. (ed.) “Research for the Potato in the Year 2000. International Potato Centre (CIP), Lima, Peru. pp. 17-18.

Li, C. H. and Shen, C. P. 1979. Production of marketable and seed potatoes from botanical seed in the People’s Republic of China. In: International Potato Centre Report of the Planning Conference on the production of potatoes from true seed. Manila, the Philippines. pp. 21-28.

Malagamba, P. 1988. Potato production from true seed in tropical climates. *Hort. Sci.,* **23**: 495-500.

Maleque, M. A. 1997. Effects of date of seed sowing and harvesting on the growth and development of TPS seedling tubers. An MS thesis, Department of Horticulture, BAU, Mymensingh. 68 p.

Malik,Y. S., Bhatia, A. K., Singh, N.; Nehra, B. K. and Khurana, S. C. 2002. Effect of nitrogen, seed size and spacing on seed potato production in cv. Kufri Sutlej. Potato global research and development. Proceedings of the Global Conf. on Potato. Dec 6-11. New Delhi, India, 1999: Vol-**2**. pp. 861-865.

Mandala, N. N. and Arora, P. N. 1987. Effect of nitrogen, spacing and planting materials on the yield of potato. *Veg. Sci*., **5** (2): 72-77.

MOA. 2009. Hand Book of Agricultural Statistics. Market Monitoring and Information System, Ministry of Agriculture (MOA), Govt. People’s Repub. Bangladesh. p. 493.

Mukhopadhyay, S. K. 2001. Effect of size of TPS tuberlets and NPK nutrition on potato production. *Hort. J. India.*, **14** (1): 61-68.

Nankar, J. T. 1990. Standardization of TPS agronomy and performance of TPS populations in Maharashtra. (Gaur, P. C. edited) Commercial adoption of true potato seed technology- Prospects and problems. Central Potato Research Institute, Shimla, India. pp. 68-76.

Nizamuddin, M., Mirza, B., Shakirullah, Asghar, M., Ahmad, S., Din, M., Hussain, I. and Baig, D. 2010. Yield Performance of True Potato Seeds (TPS) Hybrids Under Climatic Conditions of Northern Areas. *Sarhad J. Agric*., **26** (2): 1-4.

Pallais, N. 1994. True potato seed: A global perspective. International Potato Center Circular, **20**: 2-3.

Pande, P. C., Kadian, M. S. and Upadhya, M. D. 1990. Field performance of seedling tubers in three successive clonal generations. *J. Indian Potato Assoc*., **17** (1&2): 30-33.

Patel, B. T., Barad, A. V., Chaudhari, S. M., Patel, C. K. and Patel, R. N. 2002 Standardization of spacing for seed tuberlet production from TPS under nursery beds in Gujarat. *Indian J. Potato. Assoc*., **29** (3/4): 143-146.

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

Popova, R. I. 1979. Effect of tuber size and plant density on total yield and yield of seed tubers of potatoes. Kertophyarsto, Respublikanikie Mizhahridomchll Tematichnii Naukovii Zibranik. **10**: 57-58. [Cited from *Field Crop Abst*. **3** (11), 1980].

Rashid, A., Rashid, M. H. and Khan, A. I. 1979. Role of plant population on the production of potato. Proc. 2nd workshop of potato research workers. PRC, BARI, Joydebpur, Gazipur. pp. 63-68.

Rashid, M. H., Akhter, S., Elias, M., Rasul, M. G. and Kabir, M. H. 1993b. Seedling tubers for ware potato production: Influence of size and plant spacing. *Asian Potato J.,* **3**: 14-17.

Rashid, M. H., Kabir, M. H., Hossain, M. M. and Rashid, M. M. 1993a. Assessment of true potato seed families for tuberlet production under the climatic conditions of Bangladesh. *Asian Potato J*., **3**: 11-13.

Rashid, M. M. 1987. Problems of production of true potato seeds in Bangladesh. Pro. On true potato seed research in Bangladesh, Oct. 5-7, BARI, Gazipur-1701. pp. 5-7.

Razzaque, M. A., Satter, M. A., Amin, M. S., Quaium, M. A. and Alam, M. S. 2000. Krishi Projukti Hatboi (in Bangla). Bangladesh Agricultural Research Institute, Gazipur. pp. 180-181.

