EFFECT OF TUBER SIZE AND PLANT SPACING ON GROWTH AND YIELD OF SEEDLING TUBER DERIVED FROM TRUE POTATO SEED

A Thesis

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CERTIFICATE

This is to certify that the thesis entitled **" EFFECT OF TUBER SIZE AND PLANT SPACING ON GROWTH AND YIELD OF SEEDLING TUBER DERIVED FROM TRUE POTATO SEED"** submitted to the **DEPARTMENT OF AGRONOMY,** Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in AGRONOMY,** embodies the results of a piece of bonafide research work carried out by **MOHSIN TOHIN,** Registration No. **08-03252**, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

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

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ABSTRACT

A field experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka, 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. The experiment was laid out in randomized complete block design factorial with three replications. The growth parameters such as plant height, stems hill^{-1}, leaves hill^{-1}, leaf length and breadth, leaf area (LA) plant^{-1} and leaf area index (LAI), total dry mass (TDM) plant^{-1} and TDM m^{-2}, crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR), yield attributes such as tubers hill^{-1} and tuber weight and tuber yield of gross, marketable and non-marketable were significantly influenced by seed tuber weight and plant spacing. Results revealed that in general, 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 ha^{-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}. In contrast, the lowest tuber yield ha^{-1} both gross and marketable was recorded in the smaller seed tuber of 10 ± 2 g. Results showed that stems and leaves hill^{-1}, leaf length and breadth, LA, TDM plant^{-1}, tubers hill^{-1}, single tuber weight and tuber weight hill^{-1} increased with increasing plant spacing while reverse trend was observed in plant height, LAI, TDM m^{-2} and CGR. The highest number of stems and leaves hill^{-1}, LA, TDM plant^{-1}, tubers hill^{-1}, single tuber weight and tuber weight hill^{-1} were observed in the wider spacing of 60 cm × 25 cm and the lowest of the above parameters was observed in the closer spacing of 60 cm × 15 cm. However, the highest gross and marketable tuber yield ha^{-1} was observed in the plant spacing of 60 cm × 20 cm and the lowest was recorded in the closer spacing of 60 cm × 15 cm. For combined effect of seed tuber weight and plant spacing, the highest gross and marketable tuber yield was observed in the treatment combination of 40 ± 2 g seed tuber with the plant spacing of 60 cm × 25 cm. But economic point of view with high yield performance, the seed tuber size of 30 ± 2 g with plant spacing of 60 cm × 20 cm was more profitable than those of other treatment combinations.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER I
INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important food crops of the world and holds the fourth position in production next to wheat, rice and maize (FAO, 2007). It is grown almost all countries of the world. 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). It is considered as a vegetable crop and contributes as much 55 % of the total vegetable production in Bangladesh (BBS, 2009).

Potato has acquired great importance in rural economy in Bangladesh. It is not only a cash crop but also a alternative of food crop against rice and wheat. Bangladesh has a great agro-ecological potential of growing potato. The area and production of potato in Bangladesh has been increasing during the last decades but the yield per unit area remains more or less static. The yield is very low in comparison to that of the other leading potato growing countries of the world, 40.16 tha^{-1} in USA, 42.1 tha^{-1} in Denmark and 40.0 tha^{-1} in UK (FAO, 2007). The reasons responsible for such a low yield of potato in Bangladesh are use of low quality seed and use of sub-optimal production practices. Available reports indicated that potato production in Bangladesh can be increased by improving cultural practices among which optimization of manure and fertilizer, planting time, spacing and use of optimal sized seed are important 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. Studies conducted at Tuber Crop Research Centre BARI showed that a good TPS progeny can produce 500 to 800 small tubers (called seedling tuber) 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). The weight of the seedling tubers varies from 1 g to 50 g, the majority being less than 20 ± 2 g. 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 an optimum plant spacing is used.

Seedling tuber weight and plant spacing are considered 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 seed size, higher the profit in potato cultivation. However, plant spacing has a direct influence on seed rate and ultimately on cost of production. In traditional method of potato production, seed tuber weight and plant spacing have been found to influence the yield and economic return (BongKyoon *et al.*, 2001; Conley *et al*., 2001; Upadhya and Cabello, 2001; Malik *et al.,* 2002; Patel *et al*., 2002; Shingrup *et al*., 2003; Bayorbor and Gumah, 2007). But only a few studies have been done considering size of seedling tubers and plant spacing on the growth and yield of potato in bangladesh. Therefore the present experiment was undertaken with the following objectives:

i) to find out the effect of tuber weight on growth, yield and economic return of potato;
ii) to assess a suitable plant spacing for getting higher yield of potato; and
iii) to study the combined effect of tuber weight and plant spacing on growth and yield of potato.

CHAPTER II

REVIW OF LITERATURE

In this chapter, research works have been reviewed in this chapter relating to the present study under the following heading.

2.1 Effect of tuber weight on growth and yield of potato

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. However, the net yield is generally higher with seed of medium size (Bayorbor and Gumah, 2007).

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 per plant^{-1}. Similar result was also reported by (Escribeno, 1992).

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 (60x10cm and 60x15 cm) and dehaulming of potatoes (cv. Kufri Jyoti) on number and yield of seed- size tubers. They reported that 40-50 g seed tubers planted at 60x10 cm showed the highest seed yield. The higher economic yield of seed-sized tubers could be achieved from 15-20 g of seeds at 60x10 cm spacing.

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

Three experiments were conduced 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 per plant, marketable tuber weight, and stems plant^{-1}.

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.

BongKyoon *et al*. (2001) conducted an experiment with tubers of potato (*Solanum tuberosum*) cv. Dejima weighing 10, 20, 30, 40, and 50 g were planted in plug trays with vermiculite-based root medium to determine the effects of mini-tuber size on plug seedling growth and field performance of plug seedlings.

For a control, common potato tubers weighing 50 g were also planted. The authors reported that as size of seed tubers planted increased from 10 to 50 g, seedling height decreased from 24.6 to 20.0 cm while shoot number per seedling increased from 2.0 to 3.5, main stem diameter from 4.3 to 6.1 mm, and fresh weight of root + top from 9.3 to 19.4 g/seedling. At 90 days after transplanting, the total tubers plant^{-1} was increased from 3.62 to 4.72, average tuber weight from 62.9 to 72.8 g, and total tuber yield 20.5 to 23.6 t/ha with increase in seed tuber size. Plug seedlings raised from 50 g tubers was produced 22% more tubers per plant and had 21% higher >80 g tuber yield than the directly planted potatoes.

The effect of tuber size (25-30, 30-55, 55-75 and 75-85 mm) on potato growth and yield was 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 as compared to small tubers which resulted in higher yield compared to small ones.

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 opined that by using small graded seed, farmers might significantly reduce production costs.

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

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

Trials were conducted in 2000, 2001 and 2002 in Tamil Nadu, India by BongKyoon *et al.* (2001) to investigate suitable agro-techniques for obtaining the maximum number of seed size tubers from potato cultivars Kufri Swarna and Kufri Jyoti. Treatments included: tuber weights of 10-20, 20-30, 30-40 and 40-50 g; intra-row spacings of 10, 15 and 20 cm; and 2 dates of haulm killing (75 and 90 days after planting). The authors reported that in both cultivars, 30-50 and 20-50 g tubers, might be used at an intra-row spacing of 10 cm, and with haulm killing at 90 days after planting to obtain the maximum number of seed size tubers.

A field experiment was 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 intrarow 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 per tuber were greatly affected by seed size and spacing. Tuber yield (305.24 q/ha) and the number of tuber plant (10.40) were significantly highest with big seed size and 25 cm intrarow spacing, while average weight per tuber (53.93 g) was highest with large seed size and 30 cm intrarow spacing.

An experiment was conducted by Sonawane and Dhoble (2004) during the winter (rabi) 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.

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

A study was 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: A (≥ 10. 0 g), size B (7.0-9.9 g), size C (3.0-6.9 g) and size D (<3.0 g); three intra-row spacings of 20 cm, 30 cm and 40 cm were also used. The authors reported that leaf area index (LAI) and crop growth rate (CGR) were greater in larger seeds than smaller ones. The authors further reported that yield increased with the use of heavier 'seed' tubers. On the average, yield of plants of category B 'seed' tubers was 52% higher than those obtained from 'seed' tubers of category A and 58% and 59% higher than those of categories C and D, respectively.

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. 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 per hill) 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.

The effects of different in-row spacing (20, 25, 30 and 35 cm) and seed size (small, medium and large) treatments on yield components and tuber yield of early potato were studied by Gulluoglu and Aroglu (2009) in Adana, Turkey and reported that planting larger seeds positively affected all growth and yield components. Tuber yield per hectare was increased up to certain stem density and then was started to decline at all seed sizes. However, the optimum stem density for the maximum tuber yield per hectare markedly differed depending on size of seed tubers. The optimum stem density increased with increasing seed size .The authors indicated that size of seed tuber has further importance for growth of potato plant as well as competition aspect in early potato production in the mediterranean-type environments. The author concluded that using larger tubers had an advantage for vigorous early growth and for obtain high tuber yield in early potato production in the mediterranean-type environments. Seed size should be considered during recommendation for planting density in potato production.

2.2 Effect of plant spacing on growth and yield of potato

In a field trial Gregoriou (2000) planted seed tubers within-row spacings of 10, 20, 30 or 40 cm and reported that seedling emergence was reduced at 10 cm spacing. The author further reported that tuber yield decreased with increasing spacing. The best combination of total potato yield was estimated to be with a 30 cm planting distance.

An experiment was conducted by Yenagi. *et al* (2004) in 1995 and 1996 to determine optimum spacing for the potato cultivars, Awash, Menagesha and Tolcha and reported that there were significant varietal and spacing effects on seed tuber size, average tuber weight and number per square metre. The highest yields of 38.5, 62.6 and 46.5 t ha^{-1} were obtained for Awash, Menagesha and Tolcha, respectively, from a 45 cm between-row spacing with either 25 or 30 cm in-row spacing. However, in Menagesha tuber weight exceeding 40 mm constituted >80% of the total yield thus showing the need for a narrower in-row distance for seed size tuber production. In-row spacing regulated tuber weight more than yield. The cultivars showed different requirements for spacing for the development of optimum leaf area and maximum tuber number and yield.

An experiment was conducted by Ahire *et al.* (2000) at Rahuri, Maharashtra, India, during the rabi season of 1996-97. Treatments consisted of 2 row spacings (60 and 45 cm), 2 planting systems (normal and paired row) and 2 irrigation methods (trickle and surface). The authors reported that the wider spacing of 60 cm increased plant growth and tuber yield (20.29 t/ha) compared with the narrow spacing of 45 cm (17.86 t/ha). Normal planting resulted in higher growth and yield components compared to paired row planting.

Wadhwa *et al*. (2000) were transplanted fifty-day-old potato seedlings at 3 inter-row (40, 50 and 55 cm) and intra-row (5, 10 and 15 cm) plot spacings on one side of the furrow ridge during 14 and 15 December 1991 and 1992, respectively, in Hisar, Haryana, India and reported that plant height and growth was not influenced by spacing. Increases in plant to plant spacings from 5-10 and 10-15 cm decreased seedling mortality. The number of leaves, branches and tubers per plant increased, while yield and leaf dry weight decreased with an increase in row and plant spacing.

Conley *et al.* (2001) studied the effect of interrow (76 and 91 cm) and intrarow (30 cm) spacings of potato cultivars (Russet Burbank, Russet Norkotah, Goldrush, Dark Red Norland, Snowden and Atlantic) and reported that the total marketable yield (TMY) and the net crop value (NCV) of the cultivars were higher in the 91 cm than in the 76 cm row spacing. Reduced weed biomass coupled with a high TMY and NCV indicated that the 91 cm row spacing was optimal for all cultivars.

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 were investigated by Khalafalla (2001) during winter of 1991, 1992 and 1993 at Shambat and Shehainab in Sudan. The author observed that yield decreased with decrease in seed size and increase in spacing at both locations. Seed size had significant effect on marketable tubers per plant, marketable tuber weight, and number of stems per plant. Plant spacing had significant effect on these parameters, except for number of stems per plant.

The effects of shade, unshaded control (C), 48% shading and 76% shading at different growth stages, vegetative to beginning of tuber initiation (stage I), tuber initiation to initial tuber bulking (stage II) and tuber bulking to maturity (stage III) on nitrate reductase (NR) activity, plant growth and yield of field grown potatoes (*Solanum tuberosum* cultivars May Queen and Dejima) under two levels of spacing, (66 cm × 30 cm and 66 cm × 15 cm) were studied by Ghosh *et al*. (2002). The authors observed that main stem length was increased by denser plant spacing but decreased stem and leaf number plant^{-1}. Denser plant spacing also increased the leaf area index (LAI).

An experiment was conducted by Yenagi *et al.* (2002) during the Kharif season of 1999 in Dharwad, Karnataka, India to determine the optimum row spacing (45 and 60 cm), planting date (18 and 25 June and 10 July) and N level (0, 50, 100, and 150 kg/ha) requirements of potato (cv. Kufri Chandramukhi) and reported that high tuber yield was obtained with 45 cm spacing (12.21 tha^{-1}) than 60 cm spacing, 18 June planting (12.76 tha^{-1}), and application of 150kg Nha^{-1}(15.68 tha^{-1}).

Fifty-day-old potato cv. HPS-1/13 seedlings were planted at 45, 50 and 55 cm row spacing and 5, 10 and 15 cm plant spacing in a field experiment conducted in Haryana, India during 1991-92 by Wadhwa *et al*. (2002) to determine the optimum spacing for transplanting potato seedlings. The authors reported that plant and row spacing did not influence plant height. The number of branches per plant was not influenced by row spacing but increased with increasing plant spacing. Crop yield and dry weight of foliage were highest at 45 cm row and 5 cm plant spacing while the number of tuber plant was highest with 55 cm row spacing and 15 cm plant spacing.

Khurana and Bhutani (2003) studied the effect of spacing (60 ×15 and 60 × 10 cm), fertilizer rate and crop duration on the production of seed number of stems per plant tubers of potato and reported that the number and yield of small (<10 g) and medium-sized tubers increased with decrease in spacing from 15 to 10 cm.

Trials were conducted in 2000, 2001 and 2002 in Tamil Nadu, India by Ravichandran and Singh (2003) to investigate suitable agro-techniques for obtaining the maximum number of seed size tubers from potato cultivars Kufri Swarna and Kufri Jyoti. Treatments included: tuber weights of 10-20, 20-30, 30-40 and 40-50 g; intra-row spacings of 10, 15 and 20 cm; and 2 dates of haulm killing (75 and 90 days after planting). The authors observed that in both cultivars, 30-50 and 20-50 g tubers, may be used at an intra-row spacing of 10 cm, and with haulm killing at 90 days after planting to obtain the maximum number of seed size tubers.

An experiment was conducted by Suman *et al.* (2003) with potato cv. Kufri Sutlej in Hisar, Haryana, India, in 2001, involving 3 plant spacings (10, 15 and 20 cm) and 2 crop durations (75 and 85 days) and reported that decrease in plant spacing increased stems per unit area, plant height, haulm weight, total as well as number of different size tubers per unit area, and yield of total as well as of >25-50, >50-75 and >75 g size tubers.

A field experiment was conducted by Shingrup *et al*. (2003) on clayey soil during the rabi season of 1999-2000 at the farm of the Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India, to study the effect of row spacing, seed tuber size and fertility level on the economics of potato cultivation. The authors reported that that cost of cultivation and gross monetary returns were significantly greater under 45 cm row spacing, as compared to 60 cm row spacing. Yadav *et al.* (2003) studied the effects of irrigation level and spacing (15, 20 or 25 cm) on the performance of potato cv. Kufri Sutlej were studied in Hisar, Haryana, India and reported that yield (153.32 and 104.94 quintal/ha) and number (101.46 and 84.32 per plot) of large tubers were highest with a spacing of 20 cm.

An experiment was conducted by Sonawane and Dhoble (2004) during the winter (rabi) 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*). The authors observed that significant increase in the tuber yields was recorded due to spacing of 45 cm. The intra-row spacing of 10 cm was at par with 15 cm, but was significantly superior to 20 cm plant spacing. The net returns and benefit:cost ratio, plant spacing of 15 cm was found advantageous over 10 and 20 cm, whereas row spacing was equally effective.

Yenagi *et al.* (2004) conducted an experiment during kharif 1999 at the Main Agricultural Research Station of the University of Agricultural Sciences in Dharwad, Karnataka, India, to determine the effect of row spacing (60 and 45cm), planting date (18 June, 25 June and 10 July) and nitrogen rate (0, 50, 100 and 150 kg N/ha) on the tuber grade, yield and economics of potato (cv. Kufri Chandramukhi) and reported that higher tuber yield (12.21 t ha^{-1}) was recorded with narrow row spacing (45 cm), although more A-grade tubers were recorded with the wider row spacing. However, the net income (Rs. 41 906 ha^{-1}) and B:C ratio of 2.84 were higher with treatment combination of June 3rd week planting with 45-cm row spacing supplied with 150 kg N ha^{-1}.

A field experiment was conducted by Yenagi *et al.* (2005) during the kharif season in Dharwad, Karnataka, India, on potato to determine the effect of row spacing (45 and 60 cm), planting date (18 and 25 June, and 10 July) and N fertilizer rates (0, 50, 100 and 150 kg/ha) and reported that plant height, leaf area index, total dry matter production, crop growth rate, tubers per plant and tuber yield was highest with 45 cm row spacing, 18 June planting and 150 kg N/ha supplementation. Tuber weight was highest with 60 cm row spacing, 18 June planting and 150 kg N/ha supplementation.

Kushwah and Singh (2008) conducted an experiment during 2004-05, in Madhya Pradesh, India, to evaluate the effects of intra-row spacing (10.0, 12.5, 15.0, 17.5, 20, 22.5 and 25.0 cm) and haulm cutting date (60, 65, 70, 75 and 80 days after planting (DAP)) on the production of small-sized tubers of potato. Data were recorded for plant height, stems plant^{-1}, fresh haulm weight, tuber yield per hectare and NPK content of soil after potato harvest. Intra-row spacing of 25 cm and haulm cutting at 80 DAP recorded the highest values for plant height, stems per plant, fresh haulm weight, tuber yield per hectare and NPK content of soil as well as the highest net returns and benefit:cost ratio.

Bayorbor and Gumah (2007) studied the effects of four different 'seed' tuber weights and three intra-row spacing on the yield and yield components of 'Frafra' potato. The 'seed' tubers were categorized according to weight: A (10. 0 g), size B (7.0-9.9 g), size C (3.0-6.9 g) and size D (<3.0 g); three intra-row spacings of 20 cm, 30 cm and 40 cm were also used. Neither 'seed' tuber nor spacing had significant effect on percentage survival at three (3) weeks after planting (WAP), number of branches at 3WAP and 6WAP, number of tubers and tuber weight. However, percentage survival at 6WAP reflected the importance of relatively large 'seed' tubers and wide plant spacing. The response of the leaf area index (LAI) to intra-row spacing was also significant with plants closely spaced exhibiting the highest LAI. Yield increased with decreasing intra-row spacing: 20 cm > 30 cm > 40 cm. The plants produced by category B 'seed' tubers and 20 cm intra-row spacing were the most promising in terms of yield, they reported.

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

The growth (plant height, number of stem per hill, leaf area and total dry matter production (leaves, stems and tubers plant^{-1}), yield and quality (reducing sugar content) of potato cv. 'Kufri Pukraj' were evaluated at different intra-row spacings (60x15, 60x20 and 60x25 cm) and fertilizer levels by Kumar *et al.* (2009). The author reported that potato seed crop grown by seed tuber at a spacing of 60 × 15 cm with application of 125% of the RDF (recommended dose of fertilizer), followed by 60 × 20 cm with application of 100% of the RDF, was proved advantageous to obtain higher yield of seed-size tuber as well as total tuber yield/ha during the rainy season.

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 per hill and percentages of large and medium weight tubers. Total yields increased as increasing planting density up to 20 cm spacing. The authors opined that seed size should be considered during recommendation for planting density in potato production.

From the above review it is regarded that potato yield can be optimized with the use of ideal seed weight under optimum plant spacing during potato cultivation.

CHAPTER III

MATERIALS AND METHODS

In this chapter the details of different materials used and methodologies followed during the experimental period are presented under the following heads:

3.1 Experimental site

The experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka, during the period from 10 November 2009 to 10 March 2010. 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 experimental field was medium high land belonging to the Madhupur Tract. The soil was silty loam. Fertility status has been in the Appendix I.

3.2 Climate and weather

The experimental field was under subtropical climates characterized by heavy rainfall during the month of April to September and scanty rainfall during October to March. The monthly means of daily maximum, minimum and average temperature, relative humidity, total rainfall and sunshine hours received at the experimental site during the period between November 2009 to March 2010 have been presented in Appendix II.

3.3 Treatments

The experiment comprised of two factors:

Factor A: Seedling tuber size -4

T_1= 40 ± 2 g

T_2= 30 ± 2 g

T_3= 20 ± 2 g

T_4= 10 ± 2 g

Factor B: Spacing-3

S_1 = 60cm×25cm

S_1 = 60cm×20cm

S_1 = 60cm×15cm

Twelve treatment combinations were as follows:

$T_1 \times S_1$ = 40 ± 2 g seedling tuber planted at 60 cm × 25 cm

$T_1 \times S_2$ = 40 ± 2 g seedling tuber planted at 60 cm × 20 cm

$T_1 \times S_3$ = 40 ± 2 g seedling tuber planted at 60 cm × 15 cm

$T_2 \times S_1$ = 30 ± 2 g seedling tuber planted at 60 cm × 25 cm

$T_2 \times S_2$ = 30 ± 2 g seedling tuber planted at 60 cm × 20 cm

$T_2 \times S_3$ = 30 ± 2 g seedling tuber planted at 60 cm × 15 cm

$T_3 \times S_1$ = 20 ± 2 g seedling tuber planted at 60 cm × 25 cm

$T_3 \times S_2$ = 20 ± 2 g seedling tuber planted at 60 cm × 20 cm

$T_3 \times S_3$ = 20 ± 2 g seedling tuber planted at 60 cm × 15 cm

$T_4 \times S_1$ =10 ± 2 g seedling tuber planted at 60 cm × 25 cm

$T_4 \times S_2$ =10 ± 2 g seedling tuber planted at 60 cm × 20 cm

$T_4 \times S_3$ =10 ± 2 g seedling tuber planted at 60 cm × 15 cm

3.4 Plating material

The first generation TPS seedling tubers of BARI TPS-1 were collected from the Tuber Research Centre, Bangladesh Agricultural Research Institute, Gazipur.

3.5 Land preparation

The land of the experimental site was first opened in the last week of October with power tiller. Later on, the land was ploughed and cross-ploughed four times followed by laddering to obtain the desirable tilth. The corners of the land were spaded and weeds and stubbles were removed from the field. The land was finally prepared on 05 November 2009 three days before planting the seed. 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.

3.6 Experimental design and lay out

The two-factor experiment was laid out in a randomized complete block design with three replications. The size of the unit plot was 2.5 m $\times$ 2.0 m. Distances between block to block and plot to plot were 1.0 m and 0.50 m, respectively. Treatments were randomly distributed within the blocks. The plots were raised up to 10 cm.

3.7 Manure and fertilizer application

The crop was fertilized as per recommendation of TCRC (2009). Urea, triple superphosphate (TSP), muriate of potash (MOP), zypsum, zinc oxide and boric acid were used as sources of nitrogen, phosphorus, potassium, sulphur, zinc and boron, respectively. The doses of fertilizers were 320, 232, 285, 120, 10, 10 and 10000 kg ha^{-1} for urea , TSP, MOP, gypsum, ZnO, 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.

3.8 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 of 40 ± 2, 30 ± 2, 20 ± 2 and 10 ± 2 g and kept under diffuse light conditions to have healthy and good sprouts. Planting was done on November 10, 2009. The well sprouted seed tubers were planted at a depth of 5-7 cm in furrow made 60 cm apart. Hill to hill distance was maintained as per treatments of the experiment. After planting, the seed tubers were covered with soil.

3.9 Intercultural operations

3.9.1 Weeding

First weeding was done two weeks after emergence. Another weeding was done before 2nd top dressing of urea.

3.9.2 Earthing up

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

3.9.3 Irrigation

Three irrigations were provided through out 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.

3.9.4 Plant protection

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

3.10 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.

3.11 Harvesting

The crops were harvested to study growth and development rate from 60 DAP to 90 DAP at 15 days interval and the final harvest was taken at 90 DAP. The harvested plants were tagged separately plot wise. Ten sample plants were randomly selected from each plot and tagged for recording necessary data and then the whole plot was harvested with the help of spade. 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 plotwise and converted into tons hectare^{-1}. Care was taken to avoid injury in potatoes during harvesting.

3.12 Data collection

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

i) Plant height: Plant height was taken to be the length between the base of the plant to the tip at 60, 75 and 90 DAP.

ii) Stems hill^{-1}: The number of stems hill^{-1} was calculated from the average of 5 plants selected randomly from each unit plot at 60, 75 and 90 DAP.

iii) Leaves plant^{-1}: The number of leaves was counted from five plants of each plot periodically after every 15 days starting from 60 DAP to 90 DAP and mean value was calculated.

iv) Leaf length: Length of ten randomly selected leaves from each were measured and then divided by ten to get single leaf length in centimeter.

v) Leaf breadth: Breadth of ten randomly selected leaves from each plot were measured and then divided by ten to get single leaf length in centimeter.

vi) Leaf area plant^{-1}: Leaf area per plant was measured by an automatic leaf area meter (Model: LICOR 2000).

vii) Leaf area index: It is the ratio of leaf area to land area.

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

viii) Total dry matter: The total dry matter was recorded by drying parts (80 ^{0}C ± 2) for 72 hours and calculated from summation of leaves, stem, tuber and roots weights was taken in an electronic balance.

ix) Crop growth rate (CGR) : Rate of dry matter production per unit of time per area.

$$\text{i.e. } CGR = \frac{1}{A} \times \frac{W_2 - W_1}{(T_2 - T_1)} \quad \text{g m}^{-2} \text{ day}^{-1}$$

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

A= Unit area (m^2)

x) Relative growth rate (RGR): Rate of dry matter production per unit of dry matter per unit of time.

$$\text{i.e. } RGR = \frac{\ln W_2 - \ln W_1}{T_2 - T_1} \quad \text{g g}^{-1} \text{ day}^{-1}$$

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

xi) Net assimilation rate (NAR) : Rate of DM production per unit of leaf area per unit of time.

$$\text{i.e. NAR} = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{\ln LA_2 - \ln LA_1}{LA_2 - LA_1} \quad \text{g cm}^{-2}\ \text{day}^{-1}$$

where LA_2 and LA_1 are the leaf area at time T_2 and T_1, respectively

xii) Tubers hill^{-1}: The number of tubers hill^{-1}was determined from the average of 10 plants selected from each unit plot.

xiii) Single tuber weight: Twenty randomly tubers from each of the plot were weighed and then divided by twenty to get single tuber weight.

xiv) Tuber yield: The weight of tuber per hill was calculated from 10 plants from each unit plot at harvest. All the tubers weight per plot was recorded and the tuber weight was finally converted into tons hectare^{-1}.

xv) Grade of tubers: The grading of tubers was done in the following manner:

Grade A = $>$ 55 mm in diameter

Grade B = $>$ 35 - $<$ 55 mm in diameter

Grade C = $>$ 20 - $<$ 35 mm in diameter

Grade D = $<$ 20 mm in diameter

3.13 Benefit-cost 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. The details economic analysis have been presented in Appendix-XIII.

The benefit cost ratio was calculated by the following formula:

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

3.14 Statistical analysis

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT) using the statistical computer package program, MSTAT-C (Russell, 1986).

CHAPTER IV

RESULTS AND DISCUSSION

The results of the study regarding the effect of seed tuber weight and plant spacing on growth characters, yield and yield related traits of potato have been presented and possible interpretations have been made in this chapter.

4.1 Effect of seed tuber weight, spacing and their interaction on morpho-physiological characters of potato

4.1.1 Plant height

Plant height was significantly influenced by seed tuber weight at 3 growth stages (60 ,75 and 90 DAP) of potato (Table 1) and (Appendix III). Result showed that plant height increased with increasing tuber weight. The significantly tallest plant was recorded in tuber weight of 40 ± 2 g (38.8, 47.8 and 54.7 cm at 60, 75 and 90 DAP, respectively) followed by tuber weight of 30 ± 2 g (38.4, 48.1 and 53.7 cm at 60, 75 and 90 DAP, respectively) at all growth stages. In contrast, the tuber size of 10 ± 2 g had the shortest plant height at all growth stages (27.6, 35.1 and 38.5 cm at 60, 75 and 90 DAP, respectively). The plant height was higher in larger 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; Cornwall, 2004; Yenagi *et al.,* 2005; Kumar *et al.,* 2009) in potato who reported that plant height of potato increased with increasing seed tuber size.