Reust, W. 2002. What about productivity of small seed potato tubers? *Revue Suisse-d'-Agril.,* 34 (1): pp .5-8. [Cited from AGRIS Abst., 2003].

Roy, H. C. 1997. Growth and development of potato grown from TPS seedling tubers of different sizes. An MS thesis, Department of Horticulture, BAU, Mymensingh. 72 p.

Roy, T. S., Ali, M. H., Huq, Z. N., Amin, A. K. R. and Akhtar, M. I. 1999. The promotion of true potato seed technology for potato production in Bangladesh. *J. Agril. Edu. Tech.,* **2**: 103-108.

Roy, T. S., Nishizawa, T. and Ali, M. H. 2005. Studies in the utilization of true potato seeds: Productivity of tubers under subsequent clonal generations. *J. Japanese Soc. Hort. Sci.,* **74**: 374-380.

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. *International J. Agri. Env. Biote*., **2** (4): 385-392.

Roy, T. S., Rasul, M. G., Hossain, M. J., Hossain, A. E. and Ahmed, H. U. 1997. Replacement of inorganic fertilizer by farmyard manure for seedling tuber production by true potato seed in beds. *Bangladesh J. Agril. Res.,* **22** (2): 297-302.

Sadik, S. 1983. Potato production from true seed- Present and future. In: Hooker, W. J. (ed.) “Research for the Potato in the Year 2000”. International Potato Centre (CIP), Lima, Peru. pp. 18-25.

Saikia, M. and Rajkhowa, D. J. 1998. Effect of planting density and vermicompost on the yield of potato raised from seedling tubers. *J. Indian Potato Assoc*., **25** (3-4): 141-142.

Salaman, R. N. 1949. The history and social influence of the potato. Cambridge University Press. 685 p.

Shingrup, P.V., Giri, D. G., Jahagirdar, S. W. and Barde, P. R. 2003. Economics of potato (*Solanum tuberosum* L.) cultivation as influenced by different agro techniques. *J. Soils Crops*., 13 (2): 291-293.

Siddique, M. A. 1998. Prospects for high quality seed potato production in Bangladesh through TPS technology. Paper presented in a seminar at ATDP/IFDC, Dhaka on 23 April, 1998.

Siddique, M. A., Rabbani, M. G. and Azad, M. I. 1987. Effect of seed size, number of eyes in a seed piece and plant spacing on the yield of potato. *Bangladesh J. Agri.,* **12** (2): 73-81.

Sikka, L. C. 1987. Review of TPS research in Bangladesh. Proc. of the workshop on true potato seed (TPS) research in Bangladesh. PRC, BARI, Joydebpur, Gazipur. pp. 8-16.

Singh, A. N. 1999. True potato seed- a low cost planting material for small farmers. *Indian Farming,* **49** (9): 43-46.

Singh, B. N. and Chhabaria, G. T. 1980. Yield dynamics of seed potato in relation of seed size and spacing. *J. Indian Potato Assoc*., **7** (1): 27-34.

Singh, J., Khurana, S. C., Malik, Y. S. and Mehla, C. P. 1999. Effect of seedling tuber size and crop duration on tuber yield of potato. In: Abstracts, Global conference on potato. New Delhi, India. 256 p.

Singh, K. 1992. Effect of seed size and seed rate on growth and yield of potato. *Indian J. Agron.,* **37** (3): 506-509.

Singh, M. V., Singh, A. P. and Verma, S. K. 1998. Effect of nitrogen and seed size on potato grown through seedling tubers. *J. Indian Potato Assoc*., **25** (1&2): 79-80.

Sonawane, P. D. and Dhoble, M. V. 2004. Effect of spacing and seedling tuber size on potato (*Solanum tuberosum*) grown through true potato seed. *Indian J. Agron*., **49** (3): 194-197.

Sultana, N. 1998. Effect of seedling tuber size and depth of planting on the growth and yield of potato. An MS thesis, Department of Horticulture, BAU, Mymensingh. 85 p.

Tabibullah, M.; Hossain, M. M. and Akanda, M. A. M. 1982. Performance of different types of cut halves seed potato compared with whole seed potato. Proc. 5th workshop of potato research workers. Potato Research Centre (PRC), BARI, Joydebpur, Gazipur. pp. 40-45.