Result showed that plant height increased with decreasing plant spacing at all growth stages (Table 1). The tallest plant was recorded at 60 cm ×15 cm plant spacing (35.8, 45.3 and 50.9 cm at 60, 75 and 90 DAP, respectively) followed by

60 cm ×20 cm plant spacing (34.5, 43.0 and 48.4 cm at 60, 75 and 90 DAP, respectively). In contrast, the plant spacing of 60 cm ×25 cm had the shortest plant height (33.4, 42.2 and 46.7 cm at 60, 75 and 90 DAP, respectively). The taller plant in closer spacing might have resulted due to competition between plants for sunlight. These results are in agreement with that of Bayorbor and Gumah (2007) who reported that plant spacing had significant effect on plant height of potato. Similar result was also reported by Kushwah and Singh (2008) in potato that plant height increased with decreasing plant spacing.

Table 1. Effect of tuber weight and spacing on plant height and stem number hill^{-1} of potato at different days after planting

Treatments	**Plant height (cm)**			**Stems hill^{-1}**
Tuber weight (g)	**60 DAP**	**75 DAP**	**90 DAP**	**90 DAP**
40 ± 2	38.8 a	47.8 a	54.7 a	5.05 a
30 ± 2	38.4 a	48.1 a	53.7 a	4.87 a
20 ± 2	33.4 b	42.9 b	47.8 b	3.05 b
10 ± 2	27.6 c	35.1 c	38.5 c	1.82 c
F-test	**	**	**	**
SE	.726	.822	.884	.058
Spacing				
60 cm × 25 cm	33.4 b	42.2 b	46.7 b	3.84 a
60 cm × 20 cm	34.5 ab	43.0 b	48.4 b	3.17 c
60 cm × 15 cm	35.8 a	45.3 a	50.9 a	3.30 ab
F-test	*	*	**	**
SE	0.628	0.712	0.765	0.050
CV (%)	6.31	5.67	5.45	4.91

In a column, means followed by same letter (s) do not differ significantly at 5% or 1% level of significant by DMRT; *, ** indicate significant at 5% and 1% levels of probability, respectively.

The interaction between seed tuber size and plant spacing had significant effect on plant height at three growth stages of 60, 75 and 90 DAP in potato (Table 2). The highest plant height was recorded in the treatment combination of 40 ± 2 g tuber size with 60 cm × 15 cm plant spacing (40.1, 50.3 and 57.8 cm at 60, 75 and 90 DAP, respectively) and the lowest was recorded in the treatment combination of 10 ± 2 g tuber with 60 cm × 25 cm spacing (27.4, 34.7 and 37.2 cm at 60, 75 and 90 DAP, respectively).

4.1.2 Stems hill^{-1}

Seed tuber weight had significant influence on stem production hill^{-1} in potato at 90 DAP (Table 1). Result revealed that stems hill^{-1} decreased with decreasing seed tuber weight. The highest stems hill^{-1} was observed in the tuber weight of 40 ± 2 g (5.05) followed by tuber weight of 30 ± 2 g (4.87) with same statistical rank. In contrast, the lowest stems hill^{-1} was recorded in the tuber weight of 10 ± 2 g (1.82). The increased of stems hill^{-1} obtained from the large seed tuber might be due to the higher number of potential eyes present per tuber which led to production of higher stems hill^{-1}. The findings of the present study also supported by Gulluoglu and Aroglu (2009) who reported that stems hill^{-1} of potato increased with increasing seed tuber weight.

In spacing, stems hill^{-1} varied significantly (Table 1). Result showed that stems hill^{-1} increased with increasing plant spacing. The highest stems hill^{-1} (3.84) was recorded in 60 cm × 25 cm spacing which was statistically similar to 60 cm × 20 cm spacing (3.69). The lowest stems hill^{-1} was recorded in 60 cm × 15 cm spacing

(3.17). Reduction in stem number in densely populated area might be due to increased number of plants per unit area. This increased number of plants per unit area exerted competition among plants for nutrients and light that caused a reduction in branch number. Similar result was also reported by Yenagi *et al.* (2002) in potato.

Table 2. Interaction effect of tuber weight and spacing on plant height and stem number hill^{-1} of potato at different days after planting

Interaction (Tuber weight × spacing)	Plant height (cm)			Stems hill^{-1}
	60 DAP	**75 DAP**	**90 DAP**	**90 DAP**
$T_1 \times S_1$	37.7 ab	46.1 a-c	52.0 b-e	5.47 a
$T_1 \times S_2$	38.5 ab	47.0 ab	54.2 a-c	5.20 a
$T_1 \times S_3$	40.1 a	50.3 a	57.8 a	4.47 b
$T_2 \times S_1$	36.0 a-c	46.5 a-c	50.9 c-f	5.20 a
$T_2 \times S_2$	39.3 a	47.9 ab	54.0 a-d	5.00 a
$T_2 \times S_3$	39.8 a	50.0 a	56.2 ab	4.30 b
$T_3 \times S_1$	32.3 c	41.4 d	46.7 f	3.30 d
$T_3 \times S_2$	33.3 c	42.0 cd	47.5 ef	3.13 d
$T_3 \times S_3$	34.6 bc	45.3 b-d	49.2 d-f	2.73 e
$T_4 \times S_1$	27.4 d	34.7 e	37.2 g	1.87 f
$T_4 \times S_2$	27.0 d	35.0 e	38.0 g	1.90 f
$T_4 \times S_3$	28.5 d	35.7 e	40.4 g	1.69 f
F-test	*	*	*	*
SE	1.257	1 .424	1.531	.101
CV (%)	6.31	5.67	5.45	4.91

In a column, means followed by same letter (s) do not differ significantly at 5% level of significant by DMRT; * indicate significant at 5% levels of probability; T_1 = 40 ± 2 g; T_2 = 30 ± 2 g; T_3 = 20 ± 2 g; T_4 = 10 ± 2 g; S_1 = 60 cm × 25 cm; S_2 = 60 cm × 20 cm; S_3 = 60 cm × 15 cm.

The interaction between seed tuber weight and plant spacing had significant effect on stems hill^{-1} (Table 2). The highest stems hill^{-1} was observed in 40 ± 2 g tuber weight with 60 cm × 25 cm spacing (5.47) followed by the treatment combination of 40 ± 2 g seed tuber and 60 cm × 20 cm spacing (5.2) and 30 ± 2 g seed tuber with 60 cm × 25 cm spacing (5.2) with same statistical rank.The lowest stems hill^{-1} was recorded in the treatment combination of 10 ± 2 g tuber with 60 cm × 15 cm spacing (1.69).

4.1.3 Leaves hill^{-1}

The effect of seed tuber weight on leaves hill^{-1} was statistically significant at 3 growth stages (Table 3). Result showed that leaf number increased with age till 75 DAP followed by a decline due to leaf shedding in all the treatments.Results revealed that leaves hill^{-1} increased with increasing seed tuber weight. The highest leaves hill^{-1} was observed in 40 ± 2 g tuber (60.1, 74.9 and 63.2 leaves hill^{-1} at 60, 75 and 90 DAP, respectively) followed by 30 ± 2 g seed tuber weight (58.4, 72.0 and 57.5 hill^{-1} at 60, 75 and 90 DAP, respectively. The lowest leaf number was recorded in 10 ± 2 g seed tuber weight (28.6, 43.9 and 33.4 hill^{-1} at 60, 75 and 90 DAP, respectively). Increased leaf number in larger tuber might be due to increased stems hill^{-1}. The result is consistent with the findings of Gulluoglu and Aroglu (2009) in potato who reported that leaf number in potato decreased with decreasing tuber weight.

Table 3. Effect of tuber weight and spacing on leaf production and leaf characters of potato at different days after planting

Treatments	Leaves hill^{-1}			Leaf characters at 75 DAP	
Tuber weight (g)	**60 DAP**	**75 DAP**	**90 DAP**	**Leaf length (cm)**	**Leaf breadth (cm)**
40 ± 2	60.1 a	74.9 a	63.2 a	20.1 a	9.53 a
30 ± 2	58.4 a	72.0 b	57.5 b	18.1 b	9.17 b
20 ± 2	45.8 b	55.2 c	41.6 c	16.6 c	8.78 c
10 ± 2	28.6 c	43.9 d	33.4 d	14.6 d	7.82 d
F-test	**	**	**	**	**
SE	0.938	0.898	0.934	0.314	0.091
Spacing					
60 cm × 25 cm	50.9 a	64.1 a	54.5 a	17.6 a	8.91 a
60 cm × 20 cm	48.2 b	62.1 a	49.6 b	17.7 a	8.93 a
60 cm × 15 cm	45.6 c	58.3 b	42.6 c	16.8 b	8.63 b
F-test	**	**	**	*	*
SE	0.813	0.778	0.809	0 .272	0.078
CV (%)	5.84	4.38	5.73	5.44	3.09

In a column, means followed by same letter (s) do not differ significantly at 5% or 1% level of significant by DMRT; *, ** indicate significant at 5% and 1% levels of probability, respectively.

The leaves hill^{-1} showed significant differences among plant spacing (Table 3). Results showed that leaf number increased with increasing plant spacing. The highest leaves hill^{-1} was recorded in 60 cm × 25 cm spacing (50.9, 64.1 and 54.5 hill^{-1} at 60, 75 and 90 DAP, respectively). On the other hand, the lowest leaves hill^{-1} was recorded in closer spacing, 60 cm × 15 cm (45.6, 58.3 and 42.6 at 60, 75 and 90 DAP, respectively). Leaf number was lower in closer spacing because of fewer stems hill^{-1} (Table 1) than wider spacing. This result is consistent with Cites *et al*. (2000) who reported that leaf number decreased with closer spacing.

The interaction effect of seed tuber weight and plant spacing had significant effect on leaves hill^{-1} (Table 4). The highest leaves hill^{-1} was observed in 40 ± 2 g tuber weight with 60 cm × 25 cm spacing (65.4, 80.0 and 73.8 leaves hill^{-1} at 60, 75 and 90 DAP, respectively). The lowest leaves hill^{-1} was recorded in the treatment combination of 10 ± 2 g tuber with 60 cm × 15 cm spacing (29.3, 43.0 and 28.8 leaves hill^{-1} at 60, 75 and 90 DAP, respectively).

4.1.4 Leaf length and breadth

The effect of seed tuber weight on leaf length and breadth was statistically significant (Table 3). Result showed that leaf length and breadth increased with increasing seed tuber weight. The highest leaf length (20.1 cm) and breadth (9.53 cm) was recorded at the tuber weight of 40 ± 2 g followed by the tuber weight of 30 ± 2 g (18.1 and 9.17 cm for leaf length and breadth, respectively). The lowest leaf length and breadth were observed in the tuber weight of 10 ± 2 g (14.6 and 7.82 cm, for leaf length and breadth, respectively). The plant from larger tuber has vigorous growth and development than smaller ones which resulted large leaf size (Gregoriou, 2000). In present experiment, similar phenomenon may be happened and larger tuber showed large leaf size than smaller tuber ones.

The different levels of plant spacing had significant effect on leaf length and breadth (Table 3). Result revealed that leaf length and breadth increased with increasing plant spacing upto 60 cm × 20 cm spacing. The highest leaf length and breadth was recorded in 60 cm × 20 cm spacing followed by 60 cm × 25 cm spacing with same statistical rank. In contrast, the lowest leaf length and breadth was observed in closer spacing of 60 cm × 15 cm (16.8 and 8.63 cm for leaf length and breadth, respectively). The result is consistent with the findings of Ahire *et al.* (2000) who reported that leaf length and breadth in potato increased with increasing plant spacing.

The interaction effect of tuber weight and plant spacing in relation to leaf length and breadth was also statistically significant (Table 4). The longest leaf length and breadth was observed in the treatment combination of 40 ± 2 g tuber with 60 cm × 25 cm spacing (20.4 and 9.80 cm for leaf length and breadth, respectively) and 30 ± 2 g tuber with 60 cm × 25 cm spacing (21.1 and 9.78 cm for leaf length and breadth, respectively). The shortest leaf length and breadth was recorded in 10 ± 2 g tuber with 60 cm × 15 cm spacing (14.2 and 7.77 cm for leaf length and breadth, respectively).

Table 4. Interaction effect of seed tuber weight and plant spacing on leaf production and leaf characters of potato at different days after planting

Interaction (Tuber weight × spacing)	Leaves hill^{-1}			Leaf characters at 75 DAP	
	60 DAP	75 DAP	90 DAP	Leaf length (cm)	Leaf breadth (cm)
$T_1 \times S_1$	65.4 a	80.0 a	73.8 a	20.4 ab	9.80 a
$T_1 \times S_2$	59.2 bc	74.2 b	65.4 b	21.1 a	9.78 a
$T_1 \times S_3$	55.6 c	70.6 bc	50.3 d	18.9 bc	9.02 bc
$T_2 \times S_1$	61.2 ab	74.3 b	61.3 bc	18.4 cd	9.10 bc
$T_2 \times S_2$	59.3 bc	72.6 bc	59.1 c	18.1 cd	9.40 ab
$T_2 \times S_3$	54.6 c	69.2 c	52.0 d	17.8 c-e	9.00 bc
$T_3 \times S_1$	48.2 d	58.1 d	45.1 e	16.8 de	8.83 c
$T_3 \times S_2$	46.3 de	57.0 d	40.4 ef	16.8 de	8.75 c
$T_3 \times S_3$	42.9 e	50.4 e	39.4 f	16.1 ef	8.75 c
$T_4 \times S_1$	28.6 f	44.0 f	37.7 fg	14.8 fg	7.90 d
$T_4 \times S_2$	28.0 f	44.6 f	33.6 g	14.9 fg	7.80 d
$T_4 \times S_3$	29.3 f	43.0 f	28.8 h	14.2 g	7.77 d
F-test	*	*	**	*	*
SE	1.626	1.556	1.619	0 .545	0.157
CV (%)	5.84	4.38	5.73	5.44	3.09
SE	1.626	1.556	1.619	0 .545	0.157

In a column, means followed by same letter (s) do not differ significantly at 5% level of significant by DMRT; *,** indicate significant at 5% and 1% levels of probability, respectively; T_1 = 40 ± 2 g; T_2 = 30 ± 2 g; T_3 = 20 ± 2 g; T_4 = 10 ± 2 g; S_1 = 60 cm × 25 cm; S_2 = 60 cm × 20 cm; S_3 = 60 cm × 15 cm .