TCRC. 2004. Annual Report of 2003-04. Tuber Crops Research Centre, Bangladesh Agricultural Research Institute, Gazipur-1701. p. 13.

Tohin, M. 2010. Effect of seed weight and plant spacing on growth and yield of seedling tuber cv. Bari TPS-1. An MS thesis, Department of Agronomy, SAU, Dhaka-1207, pp. 28-69.

UNDP. 1988. Land Resource Apprisal of Bangladesh for Agricultural Development Report 2: Agro-ecological Regions of Bangladesh, FAO, Rome, Italy. pp. 577.

Upadhya, M. D. 1979. Potential for potato production from true seed under developing country condition. In: CIP Report of the planning conference on the production of potatoes from true seed. Manila, the Philippines. pp. 12-20.

Upadhya, M. D. 1995. Current status of TPS research and adoption in South Asia. In: Proceedings of the Workshop on true potato seed (TPS) research in Bangladesh. Tuber Crops Research Center, Bangladesh Agricultural Research Institute, Gazipur, Bangladseh, pp. 1-2.

Upadhya, M. D. and Cabello, R. 2001. Influence of seed size and density on the performance of direct seedling transplants from hybrid true potato seed. Scientist and farmer: partners in research for the 21st Century Program Report-1999-2000. pp. 207-210.

Upadhya, M. D., Cabello, R., Falcon, R. and Chujoy, E. 2003. Effects of location and year of production on hybrid true potato seed quality and performance. *Acta Hort.,* **619**: 371-374.

Upadhya, M. D., Thakur, K. C. and Kadian, M. S. 1990. Standardization of TPS Agronomy. Commercial adoption of true potato seed technology- prospects and problems. (Gaur, P. C. edited). Central Potato Research Institute (CPRI), Shimla, India. pp. 36-39.

Verma, V., Varshney, S. K., Singh, B. and Kumar, A. 2007. Effect of seedling tuberlet size on seed potato yield of TPS varieties in calcareous soils of north Bihar. *Ann. Biol.*, **23** (2): pp.137-139.

Wadhwa, B. K., Pandita, M. L. and Khurana, S. C. 2002. Effect of spacing on ware crop of potato raised from seedlings. *Haryana J. Hort. Sci*., **30** (3/&4): 280-282.

Wiersema, S. G. 1982. Evaluation of technology for production of seed tubers from true potato seed. Technology evaluation series no. 1982-1. CIP, Lima, Peru. p. 14.

Wiersema, S. G. 1983. Potato seed tuber production from true seed. In: Hooker, W. J. (ed.) “Research for the Potato in the Year 2000”. International Potato Centre (CIP), Lima, Peru. pp. 186-187.

Wiersema, S. G. 1984. The production and utilization of seed tubers derived from true potato seed. A PhD thesis, University of Reading, U. K. 229 p.

Wiersema, S. G. 1986. A method of produce seed tubers derived from true potato seed. *Potato Res*., **29**: 225-237.

Wiersema, S. G. and Cabello, R. 1986. Comparative performance of different sized seed tubers derived from true potato seed. *American J. Potato Res*., **63** (5): 241-249.

Wilson, D. R. and Murphy, H. J. 1969. Seed piece type and size for Russet Burbank. *Res. Life Sci*., **17** (4): 19-22.

APPENDICES

Appendix I. Analytical data of soil sample of the experimental plot

A. Morphological Characteristics

Morphological features	characteristics
Location	Horticulture Garden, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land Type	Medium high land
Soil Series	Tejgaon
Topography	Fairly leveled
Flood Level	Above flood level
Drainage	Well drained

B. Mechanical analysis

Constituents	Percent
Sand	27
Silt	43
Clay	30

C. Chemical analysis

Soil properties	Amount
Soil pH	5.8
Organic carbon (%)	0.45
Total nitrogen (%)	0.03
Available P (ppm)	20
Exchangeable K (%)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

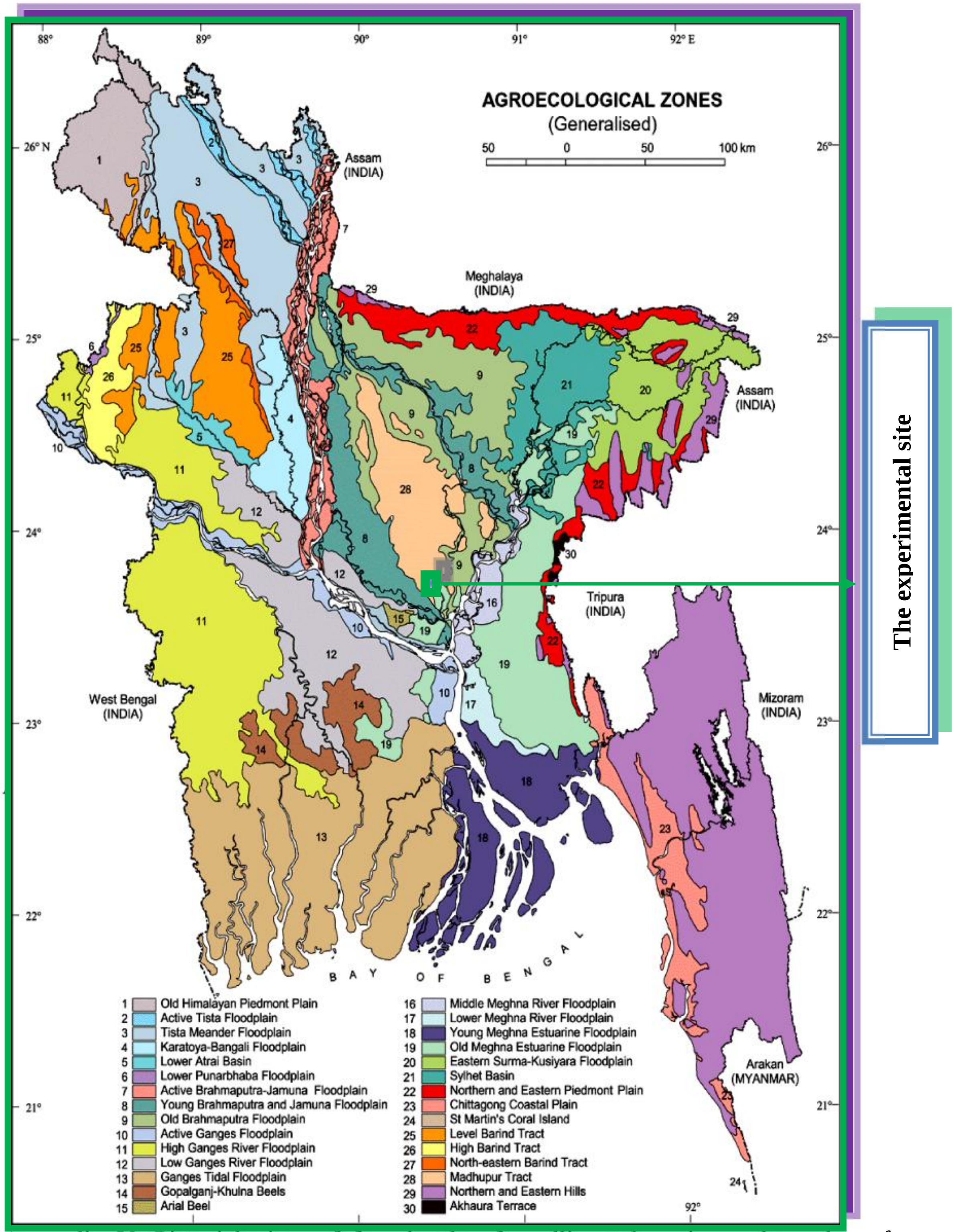
Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine during the period from November 2010 to March 2011

Year	Month	** Air temperature (^0C)			**Relative humidity (%)	*Rainfall (mm)	**Sunshine (Hours)
		Maximum	Minimum	Mean			
2010	November	28.79	18.54	23.76	82.53	83.1	235.0
	December	25.32	14.40	19.86	84.06	0.00	196.4
2011	January	21.77	10.17	15.97	83.65	Trace	165.6
	February	26.77	15.49	21.13	75.21	27.10	229.2
	March	27.95	18.11	23.03	75.39	114.00	199.3

*Monthly total, ** Monthly average

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka, Bangladesh

Appendix III. Map showing the experimental site



Appendix V. Pictorial view of four levels of seedling tuber size and number of seedling tubers per hill