4.1.5 Leaf area

The different weight of tubers had significant effect on leaf area plant^{-1} (Table 5). Result revealed that leaf area increased with increasing seed tuber weight. Result revealed that leaf area increased upto till 75 DAP followed by a decline due to leaf shedding (Table 3). The leaf production by the tuber weight of 40 ± 2 g was the highest at all growth stages. The seed tuber weight of 10 ± 2 g had the lowest leaf area plant^{-1} at all growth stages. 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.

The effect of plant spacing on leaf area plant^{-1} at three growth stages was statistically significant (Table 5). Result showed that leaf area plant^{-1} decreased with decreasing plant spacing. The highest leaf area plant^{-1} was observed in 60 cm × 25 cm spacing (2325, 2781 and 2002 cm^2 plant^{-1} at 60, 75 and 90 DAP, respectively) followed by 60 cm × 20 cm spacing. The lowest leaf area was recorded in the spacing of 60 cm × 15 cm (2148, 2435 and 1734 cm^2 plant^{-1} at 60, 75 and 90 DAP,

Table 5. Effect of tuber weight and spacing on leaf area of plant^{-1} potato at different days after planting

Treatments	Leaf area plant^{-1} (cm^2)		
Tuber weight (g)	**60 DAP**	**75 DAP**	**90 DAP**
40 ± 2	2592 a	3144 a	2258 a
30 ± 2	2492 a	2907 b	2150 a
20 ± 2	2232 b	2527 c	1718 b
10 ± 2	1653 c	2017 d	1411 c
F-test	**	**	**
SE	41.680	75.553	43.216
Spacing			
60 cm × 25 cm	2325 a	2781 a	2002 a
60 cm × 20 cm	2253 ab	2654 a	1880 b
60 cm × 15 cm	2148 b	2435 b	1734 c
F-test	**	**	**
SE	36.096	65.430	37.426
CV (%)	5.58	8.64	6.93

In a column, means followed by same letter (s) do not differ significantly at 1% level of significant by DMRT; ** indicate significant at 1% levels of probability, respectively.

The leaf area was higher in wider spacing due to increased leaves plant^{-1} (Table 2). The result is consistent with the findings of Yenagi *et al.* (2004) who reported that leaf area plant^{-1} in potato decreased with decreasing spacing in potato.

The interaction effect of seed tuber weight and plant spacing had significant effect on leaf area plant^{-1} at all growth stages (Table 6). The highest leaf area plant^{-1} was observed in 40 ± 2 g tuber weight with 60 cm × 25 cm spacing (2753, 3463 and 2420 cm^2 plant^{-1} at 60, 75 and 90 DAP, respectively) followed by tuber weight of 40 ± 2 g with 60 cm × 20 cm spacing (2623, 3228 and 2300 cm^2 plant^{-1} at 60, 75 and 90 DAP, respectively) with same statistical rank. The lowest leaf area plant^{-1} was recorded in the treatment combination of 10 ± 2 g tuber with 60 cm × 15 cm spacing (1670, 1990 and 1360 cm^2 hill^{-1} at 60, 75 and 90 DAP, respectively).

4.1.5 Leaf area index

The effect of seed tuber size on leaf area index (LAI) was significant at 60, 75 and 90 DAP (Table 7). Results showed that LAI increased with increasing tuber size. The result also showed that LAI increased with age till 75 DAP followed by a decline due to leaf shedding (Table 3). The highest LAI was observed in 40 ± 2 g tuber followed by 30 ± 2 g tuber at all growth stages. The lowest LAI was recorded in 10 g size tuber at all growth stages. The variation in LAI might occur due to the variation in leaf area hill^{-1} (Table 7). The results are also supported by the result of Verma *et al.* (2007) in potato.

Table 6. Interaction effect of tuber weight and spacing on leaf area of potato at different days after planting

Interaction (Tuber weight × spacing)	Leaf area plant^{-1} (cm^2)		
	60 DAP	75 DAP	90 DAP
$T_1 \times S_1$	2753 a	3463 a	2420 a
$T_1 \times S_2$	2623 ab	3228 ab	2300 ab
$T_1 \times S_3$	2400 b-d	2740 cd	2055 cd
$T_2 \times S_1$	2588 a-c	3080 b	2340 ab
$T_2 \times S_2$	2510 bc	2940 bc	2160 b
$T_2 \times S_3$	2380 cd	2700 cd	1950 c-e
$T_3 \times S_1$	2270 de	2670 cd	1835 d-f
$T_3 \times S_2$	2280 de	2500 d	1700 ef
$T_3 \times S_3$	2145 e	2410 de	1620 fg
$T_4 \times S_1$	1688 f	2012 ef	1462 gh
$T_4 \times S_2$	1600 f	2050 ef	1410 gh
$T_4 \times S_3$	1670 f	1990 f	1360 h
F-test	*	*	*
SE	72.192	130.861	74.853
CV (%)	5.58	8.64	6.93

In a column, means followed by same letter (s) do not differ significantly at 5% level of significant by DMRT; * indicate significant at 5% levels of probability; T_1 = 40 ± 2 g; T_2 = 30 ± 2 g; T_3 = 20 ± 2 g; T_4 = 10 ± 2 g; S_1 = 60 cm × 25 cm; S_2 = 60 cm × 20 cm; S_3 = 60 cm × 15 cm.

Table 7. Effect of tuber weight and spacing on leaf area index of potato at different days after planting

Treatments	Leaf area index		
Tuber weight (g)	**60 DAP**	**75 DAP**	**90 DAP**
40 ± 2	2.31 a	2.78 a	2.01 a
30 ± 2	2.23 a	2.59 b	1.87 a
20 ± 2	2.00 b	2.26 c	1.53 b
10 ± 2	1.49 c	1.82 d	1.26 c
F-test	**	**	**
SE	0.056	0.047	0.053
Spacing			
60 cm × 25 cm	1.63 c	1.95 c	1.40 c
60 cm × 20 cm	2.03 b	2.39 b	1.69 b
60 cm × 15 cm	2.37 a	2.68 a	1.91 a
F-test	**	**	**
CV (%)	8.48	6.09	9.57
SE	0 .049	0 .041	0 .046

In a column, means followed by same letter (s) do not differ significantly at 1% level of significant by DMRT; ** indicate significant at 1% levels of probability.

The LAI was significantly influenced by plant spacing at 3 growth stages of potato (Table 7). Result showed that LAI increased with decreasing plant spacing at all growth stages. The highest LAI was observed in the spacing of 60 cm × 15 cm (2.37, 2.68 and 1.91 at 60, 75 and 90 DAP, respectively). The lowest LAI was recorded in 60 cm × 25 cm spacing (1.63, 1.95 and 1.40 at 60, 75 and 90 DAP, respectively). The LAI was lower in closer spacing but reverse trend was observed in case of LAI might be due to larger plant population in closer spacing compared to wider spacing. The result is consistent with the findings of Ravichandran and Singh (2003) who reported that LAI in potato increased with decreasing plant spacing.

The interaction effect of seed tuber weight and plant spacing had significant effect on LAI (Table 8). The highest LAI was observed in 40 ± 2 g tuber weight with 60 cm × 10 cm spacing (2.65, 3.01 and 2.26 at 60, 75 and 90 DAP, respectively) followed by tuber size of 40 ± 2 g with 60 cm × 20 cm spacing (2.36, 2.92 and 2.07 at 60, 75 and 90 DAP, respectively). The lowest LAI was recorded in the treatment combination of 10 ± 2 g tuber with 60 cm × 25 cm spacing (1.18, 1.41 and 1.02 at 60, 75 and 90 DAP, respectively).

Table 8. Interaction effect of tuber weight and spacing on leaf area index of potato at different days after planting

Interaction (Tuber weight × spacing)	Leaf area index		
	60 DAP	**75 DAP**	**90 DAP**
$T_1 \times S_1$	1.93 c	2.42 cd	1.69 cd
$T_1 \times S_2$	2.36 ab	2.92 a	2.07 ab
$T_1 \times S_3$	2.65 a	3.01 a	2.26 a
$T_2 \times S_1$	1.81 cd	2.16 de	1.60 d
$T_2 \times S_2$	2.26 b	2.64 bc	1.90 bc
$T_2 \times S_3$	2.62 a	2.97 a	2.10 ab
$T_3 \times S_1$	1.59 de	1.87 f	1.28 ef
$T_3 \times S_2$	2.05 bc	2.25 de	1.53 de
$T_3 \times S_3$	2.36 ab	2.65 bc	1.78 cd
$T_4 \times S_1$	1.18 f	1.41 g	1.02 f
$T_4 \times S_2$	1.44 ef	1.85 f	1.27 ef
$T_4 \times S_3$	1.84 cd	2.19 de	1.50 de
F-test	NS	*	*
SE	0 .098	0 .0822	0.092
CV (%)	8.48	6.09	9.57

In a column, means followed by same letter (s) do not differ significantly at 5% level of significant by DMRT; * indicate significant at 5% levels of probability; NS= Not significant; T_1 = 40 ± 2 g; T_2 = 30 ± 2 g; T_3 = 20 ± 2 g; T_4 = 10 ± 2 g; S_1 = 60 cm × 25 cm; S_2 = 60 cm × 20 cm; S_3 = 60 cm × 15 cm.

4.2 Effect of seed tuber weight, spacing and their interaction on growth characters of potato

4.2.1 Total dry mass

There was a significant variation in total dry mass (TDM) production plant^{-1} and total dry mass m^{-2} at 60, 75 and 90 DAP due to seed tuber weight (Table 9). Result showed that total dry mass plant^{-1} and total dry mass m^{-2} increased with

Table 9. Effect of tuber weight and spacing on total dry mass production of potato at different days after planting

Treatments	**Total dry mass m^{-2} (g)**		
Tuber weight (g)	**60 DAP**	**75 DAP**	**90 DAP**
40 ± 2	474.1 a	889.9 a	1056.7 a
30 ± 2	428.0 b	839.1 b	1013.3 a
20 ± 2	320.3 c	566.7 c	789.6 c
10 ± 2	189.4 d	371.0 d	470.8 d
F-test	**	**	**
SE	8.154	10.454	14.588
Spacing			
60 cm × 25 cm	288.7 c	551.1 c	720.6 c
60 cm × 20 cm	361.8 b	677.2 b	948.9 a
60 cm × 15 cm	408.3 a	771.8 a	941.1 b
F-test	**	**	**
SE	7.061	9.053	12.634
CV (%)	6.93	4.70	5.31

In a column, means followed by same letter (s) do not differ significantly at 1% level of significant by DMRT; ** indicate significant at 1% levels of probability.

Increasing tuber weight. The highest TDM plant^{-1} and TDM m^{-2} was recorded in tuber weight of 40 ± 2 g (53.3, 100.1 and 119.5 g plant^{-1} at 60, 75 and 90 DAP, respectively, and 474.1, 889.9 and 1056.7 g m^{-2} at 60, 75 and 90 DAP, respectively) followed by tuber weight of 30 ± 2 g (48.0, 94.0 and 106.4 g plant^{-1} at 60, 75 and 90 DAP, respectively) at all growth stages. In contrast, the tuber weight of 10 ± 2 g had the lowest TDM plant^{-1} and TDM m^{-2} at all growth stages (21.1, 41.4 and 54.4 g plant^{-1} at 60, 75 and 90 DAP, respectively and 189.4, 371.0 and 470.8 g m^{-2} at 60, 75 and 90 DAP, respectively). The TDM was higher in larger tubers because of larger tuber seedling had huge stored food material that promoted increased vegetative growth of the plants. This result is consistent with many workers (Garg *et al*., 2000; Khalafalla, 2001; Reust, 2002; Cornwall, 2004; Yenagi *et al.,* 2005; Kumar *et al.,* 2009) in potato who reported that TDM increased with increasing seed tuber weight.

The effect of plant spacing on TDM production both per plant and per square meter on 60, 75 and 90 DAP was significant (Table 9). Result showed that total TDM production both per plant and m^{-2} increased with increasing plant spacing at all growth stages. The highest TDM plant^{-1} was observed in the spacing of 60 cm × 25 cm (41.2, 78.7 and 99.5 g plant^{-1} at 60, 75 and 90 DAP, respectively) followed by 60 cm × 20 cm spacing (40.2, 75.2 and 75.2 g plant^{-1} at 60, 75 and 90 DAP, respectively). The lowest TDM plant^{-1} was recorded at 60 cm × 15 cm plant spacing (35.8, 45.3 and 50.9 cm at 60, 75 and 90 DAP, respectively) followed by 20 cm plant spacing (37.1, 70.2 and 85.0 g plant^{-1} at 60, 75 and 90 DAP, respectively). The increase in TDM plant^{-1} in wider spacing probably due to less competition among the plants for space, light, water and nutrients which was ultimately led to the rapid growth and development resulting higher TDM plant^{-1}. Reverse trend was observed in case of TDM m^{-2}. The highest TDM m^{-2} was observed in 60 cm × 20 cm spacing (948.9 g m^{-2} at 90 DAP) and the lowest TDM m^{-2} was observed in wider spacing (288.7, 551.1 and 720.6 g m^{-2} at 60, 75 and 90 DAP, respectively) because of plant density was lower in wider spacing than closer spacing. These results are in agreement with that of Bayorbor and Gumah (2007) who reported that plant spacing had significant effect on plant height of potato. Similar result was also reported by Kushwah and Singh (2008) in potato that plant height increased with decreasing plant spacing.

The interaction effect of seed tuber weight and plant spacing had significant effect on TDM plant^{-1} and TDM m^{-2} at three growth stages of 60, 75 and 90 DAP in potato (Table 10). The highest TDM plant^{-1} was recorded in the treatment combination of 35 g tuber weight with 60 cm × 25 cm plant spacing (57.0, 108.3 and 133.3 at 60, 75 and 90 DAP, respectively) and the lowest was recorded in the treatment combination of 10 ± 2 g tuber with 60 cm × 15 cm spacing (20.7, 40.1 and 52.1 g plant^{-1} at 60, 75 and 90 DAP, respectively). However, the highest TDM m^{-2} was observed in the treatment combination of larger tuber with closer spacing,40 ± 2 g tuber with spacing of 60 cm × 15 cm (534.6, 1007.6 and 1157.0 g m^{-2} at 60, 75 and 90 DAP, respectively). The TDM m^{-2} was observed in the treatment combination of smaller tuber with wider spacing, 20 ± 2 g tuber with spacing of 60 cm × 25 cm (149.3, 293.7 and 389.8 g m^{-2} at 60, 75 and 90 DAP, respectively).