Plate-1. Seedling tuber size 6-<7 g

Plate-2. Seedling tuber size 7-<8 g

Plate-3. Seedling tuber size 8-<9 g

Plate-4. Seedling tuber size 9-<10 g

Appendix VI. Analysis of variance on data with the effect of seedling tuber size and clump planting on the emergence and plant height (cm) of potato at different days after planting (DAP)

Source of variation	Degrees of freedom	Days to 1st emergence		Days to 80% emergence		Plant height (cm)							
						40 DAP		55 DAP		70 DAP		100 DAP	
		Mean square	F-value	Mean square	F-value	Mean square	F-value	Mean square	F-value	Mean square	F-value	Mean square	F-value
Replication	2	0.361	0.5200	1.361	1.6090	0.438	0.2374	0.452	0.1745	1.751	1.1868	6.513	8.1687
Factor A	3	2.546*	3.6667	4.074*	4.8159	456.118**	247.4161	549.703**	212.2551	519.694**	352.2127	442.833**	555.4443
Factor B	2	0.194	0.2800	3.528*	4.1701	25.612**	13.8931	36.209**	13.9811	43.130**	29.2306	32.896**	41.2619
AB	6	0.824	1.1867	3.046*	3.6010	4.217*	2.2877	4.187	1.6168	2.699	1.8295	3.187*	3.9978
Error	22	0.694		0.846		1.844		2.590		1.476		0.797	

Appendix VII. Analysis of variance on data with the effect of seedling tuber size and clump planting on the number of leaves per plant of potato at different days after planting (DAP)

Source of variation	Degrees of freedom	Number of leaves plant^{-1}							
		40 DAP		55 DAP		70 DAP		100 DAP	
		Mean square	F- value	Mean square	F -value	Mean square	F -value	Mean square	F -value

Replication	2	25.202	10.3538	29.461	10.0583	16.934	9.2994	18.769	12.5800
Factor A	3	588.279**	241.6857	594.565**	202.9914	576.576**	316.6328	693.655**	464.9337
Factor B	2	25.529**	10.4881	89.516**	30.5618	45.121**	24.7786	47.545**	31.8680
AB	6	8.954**	3.6787	7.327*	2.5016	14.298**	7.8522	10.453**	7.0061
Error	22	2.434		2.929		1.821		1.492	

Appendix VIII. Analysis of variance on data with the effect of seedling tuber size and clump planting on the leaf area plant^{-1} (cm^2) of potato at different days after planting (DAP)

Source of variation	Degrees of freedom	Leaf area plant^{-1} (cm^2)							
		40 DAP		55 DAP		70 DAP		100 DAP	
		Mean square	F- value	Mean square	F -value	Mean square	F -value	Mean square	F -value
Replication	2	2154.444	0.7018	42117.930	0.7027	4458.595	0.3434	6863.888	0.4775
Factor A	3	1319833.537**	429.9281	1915144.219**	31.9539	1978024.174**	152.3349	1762499.409**	122.6147
Factor B	2	121693.363**	39.6409	342256.489*	5.7105	193802.692**	14.9255	177094.005**	12.3202
AB	6	4628.822	1.5078	21682.923	0.3618	45813.327*	3.5283	40556.512*	2.8215
Error	22	3069.893		59934.659		12984.705		14374.296	

Appendix IX. Analysis of variance on data with the effect of seedling tuber size and clump planting on the leaf area index of potato at different days after planting (DAP)

Source of variation	Degrees of freedom	Leaf area index							
		40 DAP		55 DAP		70 DAP		100 DAP	
		Mean square	F- value	Mean square	F -value	Mean square	F -value	Mean square	F -value
Replication	2	0.009	0.7310	0.081	0.3062	0.017	0.3331	0.028	0.4809
Factor A	3	5.280**	430.8246	8.270**	31.2935	7.923**	152.9758	7.059**	122.3102
Factor B	2	0.485**	39.5910	1.381*	5.2248	0.777**	14.9966	0.706**	12.2352

AB	6	0.019	1.5274	0.062	0.2342	0.183*	3.5255	0.163*	2.8170
Error	22	0.012		0.264		0.052		0.058	

Appendix X. Analysis of variance on data with the effect of seedling tuber size and clump planting on the fresh mass (g) production plant^{-1} at different days after planting (DAP)