Table 10. Interaction effect of tuber weight and spacing on total dry mass production of potato at different days after planting

Interaction (Tuber weight × spacing)	Total dry mass plant^{-1} (g)			Total dry mass m^{-2} (g)		
	60 DAP	75 DAP	90 DAP	60 DAP	75 DAP	90 DAP
$T_1 \times S_1$	57.0 a	108.3 a	133.3 a	399.0 cd	758.4 c	933.1 cd
$T_1 \times S_2$	54.3 ab	100.4 b	120.0 ab	488.7 b	903.6 b	1080.0 b
$T_1 \times S_3$	48.6 cd	91.6 cd	105.2 bc	534.6 a	1007.6 a	1157.0 a
$T_2 \times S_1$	50.2 bc	98.2 bc	125.6 ab	351.7 ef	687.3 d	937.2 cd
$T_2 \times S_2$	48.7 cd	95.4 bc	115.3 b	438.3 c	858.6 b	1113.0 ab
$T_2 \times S_3$	44.9 d	88.3 d	102.3 bc	493.9 ab	971.5 a	1035.7 b
$T_3 \times S_1$	36.4 e	66.4 e	88.5 d	254.7 g	464.8 f	619.3 f
$T_3 \times S_2$	36.5 e	63.2 e	90.0 d	328.5 f	568.8 e	810.0 e
$T_3 \times S_3$	34.3 e	60.6 e	85.4 d	377.6 de	666.6 d	939.4 cd
$T_4 \times S_1$	21.3 f	42.0 f	55.7 e	149.3 i	293.7 h	389.8 g
$T_4 \times S_2$	21.3 f	42.0 f	55.5 e	191.7 h	378.0 g	449.5 g
$T_4 \times S_3$	20.7 f	40.1 f	52.1 e	227.1 gh	441.4 f	573.1 f
F-test	*	*	*	*	*	*
SE	1.615	2.157	4.935	14.123	18.107	25.268
CV (%)	7.08	5.00	9.21	6.93	4.70	5.31

In a column, means followed by same letter (s) do not differ significantly at 5% level of significant by DMRT; * indicate significant at 5% levels of probability, respectively; T_1 = 40 ± 2 g; T_2 = 30 ± 2 g; T_3 = 20 ± 2 g; T_4 = 10 ± 2 g; S_1 = 60 cm × 25 cm; S_2 = 60 cm × 20 cm; S_3 = 60 cm × 15 cm.

4.2.2 Crop growth rate

Crop growth rate (CGR) was significantly influenced by seed tuber size at 60-75 and 75-90 DAP (Table 11). Results showed that at 60-75 DAP, the CGR increased with increasing tuber size. At 60-75 DAP, the highest CGR was recorded in tuber size of 40 ± 2 g (27.7 g $m^{-1}d^{-1}$) followed by the tuber size of 30 ± 2 g (27.4g $m^{-1}d^{-1}$) with same statistical rank. In contrast, the lowest CGR both at 60-75 and 75-90 DAP was observed in 10 ± 2 g tuber (12.1 and 7.65 g m-2 d^{-1}at 60-75 and 75-90 DAP, respectively). Further at 75-90 DAP, the highest CGR was observed in 20 ± 2 tuber (14.86 g m^{-2} d^{-1}). The CGR was higher in larger tuber might be due to increased TDM $plant^{-1}$. This result is consistent with Divis and Barta (2001) in potato who reported that larger tuber produced higher number of stems $plant^{-1}$, crop growth rate as compared to small tubers which resulted in higher yield compared to small ones.

The effect of plant spacing on CGR at 60-75 DAP was significant but at 75-90 DAP was non-significant (Table 11). AT 60-75 DAP, the highest CGR was observed in closer spacing, 60 cm × 15 cm (24.2 g m^{-2} d^{-1}) and the lowest was recorded in wider spacing, 60 cm × 25 cm (17.5 g m^{-2} d^{-1}). The CGR was higher in closer spacing because of producing increased TDM m^{-2}. This result in consistent with Ravichandran and Singh (2003) in potato who reported that CGR was higher in closer spacing than wider spacing. The interaction effect of seed tuber size and plant spacing on CGR was significant (Table 12). The highest CGR was recorded in the treatment combination of 30 ± 2g tuber size with 60 cm × 15 cm plant spacing (31.84 g m^{-2} d^{-1}). The lowest CGR was observed in 10 ± 2 g tuber with 60 cm ×25 cm spacing (9.63 g m^{-2} d^{-1}).

Table 11. Effect of tuber weight and spacing on growth of potato at different days after planting

Treatments	Crop growth rate (g m^{-2} d^{-1})		Relative growth rate (mg g^{-1} d^{-1})		Net assimilation rate (mg cm^{-2} d^{-1})
Tuber weight (g)	**60-75 DAP**	**75-90 DAP**	**60-75 DAP**	**75-90 DAP**	**60-75 DAP**[†]
40 ± 2	27.7 a	11.12 b	42.0 a	11.65 c	109.0 a
30 ± 2	27.4 a	9.55 c	44.9 a	10.98 c	115.7 a
20 ± 2	16.4 b	14.86 a	38.2 b	21.85 a	77.5 b
10 ± 2	12.1 c	7.65 d	44.9 a	15.94 b	75.6 b
F-test	**	**	**	**	**
SE	0.515	0.279	0.981	0.471	2.879
Spacing					
60 cm × 25 cm	17.5 c	10.37	43.2	17.15 a	95.2
60 cm × 20 cm	21.0 b	11.14	41.9	14.17 b	92.9
60 cm × 15 cm	24.2 a	10.88	42.4	13.99 b	95.2
F-test	**	NS	NS	**	NS
SE	0.446	0.241	0.850	0.408	2.493
CV (%)	7.39	7.75	6.93	9.36	9.15

In a column, means followed by same letter (s) do not differ significantly at 1% level of significant by DMRT; ** indicate significant at 1% levels of probability, respectively; NS = Not significant.

Table 12. Interaction effect of tuber weight and spacing on growth of potato at different days after planting

Interaction (Tuber weight × spacing)	Crop growth rate (g m^{-2} d^{-1})		Relative growth rate (mg g^{-1} d^{-1})		Net assimilation rate (mg cm^{-2} d^{-1})
	60-75 DAP	75-90 DAP	60-75 DAP	75-90 DAP	60-75 DAP†
$T_1 \times S_1$	23.96 c	11.65 cd	42.80 ab	13.82 c	110.0 a
$T_1 \times S_2$	27.66 b	11.76 cd	40.98 a-c	11.89 cd	105.0 a
$T_1 \times S_3$	31.53 a	9.97 e	42.25 ab	9.23 e	112.0 a
$T_2 \times S_1$	22.38 c	13.12 c	44.67 a	16.79 b	115.0 a
$T_2 \times S_2$	28.02 b	8.94 ef	44.82 a	9.68 de	116.0 a
$T_2 \times S_3$	31.84 a	6.59 g	45.10 a	6.46 f	116.0 a
$T_3 \times S_1$	14.01 ef	10.3 de	40.10 a-c	19.13 b	81.10 b
$T_3 \times S_2$	16.02 e	16.08 b	36.60 c	23.56 a	74.50 b
$T_3 \times S_3$	19.26 d	18.19 a	37.90 bc	22.87 a	76.90 b
$T_4 \times S_1$	9.63 g	6.41 g	45.10 a	18.87 b	74.80 b
$T_4 \times S_2$	12.42 f	7.77 fg	45.21 a	11.54 c-e	76.00 b
$T_4 \times S_3$	14.28 ef	8.78 ef	44.29 a	17.40 b	76.00 b
F-test	*	**	NS	**	*
SE	0.892	0.483	1.700	0.816	4.987
CV (%)	7.39	7.75	6.93	9.36	9.15

In a column, means followed by same letter (s) do not differ significantly at 5% or 1% level of significant by DMRT; *, ** indicate significant at 5% and 1% levels of probability, respectively; NS = Not significant. T_1 = 40 ± 2 g; T_2 = 30 ± 2 g; T_3 = 20 ± 2 g; T_4 = 10 ± 2 g; S_1 = 60 cm × 25 cm; S_2 = 60 cm × 20 cm; S_3 = 60 cm × 15 cm.

4.2.3 Relative growth rate

The effect of tuber size on relative growth rate (RGR) at 60-75 and 75-90 DAP was significant (Table 11). Results showed that RGR was greater at 60-75 DAP than 75-90 DAS. Results showed that there had no relation between RGR and tuber yield in potato. Result showed that the lowest RGR was observed in 20 ± 2 g tuber size at 60-75 DAP while at 75-90 DAP, the reverse trend was observed.

The effect of plant spacing on RGR at 60-75 DAP was non-significant but at 75-90 DAP was significant (Table 11). At 75-90 DAP, the RGR decreased with decreasing plant spacing in potato. The highest RGR was observed in wider spacing, 60 cm × 25 cm (17.15 mg g^{-1} d^{-1}) and the lowest was recorded in closer spacing, 60 cm × 15 cm (13.99 mg g^{-1} d^{-1}). The RGR was higher in wider spacing because of producing increased TDM m^{-2}. This result is consistent with Suman, S, Malik,Y. S and Khurana, S. C. (2003) in potato who reported that RGR was higher in wider spacing than closer spacing.

RGR was significantly influenced both at 60-75 and 75-90 DAP by the interaction effect of seed tuber size and plant spacing (Table 12). At 60-75 DAP, there had no high variation in RGR among the treatment combinations but at 75-90 DAP showed high variation. At 75-90 DAP, the highest RGR was recorded in the treatment combination of 20 ± 2 g tuber size with 60 cm × 20 cm spacing (23.56 mg g^{-1} d^{-1}), The lowest RGR was observed in 30 ± 2 g tuber with 60 cm ×15 cm spacing (6.46 mg g^{-1} d^{-1}).

4.2.4 Net assimilation rate

There was a significant variation in net assimilation rate (NAR) at 60-75 DAP due to seed tuber weight (Table 11). Result showed that NAR increased with increasing tuber size till tuber weight of 30 ± 2 g. The highest NAR was recorded in tuber size of 30 ± 2 g (115.7 mg $cm^{-2}d^{-1}$) followed by tuber weight of 40 ± 2 (109.0 mg cm^{-2} d^{-1}) with same statistical rank. In contrast, the tuber weihgt of 10 ± 2 g had the lowest NAR (75.6 mg cm^{-2} d^{-1}) that was statistically similar to tuber size of 20 g (77.5 mg cm^{-2} d^{-1}). This result is consistent with many workers (Garg *et al.*, 2000; Khalafalla, 2001; Reust, 2002; Cornwall, 2004; Yenagi *et al.*, 2005; Kumar *et al.*, 2009) in potato who reported that NAR increased with increasing seed tuber size.

The effect of plant spacing on NAR was non-significant (Table 11). These results disagrees with that of Bayorbor and Gumah (2007) who reported that plant spacing had significant effect on NAR of potato.

The interaction effect of seed tuber weight and plant spacing had significant effect on NAR at 60-75 DAS (Table 12). The higher NAR was recorded in the treatment combination of 30 ± 2 g tuber weight with 60 cm × 25 cm plant spacing (116.0 mg cm^{-2} d^{-1}) and 30 ± 2 g tuber weight with 60 cm × 20 cm plant spacing (116.0 mg cm^{-2} d^{-1}). The lower NAR was recorded in the treatment combination of 20 ± 2 g tuber with 60 cm × 20 cm spacing (74.50 mg cm^{-2} d^{-1}) and 10 ± 2 g tuber with 60 cm × 25 cm spacing (74.80 mg cm^{-2} d^{-1}).

4.3 Effect of seed tuber weight, plant spacing and their interaction on yield attributes and yield of potato

4.3.1 Tubers hill^{-1}

The effect of tuber weight on number tubers hill $^{-1}$ was statistically significant (Table 13). Result revealed that the number tubers hill^{-1} increased with increasing tuber weight till 30 ± 2 g tuber and thereafter further increase tuber weight did not increase tubers hill^{-1}. The highest production of tubers hill^{-1} was observed in the tuber weight of 30 ± 2 g (8.07) that was statistically similar to tuber weight of 40 ± 2 g (7.70 hill^{-1}). In contrast, the lowest tubers hill^{-1} was recorded in the tuber weight of 10 ± 2 g (6.46). Reduction in the tubers hill^{-1} under smaller weight seed tuber might be due to lesser stems hill^{-1} (Table 1). This result is consistent with many workers (Rashid, 1987; Garg *et al*., 2000; Khalafalla, 2001; BongKyoon *et al*., 2001; Shingrup *et al.*, 2003; Verma *et al.*, 2007) who reported that tuber number hill^{-1} increased with increasing tuber weight till 55 g seed tuber.

The number tubers hill^{-1} influenced significantly by different plant spacings (Table 13). Result showed that tuber number hill^{-1} increased with increasing plant spacing. The highest tubers hill^{-1} (7.85) was recorded in 60 cm × 25 cm spacing which was statistically similar to 60 cm × 20 cm spacing (7.57). The lowest tubers hill^{-1} was recorded in 60 cm × 15 cm spacing (6.73). Reduction in tuber number in densely populated area might be due to increased number of plants per unit area. This increased number of plants per unit area exerted competition among plants for nutrients and light that caused a reduction in tuber number. Similar result was also reported by Yenagi *et al.* (2002) in potato.

Table 13. Effect of seed tuber weight and spacing on yield attributes and yield in potato.

Treatments	Tubers hill^{-1} (no.)	Single tuber weight (g)	Tuber weight hill^{-1} (g)	Gross tuber yield (t ha^{-1})
Tuber size (g)				
40 ± 2	7.70 ab	52.03 a	304.1 a	26.47 a
30 ± 2	8.07 a	52.13 a	317.2 a	27.27 a
20 ± 2	7.30 b	45.29 b	248.5 b	22.33 b
10 ± 2	6.46 c	30.13 c	146.0 c	16.33 c
F-test	**	**	**	**
SE	0.145	1.069	7.955	0.606
Spacing				
60 cm × 25 cm	7.85 a	48.70 a	293.8 a	23.18 ab
60 cm × 20 cm	7.57 a	44.75 b	258.9 b	23.92 a
60 cm × 15 cm	6.73 b	41.24 c	209.0 c	22.20 b
F-test	**	**	**	*
SE	0.125	0.926	6.889	0.524
CV (%)	5.89	7.15	9.40	7.87

In a column, means followed by same letter (s) do not differ significantly at 5% or 1% level of significant by DMRT; *, ** indicate significant at 5% and 1% levels of probability, respectively.