Source of variation	Degrees of freedom	Fresh mass (g) production plant^{-1}							
		40 DAP		55 DAP		70 DAP		100 DAP	
		Mean square	F- value	Mean square	F -value	Mean square	F -value	Mean square	F -value
Replication	2	6.978	0.3804	26.465	0.8926	7.041	0.2788	203.529	2.9826
Factor A	3	44160.667**	2407.4848	49715.391**	1676.8453	55659.641**	2204.1765	87291.695**	1279.2180
Factor B	2	5070.277**	276.4137	6212.347**	209.5356	6888.910**	272.8076	16702.824**	244.7719
AB	6	188.855**	10.2957	743.962**	25.0930	1292.604**	51.1884	3442.074**	50.4420
Error	22	18.343		29.648		25.252		68.238	

Appendix XI. Analysis of variance on data with the effect of seedling tuber size and clump planting on the dry mass (g) production plant^{-1} at different days after planting (DAP)

Source of variation	Degrees of freedom	Dry mass (g) production plant^{-1}							
		40 DAP		55 DAP		70 DAP		100 DAP	
		Mean square	F- value	Mean square	F -value	Mean square	F -value	Mean square	F -value
Replication	2	19.177	7.0606	29.353	8.3515	5.983	0.8393	42.901	5.1515
Factor A	3	1347.856**	496.2598	1390.076**	395.5086	1906.844**	267.4677	2897.525**	347.9320
Factor B	2	196.381**	72.3046	221.344**	62.9773	290.819**	40.7924	504.220**	60.5463
AB	6	5.996	2.2077	24.703**	7.0286	34.224**	4.8005	87.175**	10.4678
Error	22	2.716		3.515		7.129		8.328	

Appendix XII. Analysis of variance on data with the effect of seedling tuber size and clump planting on dry mass (g) production m^{-2} of potato at different days after planting (DAP)

Source of	Degrees of	Dry mass (g) production m^{-2}

variation	freedom	40 DAP		55 DAP		70 DAP		100 DAP	
		Mean square	F- value	Mean square	F -value	Mean square	F -value	Mean square	F -value
Replication	2	7670.692	7.0606	11741.085	8.3515	2393.320	0.8393	17160.313	5.1515
Factor A	3	539142.282**	496.2598	556030.586**	395.5086	762737.767**	267.4677	1159010.069**	347.9320
Factor B	2	78552.515**	72.3046	88537.432**	62.9773	116327.704**	40.7924	201688.095**	60.5463
AB	6	2398.522	2.2077	9881.305**	7.0286	13689.621**	4.8005	34869.826**	10.4678
Error	22	1086.411		1405.862		2851.700		3331.141	

Appendix XIII. Analysis of variance on data with the effect of seedling tuber size and clump planting on the growth rate (g m^{-2} day^{-1}) of plant at different days after planting (DAP)

Source of variation	Degrees of freedom	Crop growth rate (g m^{-2} day^{-1})					
		40-55 DAP		55-70DAP		70-100 DAP	
		Mean square	F- value	Mean square	F -value	Mean square	F -value
Replication	2	1.944	0.5088	43.015	2.2185	7.930	1.5378
Factor A	3	31.851**	8.3344	130.065**	6.7079	51.969*	10.0779
Factor B	2	2.625	0.6868	10.819	0.5580	13.177	2.5553
AB	6	15.334*	4.0124	8.819	0.4548	8.473	1.6430
Error	22	3.822		19.390		5.157	

Appendix XIV. Analysis of variance on data with the effect of seedling tuber size and clump planting on yield attributes and gross yield of tuber

Source of variation	Degrees of freedom	Number of tubers hill^{-1}		Tubers weight (g hill^{-1})		Gross yield of tuber (t ha^{-1})	
		Mean square	F- value	Mean square	F -value	Mean square	F -value
Replication	2	0.062	0.1071	58.333	0.1920	0.583	0.1920
Factor A	3	77.75**	134.4438	13549.074**	44.6004	135.491**	44.6004
Factor B	2	7.652**	13.2316	8652.083**	28.4807	86.521**	28.4807
AB	6	1.603*	2.7713	3128.935**	10.2997	31.289**	10.2997

Error	22	0.578		303.788		3.038	

Appendix XV. Analysis of variance on data with the effect of seedling tuber size and clump planting on marketable and non-marketable yield of tubers