The interaction between seed tuber weight and plant spacing had significant effect on tubers hill^{-1} (Table 14). The highest tubers hill^{-1} was observed in 30 ± 2 g tuber weight with 60 cm × 25 cm spacing (8.60) followed by the treatment combination of 40 ± 2 g seed tuber and 60 cm × 25 cm spacing (8.60) and 20 ± 2 g seed tuber with 60 cm × 20 cm spacing (8.50) with same statistical rank. The lowest tubers hill^{-1} was recorded in the treatment combination of 10 ± 2 g tuber with 60 cm × 15 cm spacing (6.40).

4.3.2 Single tuber weight

Seed tuber size significantly influenced the single tuber weight of potato (Table 13). Result revealed that single tuber weight increased with increasing seed tuber weight till 30 ± 2 g seed tuber followed by no increment was observed. The higher single tuber weight was observed in 30 ± 2 g and 40 ± 2 g seed tuber with being the highest in 30 ± 2 g seed tuber (52.13 g). In contrast, the lowest single tuber weight was recorded in the seed tuber weight of 10 ± 2 g (30.13 g). Similar result was also reported by BongKyoon *et al*. (2001) who observed that tuber weight decreased with decreasing seed tuber weight .

Plant spacing had significant effect on single tuber weight in potato (Table 13). Results showed that single tuber weight decreased with decreasing plant spacing. The largest tuber was observed in wider spacing, 60 cm × 25 cm (48.70 g) followed by the plant spacing of 60 cm × 20 cm (44.75 g). The lowest tuber weight was observed in the closer spacing of 60 cm × 15 cm (41.24 g). The larger tuber in wider spacing was probably due to less competition among the plants for space, light, water and nutrients which were facilitated to faster growth and development of tuber thereby increase tuber size in wider spacing as compared to closer spacing. This result is consistent with Ghosh *et al*. (2002) who reported that tuber weight decreased with decreasing plant spacings.

The interaction effect of seed tuber weight and plant spacing on single tuber weight was significant (Table 14). The highest single tuber weight was recorded in the treatment combination of 60 cm × 25 cm plant spacing with 40 ± 2 g seed tuber (60.20 g) followed by the treatment combination of 60 cm × 25 cm plant spacing with 30 ± 2 g seed tuber (55.0 g). The lowest single tuber weight was recorded in the treatment combination of 60 cm × 15 cm plant spacing with 10 g seed tuber (29.0 g) that was statistically similar to in the treatment combination of 60 cm × 20 cm plant spacing with 10 ± 2g seed tuber (30.4 g) and 60 cm × 25 cm plant spacing with 10 ± 2 g seed tuber (31.0 g).

4.3.3 Tuber weight hill^{-1}

The effect of seed tuber weight on tuber weight hill^{-1} was significant (Table 13). Result revealed that tuber weight hill^{-1} increased with increasing seed tuber weight upto 30 ± 2 g seed tuber followed by decline trend. The higher tuber weight hill^{-1} was observed in 30 ± 2 and 40 ± 2 g seed tuber with being the highest in 30 ± 2 g seed tuber (317.2 g hill^{-1}). In contrast, the lowest tuber weight hill^{-1} was recorded in the seed tuber weight of 10 ± 2 g (146.0 g hill^{-1}). The lesser tuber weight in smaller size 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; Bayorbor and Gumah, 2007; Verma *et al.*, 2007; Gulluoglu and Aroglu, 2009) who observed that tuber yield decreased with decreasing seed tuber weight.

Table 14. Interaction effects of seed tuber weight and spacing on yield attributes and yield in potato.

Interaction (Tuber weight × spacing)	Tubers hill^{-1} (no.)	Single tuber weight (g)	Tuber weight hill^{-1} (g)	Tuber yield (t ha^{-1})
$T_1 \times S_1$	8.60 a	60.20 a	388.3 a	29.10 a
$T_1 \times S_2$	8.00 ab	50.10 b-d	300.6 c	27.30 ab
$T_1 \times S_3$	6.50 e	45.80 de	223.3 e	23.00 cd
$T_2 \times S_1$	8.70 a	55.00 ab	328.9 ab	28.00 ab
$T_2 \times S_2$	8.50 a	53.50 bc	341.1 b	28.20 ab
$T_2 \times S_3$	7.00 c-e	47.90 c-e	251.5 de	25.60 bc
$T_3 \times S_1$	7.60 bc	48.60 cd	277.0 cd	20.90 d
$T_3 \times S_2$	7.30 b-d	45.00 de	246.4 de	23.50 cd
$T_3 \times S_3$	7.00 c-e	42.27 e	222.1 e	22.60 cd
$T_4 \times S_1$	6.50 de	31.00 f	151.1 f	14.70 e
$T_4 \times S_2$	6.48 de	30.40 f	147.7 f	16.70 e
$T_4 \times S_3$	6.40 e	29.00 f	139.2 f	17.60 e
F-test	**	*	**	**
SE	0.251	0.852	13.778	1.049
CV (%)	5.89	7.15	9.40	7.87

In a column, means followed by same letter (s) do not differ significantly at 5% or 1% level of significant by DMRT; *, ** indicate significant at 5% and 1% levels of probability, respectively; T_1 = 40 ± 2 g; T_2 = 30 ± 2 g; T_3 = 20 ± 2 g; T_4 = 10 ± 2 g; S_1 = 60 cm × 25 cm; S_2 = 60 cm × 20 cm; S_3 = 60 cm × 15 cm.

There was a significant variation in tuber weight hill^{-1} due to plant spacings (Table 13). Results showed that tuber weight decreased with decreasing plant spacing. The highest tuber weight hill^{-1} was observed in wider spacing, 60 cm × 25 cm (293.8 g hill^{-1}) followed by the plant spacing of 60 cm × 20 cm (258.9 g hill^{-1}). The lowest tuber yield hill^{-1} was observed in the closer spacing of 60 cm × 15 cm (209.0 g hill^{-1}). The higher tuber yield hill^{-1} in wider spacing was probably due to higher number of tubers hill^{-1} and larger tuber. This result is consistent with many workers in potato (Ghosh *et al*., 2002; Yenagi *et al.*, 2002; Wadhwa *et al*., 2002; Khurana and Bhutani, 2003; Suman *et al.*, 2003; Cornwall, 2004; Yenagi *et al.*, 2005; Kushwah and Singh, 2008).

The interaction effect of seed tuber weight and plant spacing on tuber weight hill^{-1} was significant (Table 14). The highest tuber weight hill^{-1} was recorded in the treatment combination of 60 cm × 25 cm plant spacing with 40 ± 2 g seed tuber (388.3 g hill^{-1}) followed by the treatment combination of 60 cm × 25 cm plant spacing with 30 ± 2 g seed tuber (328.9 g hill^{-1}). The lowest tuber weight hill^{-1} was recorded in the treatment combination of 60 cm × 15 cm plant spacing with 10 ± 2 g seed tuber (139.2 g hill^{-1}) that was statistically similar to in the treatment combination of 60 cm × 20 cm plant spacing with 10 ± 2 g seed tuber (147.7 g hill^{-1}) and 60 cm × 25 cm plant spacing with 10 ± 2 g seed tuber (151.1 g hill^{-1}).

4.3.4 Gross yield of tuber

The gross tuber yield was significantly influenced by seed tuber weight (Table 13). Result revealed that gross tuber yield increased with increasing seed tuber weight upto 25 ± 2 g seed tuber. The highest gross tuber yield was observed in the seed tuber weight of 30 ± 2 g (27.27 t ha^{-1}) followed by the seed tuber weight of 40 ± 2 g (26.47 t ha^{-1}) with same statistical rank. In contrast, the lowest gross tuber yield was recorded in the seed tuber weight of 10 ± 2 g (16.33 t ha^{-1}). The gross tuber yield was lower in smaller weight seed tuber because of producing minimum tuber weight $hill^{-1}$. 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; Bayorbor and Gumah, 2007; Verma *et al.,* 2007; Gulluoglu and Aroglu, 2009) who observed that tuber yield decreased with decreasing seed tuber weight.

The effect of plant spacing on gross tuber yield in potato was significant (Table 13). The highest gross tuber yield was observed in the plant spacing of 60 cm × 20 cm (23.92 t ha^{-1}) that was identical to the plant spacing of 60 cm × 25 cm (23.18 t ha^{-1}). Although the plant spacing of 60 cm × 25 cm showed the highest tuber yield $hill^{-1}$ yet it produced the second highest tuber yield ha^{-1} due to lesser number of plants per unit area as compared to 60 cm × 20 cm plant spacing. The lowest tuber yield was recorded in closer plant spacing of 60 cm × 15 cm (22.20 t ha^{-1}). Again, lower tuber yield per plant as well as per unit area under densely populated condition was might be due to lesser amount of assimilate produced by the plants through lesser photosynthetic area $plant^{-1}$ and competition of nutrients uptake by the plants. This result is consistent with many workers in potato (Ghosh *et al*., 2002; Yenagi *et al.,* 2002; Wadhwa *et al*., 2002; Khurana and Bhutani, 2003; Suman *et al.,* 2003; Cornwall, 2004; Yenagi *et al.,* 2005; Kushwah and Singh, 2008).

The interaction effect of seed tuber weight and plant spacing on gross tuber yield ha^{-1} was significant (Table 14). Results revealed that gross tuber yield decreased with decreasing plant spacing in the tuber weight of 40 ± 2 g where as reverse trend was observed in case of smaller weight tuber, 10 ± 2 g. The highest gross tuber yield ha^{-1} was recorded in the treatment combination of 60 cm × 25 cm plant spacing with 40 ± 2 g seed tuber (29.10 t ha^{-1}) followed by the treatment combination of 60 cm × 20 cm plant spacing with 30 ± 2 g seed tuber (28.20 t ha^{-1}). The lowest gross tuber yield ha^{-1} was recorded in the treatment combination of 60 cm × 25 cm plant spacing with 10 ± 2 g seed tuber (14.70 t ha^{-1}) that was statistically similar to the treatment combination of 60 cm × 20 cm plant spacing with 10 ± 2 g seed tuber (16.70 t ha^{-1}) and 60 cm × 15 cm plant spacing with 10 ± 2 g seed tuber (17.60 t ha^{-1}).

4.3.5 Marketable yield of tuber

The effect of seed tuber weight on marketable yield of tubers has been present in (Fig. 1).

Result revealed that marketable tuber yield increased with increasing seed tuber weight till 30 ± 2 g seed tuber followed by slight decline. The highest marketable yield of tubers was observed in the seed tuber size of 30 ± 2 g (21.28 t ha^{-1}) followed by the seed tuber weight of 40 ± 2 g (20.31 t ha^{-1}) with same statistical rank. It was primarily due to high food reserves in large seed tubers which ultimately contributed to produce high yield through increase vegetative growth of plants and rapid development of tubers. The lowest marketable tuber yield was recorded in the seed

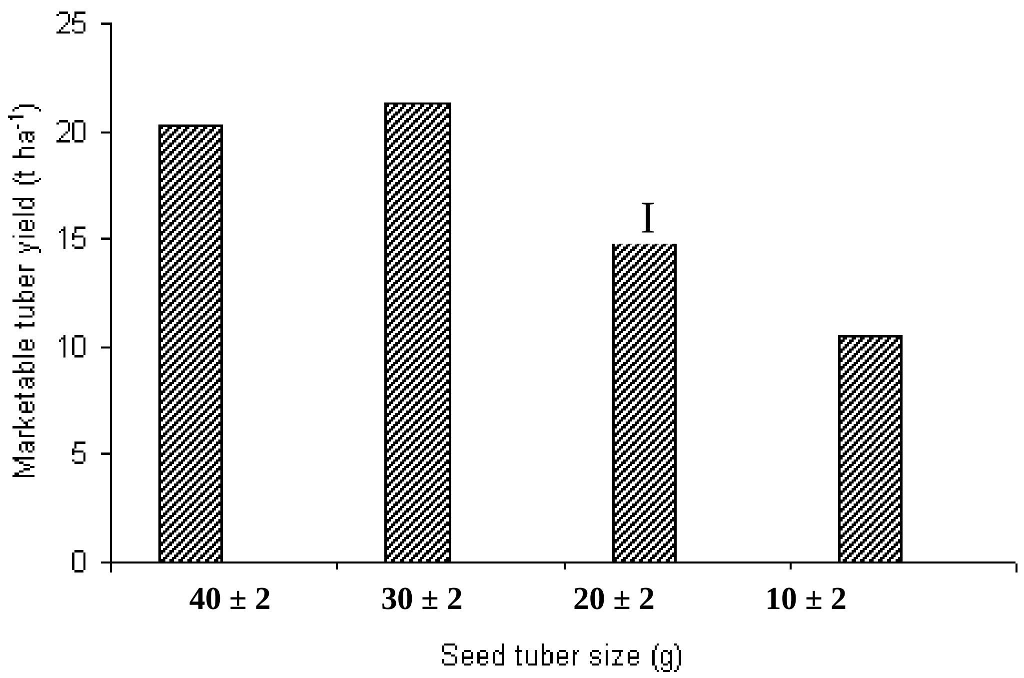

Fig. 1. Effect of seed tuber size on marketable yield in potato. Vertical bar represent SE value(1.5).

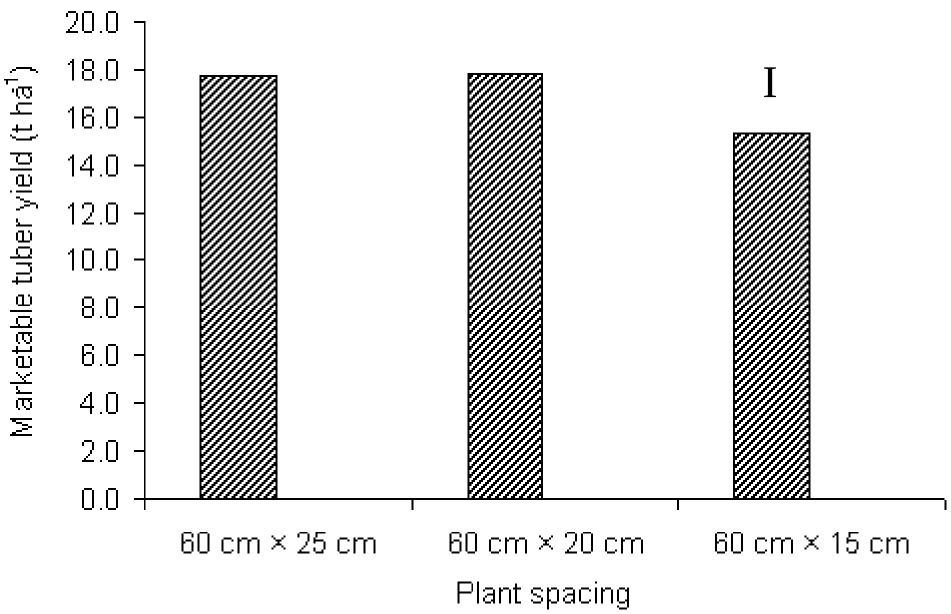

Fig. 2. Effect of plant spacing on marketable yield in potato. Vertical bar represent SE value(1.3).

tuber weight of 10 ± 2 g (10.52 t ha $^{-1}$). The marketable tuber yield was lower in smaller weight seed 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; Bayorbor and Gumah, 2007; Verma *et al.*, 2007; Gulluoglu and Aroglu, 2009) who observed that marketable tuber yield decreased with decreasing seed tuber weight.

The effect of plant spacing on marketable tuber yield in potato presented in (Fig.2). The figure shows that the highest marketable tuber yield was observed in the plant spacing of 60 cm × 20 cm (17.79 t ha^{-1}) that was identical to the plant spacing of 60 cm × 25 cm (17.75 t ha^{-1}). The lowest marketable tuber yield was recorded in closer plant spacing of 60 cm × 15 cm (15.32 t ha^{-1}). Again, lower marketable tuber yield per unit area under densely populated condition was might be due to lesser amount of assimilate produced by the plants through lesser photosynthetic area plant^{-1} and competition of nutrients uptake by the plants. This result is consistent with many workers in potato (Khurana and Bhutani, 2003; Suman *et al.,* 2003; Cornwall, 2004; Yenagi *et al.*, 2005; Kushwah and Singh, 2008).

The interaction effect of seed tuber size and plant spacing on marketable tuber yield ha^{-1} was significant (Fig. 3). The highest marketable tuber yield ha^{-1} was recorded in the treatment combination of 60 cm × 25 cm plant spacing with 40 ± 2 g seed tuber (23.28 t ha^{-1}) followed by the treatment combination of 60 cm × 25 cm plant spacing with 30 ± 2 g seed tuber (22.96 t ha^{-1}). The lowest marketabletuber yield ha^{-1} was recorded in the treatment combination of 60 cm ×

25 cm plant spacing with 10 ± 2 g seed tuber (10.14 t ha^{-1}) that was statistically similar to the treatment combination of 60 cm × 20 cm plant spacing with 10 ± 2 g seed tuber (10.85 t ha^{-1}) and 60 cm × 15 cm plant spacing with 10 ± 2 g seed tuber (10.56 t ha^{-1}).

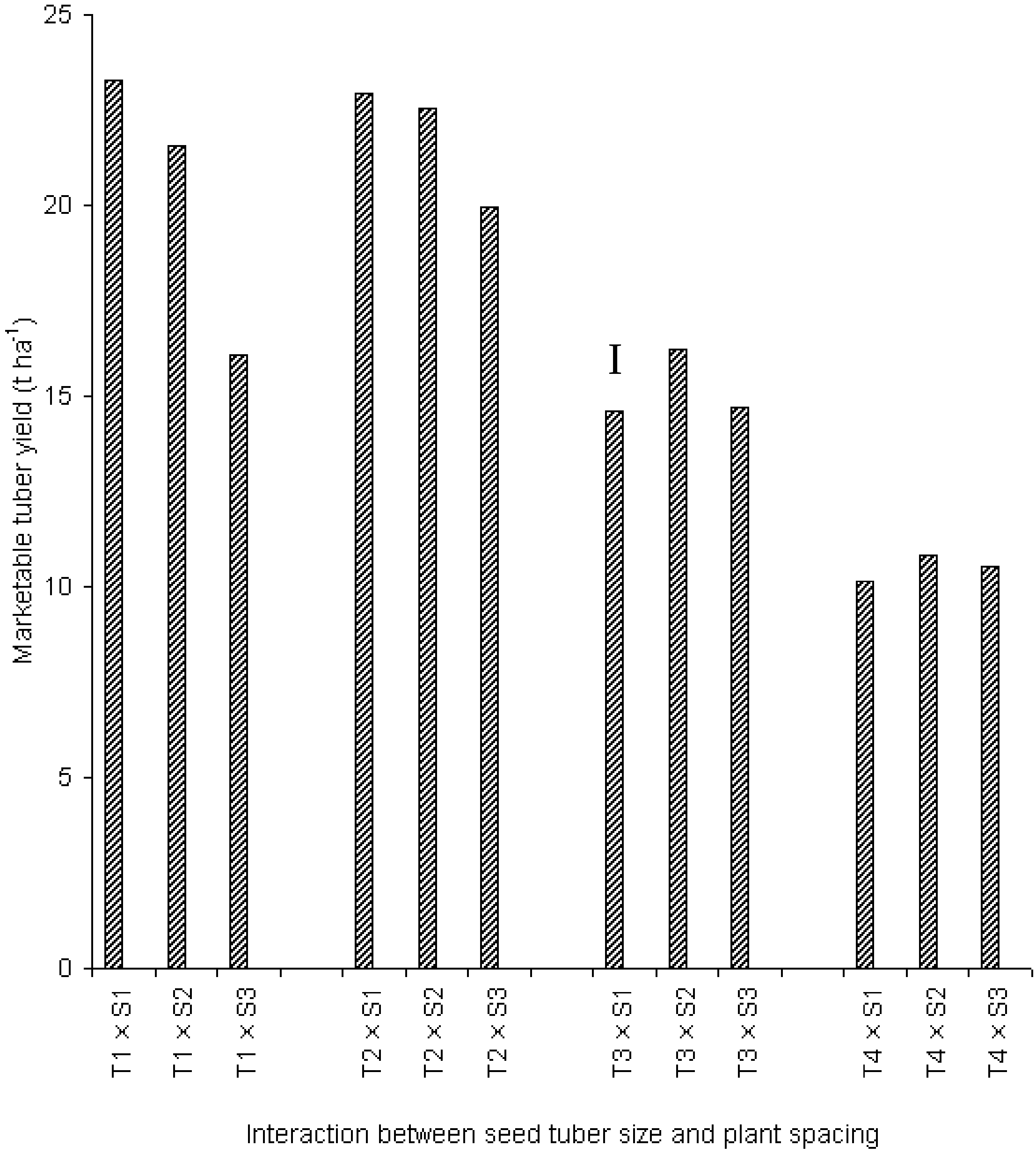

Fig. 3. Interaction effect of seed tuber size and plant spacing on tuber marketable yield in potato. Vertical bar represents SE value(0.74).

T_1 = 40 ± 2 g ; T_2 = 30 ± 2 g ; T_3 = 20 ± 2 g ; T_4 = 10 ± 2 g ; S_1 = 60 cm × 25 cm ;S_2 = 60 cm ×20cm ;S_3 = 60cm × 15cm.

4.3.6 Non-marketable yield of tuber

There was a significant difference in non-marketable yield of tubers due to seed tuber size (Fig. 4). The highest non-marketable yield of tubers was observed in the seed tuber size of 20 ± 2 g (7.15 t ha^{-1}) followed by the seed tuber size of 40 ± 2 g (6.15 t ha^{-1}). The lowest non-marketable tuber yield was recorded in the seed tuber size of 30 ± 2 g (5.40 t ha^{-1}). Verma *et al.* (2007) reported that non-marketable yield was lower in larger seed tuber than smaller seed tuber in potato.

Non-marketable tuber yield in potato was significantly influenced by plant spacing (Fig. 5). Results showed that non-marketable tuber yield increased with decreasing plant spacing. The highest non-marketable tuber yield was observed in the plant spacing of 60 cm × 15 cm (6.80 t ha^{-1}) followed by the plant spacing of 60 cm × 20 cm (6.12 t ha^{-1}). The lowest non-marketable tuber yield was recorded in wider spacing of 60 cm × 25 cm (4.46 t ha^{-1}). Again, lower non-marketable tuber yield per unit area under thin populated condition was might be due to available amount of assimilate produced by the plants through increase photosynthetic area $plant^{-1}$ and less competition of nutrients uptake by the plants. This result is consistent with many workers in potato (Suman *et al.*, 2003; Cornwall, 2004; Yenagi *et al.*, 2005; Kushwah and Singh, 2008).

The interaction effect of seed tuber size and plant spacing on non-marketable tuber yield ha^{-1} was significant (Fig. 6). The highest non-marketable tuber yield ha^{-1} was

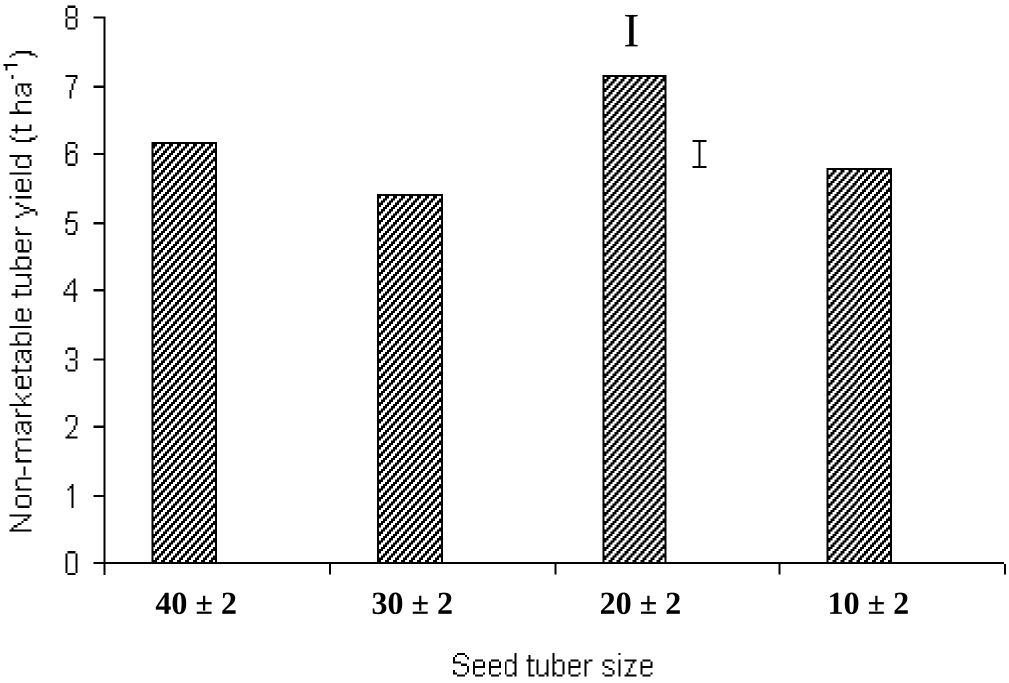

Fig. 4. Effect of seed tuber size on non-marketable yield in potato. Vertical bar represent SE value(0.51).

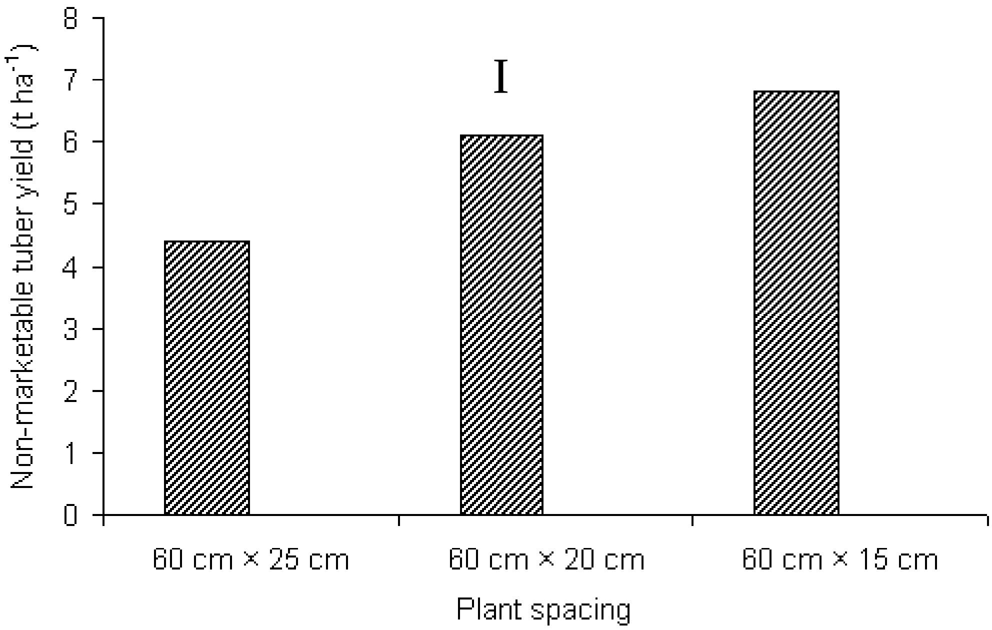

Fig. 5. Effect of plant spacing on non-marketable yield in potato. Vertical bar represent SE value(0.52).