Source of variation	Degrees of freedom	Marketable yield of tubers (t ha^{-1})		Marketable tubers (%) by number		Non-marketable yield of tubers (t ha^{-1})		Non- marketable tubers (%) by number	
		Mean square	F -value	Mean square	F- value	Mean square	F -value	Mean square	F -value
Replication	2	0.416	0.1406	1.174	0.2605	0.819	0.7388	1.174	0.2605
Factor A	3	50.625**	17.1218	75.181**	16.6894	21.288**	19.2126	75.181**	16.6894
Factor B	2	76.253**	25.7896	18.693*	4.1497	5.452**	4.9205	18.693*	4.1497
AB	6	29.714**	10.0497	113.449**	25.1846	1.604	1.4475	113.449**	25.1846
Error	22	2.957		4.505		1.108		4.505	

Appendix XVI. Analysis of variance on data with the effect of seedling tuber size and clump planting on the grade of tubers

Source of variation	Degrees of freedom	Grade of tubers (%) by number							
		< 28 mm (Grade D)		28-45 mm (Grade C)		45-55 mm (Grade B)		> 55 mm (Grade A)	
		Mean square	**F- value**	**Mean square**	**F -value**	**Mean square**	**F -value**	**Mean square**	**F -value**
Replication	2	0.913	0.0956	1.382	0.1235	1.532	0.8505	0.620	1.2575
Factor A	3	81.389**	8.5249	48.253**	4.3110	7.369*	4.0924	0.132	0.2682
Factor B	2	10.389	1.0882	3.742	0.3343	6.360*	3.5318	0.002	0.0037
AB	6	100.084**	10.4831	82.802**	7.3977	4.156	2.3080	0.551	1.1168
Error	22	9.547		11.193		1.801		0.493	

Appendix XVII. Analysis of variance on data with the effect of seedling tuber size and clump planting on the yield of seed and non-seed tubers of potato

Source of variation	Degrees of freedom	Seed tubers ($t\ ha^{-1}$)		Non-seed tubers ($t\ ha^{-1}$)	
		Mean square	F -value	Mean square	F -value
Replication	2	0.776	0.1511	0.601	0.2588
Factor A	3	70.111**	13.6553	12.220**	5.2640
Factor B	2	68.328**	13.3080	1.773	0.7639
AB	6	13.159*	2.5630	5.553	2.3922
Error	22	5.134		2.321	

Appendix XVIII. Production cost of potato per hectare (Tk)

Input cost

1.	Labour	300 labours × 150	45000
2.	Land preparation		4000
3.	Fertilizer		
	Cowdung 10 t ha^{-1} @ 600/- per ton		6000
	Urea 300 kg ha^{-1} @ 20.00/- per kg		6000
	TSP 220 kg ha^{-1} @ 25.0/- per kg		5500
	MP 250 kg ha^{-1} @ 30.0/- per kg		7500
	Gypsum 100 kg ha^{-1} @ 10.0/- per kg		1000
	Zinc sulphate 25 kg ha^{-1} @ 80.0/- per kg		2000
	Boric acid 15 kg ha^{-1} @ 100.0/- per kg		1500
4.	Irrigation three times @ 1500/- per times		4500
5.	Pesticides		5400
6.	Seed cost (Seed rate 40.0/- per kg)		Variable
7.	Land leez		40000
8.	**Total**		**124400**

Appendix XIX. Gross return of potato per hectare

Treatments	Seed cost (Tk)	Marketable yield of tubers (kg ha^{-1}) > 20 g	Return (Tk)	Non-marketable yield of tubers (kg ha^{-1}) <20 g	Return (Tk)
$S_1 N_1$	44000	9170	183400	3660	18300
$S_1 N_2$	88000	11830	236600	2500	12500
$S_1 N_3$	132000	19670	393400	4660	23300
$S_2 N_1$	52000	15500	310000	5170	25850
$S_2 N_2$	104000	13670	273400	4330	21650
$S_2 N_3$	156000	16900	338000	4600	23000
$S_3 N_1$	64000	13500	270000	6170	30850
$S_3 N_2$	128000	22070	441400	4600	23000
$S_3 N_3$	192000	18330	366600	7340	36700
$S_4 N_1$	76000	17670	353400	8000	40000
$S_4 N_2$	152000	17330	346600	6670	33350
$S_4 N_3$	228000	21070	421400	6600	33000