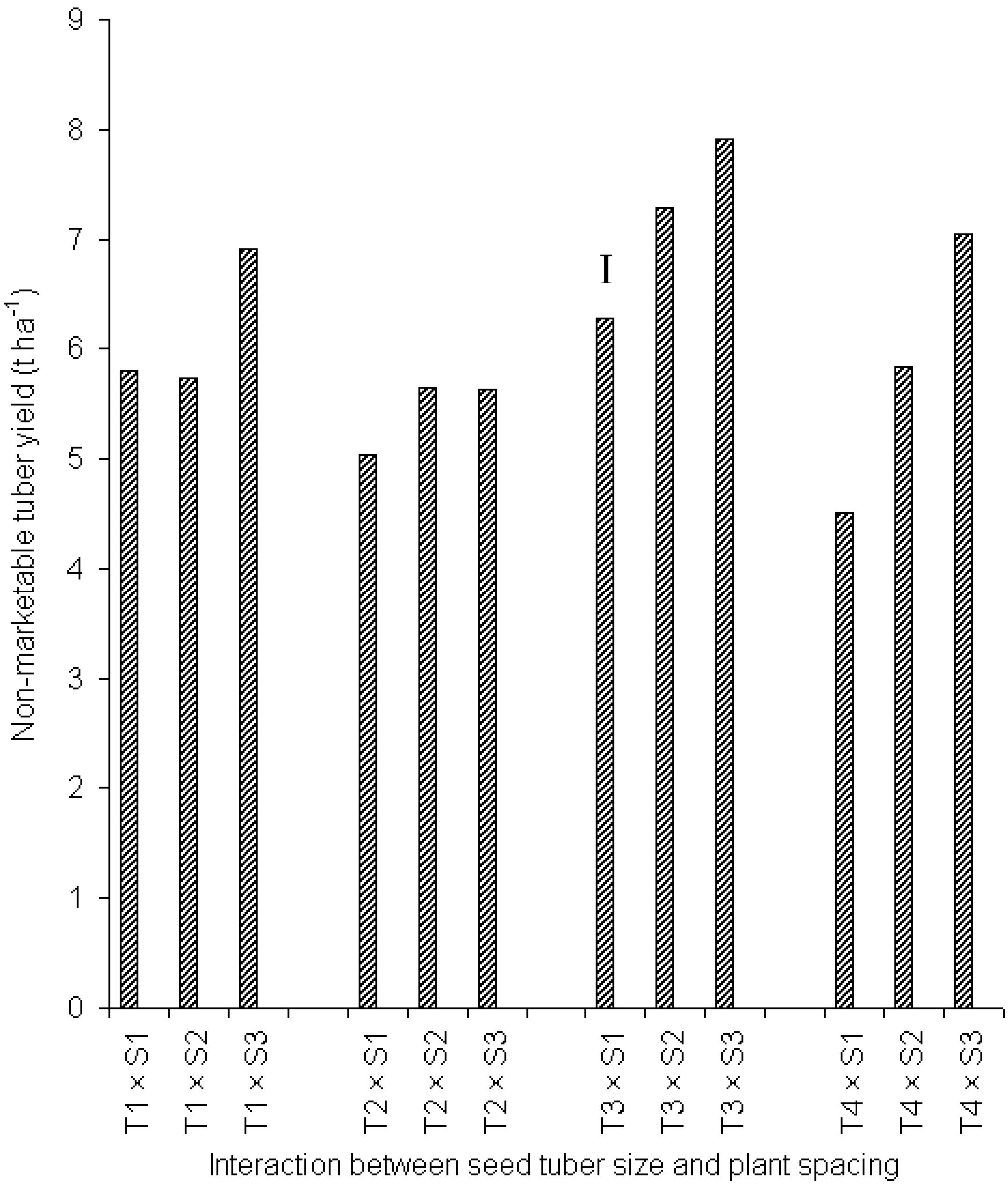

Fig. 6. Interaction effect of seed tuber size and plant spacing on non-marketable tuber yield in potato. Vertical bar represents SE value(0.25).

T_1 = 40 ± 2 g ; T_2 = 30 ± 2 g ; T_3 = 20 ± 2 g; T_4 = 10 ± 2 g ; S_1 = 60 cm × 25 cm; S_2 = 60 cm × 20 cm; $S_{3=}$ 60 cm ×15cm recorded in the treatment combination of 60 cm × 15 cm plant spacing with 20 ± 2 g seed tuber (7.91 t ha^{-1}) followed by the treatment combination of 60 cm × 25 cm plant spacing with 20 ± 2 g seed tuber (7.28 t ha^{-1}). The lowest non-marketable tuber yield ha^{-1} was recorded in the treatment combination of 60 cm × 25 cm plant spacing with 10 ± 2 g seed tuber (4.51 t ha^{-1}).

4.4 Size grade distribution of tubers

The harvested tubers were categorized into four grades according to size by number *viz*., Grade A-tuber greater than 55 mm size, Grade B-tubers in between 35-55 mm in size, Grade C- tubers in between 20-35 mm in size and Grade D-tubers less than 20 mm. It was observed that there was significant variation in size grade of tubers due to different seed tuber weight (Table 15). The highest number of Grade-A and Grade-B tuber was recorded in the seed tuber size of 40 ± 2 g (18.4% and 38.83% for grade-A and grade-B, respectively). The highest number of Grade-C and Grade-D tuber was recorded in the seed tuber size of 10 ± 2 g (45.04% and 37.37% for grade-C and grade-D, respectively). The lowest number of grade-C and grade-D tubers were recorded in the seed tuber size of 40 ± 2 g (31.13%% and 11.68% for grade-C and grade-D, respectively). Grewal *et al*. (1992) reported that larger seed tuber produced lesser number of C and D-grade tuber than smaller seed tuber which supported present experimental results.

The effect of spacing on tuber size was significantly affected by plant spacing (Table 15). Results revealed that greater number of larger tuber (grade-A & B) was produced in wider spacing, 60 cm × 25 cm (10.5 and 34.70% for grade-A and

Table 15. Effects of seed tuber weight and plant spacing on the grade of tubers by number in potato

Treatments	Grade of tubers (%) by number			
Tuber weight (g)	< 20 mm	20-35 mm	35-55 mm	> 55 mm
40 ± 2	11.68 d	31.13 d	38.83 a	18.4 a
30 ± 2	18.53 c	37.07 c	36.30 b	8.10 b
20 ± 2	21.40 b	41.50 b	31.73 c	5.37 c
10 ± 2	37.37 a	45.04 a	17.13 d	0.46 d
F-test	**	**	**	**
SE	0.677	0.993	0.799	0.225
Spacing				
60 cm × 25 cm	20.01 b	34.78 c	34.70 a	10.5 a
60 cm × 20 cm	20.90 b	37.33 b	32.88 a	8.90 b
60 cm × 15 cm	25.83 a	43.95 a	25.43 b	4.80 c
F-test	**	**	**	**
SE	0.586	0.860	0.692	0.195
CV (%)	9.14	7.70	7.74	8.38

In a column, means followed by same letter (s) do not differ significantly at 1% level of significant by DMRT; ** indicates significant at 1% levels of probability.

grade-B, respectively) followed by the plant spacing of 60 cm × 20 cm. In contrast, the lowest number of larger tuber was produced in closer spacing, 60 cm × 15 cm (4.80% and 25.43% for grade-A and grade-B, respectively). On the contrary, the highest number of smaller size tuber was produced in the closer spacing of 60 cm × 15 cm (43.95% and 25.83% for grade-C and grade-D, respectively). Wadhwa *et al*. (2000) reported that wider spacing produced higher number of large tuber than closer spacing which supported the present experimental results.

The interaction effect of seed tuber size and plant spacing on tuber grade distribution was significant (Table 16). The highest number of Grade-A and Grade-B tuber was recorded in 40 ± 2 g seed tuber with plant spacing of 60 cm × 30 ± 2 cm (24.10% and 45.20% for grade-A and grade-B, respectively). The highest number of Grade-C tuber was recorded in 10 ± 2 g seed tuber with plant spacing of 60 cm × 25 cm (47.31%) and Grade-D tuber was recorded in 10 g seed tuber with plant spacing of 60 cm × 15 cm (42.0%). However, the lowest number of Grade-D and Grade-C tuber was recorded in 40 ± 2 g seed tuber with plant spacing of 60 cm × 25 cm (9.74% and 21.0% for grade-D and grade-C, respectively).

4.5 Economic analysis

Economic ananlysis was done with a view to observing the comparative cost and benefit under different treatment combinations of seed tuber size and plant spacing. 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

Table 16. Interaction effects of tuber weight and spacing on the grade of tubers by number in potato

Interaction (Tuber weight × plant spacing)	Grade of tubers (%) by number			
	< 20 mm	20-35 mm	35-55 mm	> 55 mm
$T_1 \times S_1$	9.74 g	21.00 f	45.20 a	24.10 a
$T_1 \times S_2$	10.11 g	29.50 e	40.40 b	20.00 b
$T_1 \times S_3$	15.20 f	42.90 ab	30.90 d	11.00 c
$T_2 \times S_1$	15.40 f	32.80 de	41.20 ab	10.60 c
$T_2 \times S_2$	18.20 ef	35.60 cd	37.10 bc	9.10 d
$T_2 \times S_3$	22.00 cd	42.80 ab	30.60 d	4.60 f
$T_3 \times S_1$	19.30 de	38.00 b-d	36.00 c	6.70 e
$T_3 \times S_2$	20.80 c-e	39.20 bc	34.00 cd	6.00 e
$T_3 \times S_3$	24.10 c	47.30 a	25.20 e	3.40 g
$T_4 \times S_1$	35.60 b	47.31 a	16.40 fg	0.69 h
$T_4 \times S_2$	34.50 b	45.00 a	20.00 f	0.50 h
$T_4 \times S_3$	42.00 a	42.80 ab	15.00 g	0.20 h
F-test	*	**	**	**
SE	1.173	1.720	1.385	0.390
CV (%)	9.14	7.70	7.74	8.38

In a column, means followed by same letter (s) do not differ significantly at 5% or 1% Level of significant by DMRT; *, ** indicate significant at 5% and 1% levels of probability, respectively. T_1 = 40 ± 2 g; T_2 = 30 ± 2 g; T_3 = 20 ± 2 g; T_4 = 10 ± 2 g; S_1 = 60 cm × 25 cm; S_2 = 60 cm × 20 cm; S_3 = 60 cm × 15 cm.

were then enumerated into cost per hectare. The details economic analysis have been presented in Appendix-XVI.

Variation in cost of production was noticed due to the cost of seed tuber and different plant spacing (Table 17). The total cost of cultivation ranged between 142681 and 279121 Tk./ha. The cultivation cost increased with increasing seed tuber size and decreasing plant spacing. The highest cost of production was involved when used 40 ± 2 g seed tuber with closer spacing of 60 cm × 15 cm (Tk 279121 ha^{-1}). The lowest cost of production was involved when used 10 ± 2 g seed tuber with wider spacing of 60 cm × 25 cm (142681 Tk./ha). The highest gross return was obtained from the treatment combination of 40 ± 2 g seed tuber with wider spacing of 60 cm × 25 cm (727500 Tk./ha) that was apparently similar to the treatment combination of 30 ± 2 g seed tuber with plant spacing of 60 cm × 20 cm (705000 Tk./ha) and the lowest gross return was found from the treatment combination of 10 ± 2 g seed tuber with wider spacing of 60 cm × 25 cm (367500 Tk./ha). However, the highest net profit was obtained from the treatment combination of 40 ± 2 g seed tuber with wider spacing of 60 cm × 25 cm (513979 Tk./ha) that was apparently similar to the treatment combination of 30 ± 2 g seed tuber with plant spacing of 60 cm × 20 cm (501959 Tk./ha). The maximum benefit-cost ratio was observed in those two treatment combination (2.41-2.47). The lowest net profit and benefit-cost ratio was observed in the treatment combination of 10 ± 2 g seed tuber with plant spacing of 60 cm × 25 cm (224819 Tk. ha^{-1} and 1.58, respectively). For economic point of view, results indicated that the seed tuber size of 30 ± 2 g with plant spacing of 60 cm × 20 cm was more profitable than the other treatment combination.

Table 17. Economic analysis in potato production as influenced by tuber size and spacing

Treatments	Seed rate (kg ha^{-1})	Cost of cultivation* (Tk. ha^{-1})	Gross return * (Tk. ha^{-1})	Net profit (Tk. ha^{-1})	Benefit cost ratio
40 ± 2 g size tuber					
60 cm × 25 cm	2333	213521	727500	513979	2.41
60 cm × 20 cm	2917	238561	682500	443939	1.86
60 cm × 15 cm	3889	279121	575000	295879	1.06
30 ± 2 g size tuber					
60 cm × 25 cm	1667	185201	657500	472299	2.55
60 cm × 20 cm	2083	203041	705000	501959	2.47
60 cm × 15 cm	2778	232041	640000	407959	1.76
20 ± 2 g size tuber					
60 cm × 25 cm	1333	171001	522500	351499	2.05
60 cm × 20 cm	1667	185321	587500	402179	2.17
60 cm × 15 cm	2222	208481	565000	356519	1.71
10 ± 2 g size tuber					
60 cm × 25 cm	667	142681	367500	224819	1.58
60 cm × 20 cm	833	149801	417500	267699	1.78
60 cm × 15 cm	1110	161401	440000	278599	1.73

* Details shown in Appendix XIII

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the field of Sher-e-Bangla Agricultural University, Dhaka, during the period from 05 December 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 4 weight of seed tubers *viz*., 40 ±2, 30 ± 2, 20 ± 2 and 10 ± 2 g and 3 plant spacing *viz*., 60 cm × 25 cm, 60 cm × 20 cm and 60 cm × 15 cm. The experiment was laid out in randomized complete block design factorial with three replications. The collected data were analyzed statistically and the means were separated by DMRT at 5% level of probability.

The morpho-physiological parameters such as plant height, stems hill^{-1}, number of leaves hill^{-1}, leaf length and breadth, leaf area (LA) plant^{-1} and leaf area index (LAI), total dry mass (TDM) plant^{-1} and TDM m^{-2} were significantly influenced by seed tuber weight at different growth stages in potato. Results revealed that plant height, stems hill^{-1}, LA plant^{-1} and LAI, TDM plant^{-1} and TDM m^{-2} increased significantly with increasing seed tuber weight till the seed tuber weight of 30 ± 2 g followed by increased non-significantly. The leaves hill^{-1}, leaf length and breadth increased significantly with increasing seed tuber weight till 40 ± 2 g. The highest plant height, stems and leaves hill^{-1}, leaf length and breadth, LA, LAI, TDM plant^{-1} and TDMm^{-2} was observed in the tuber weight of 40 ± 2 g followed by the tuber weight of 30 ± 2 g. In contrast, the shortest plant height, lowest stems and leaves hill^{-1}, leaf length and breadth, LA plant^{-1}, LAI, TDM plant^{-1} and TDM m^{-2} was observed in the smaller weight seed tuber, 10 ± 2 g.

The effect of seed tuber weight on growth paramers such as crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) was significant. Results showed that growth parameters were greater in 60-75 DAS than in 75-90 DAS. AT 60-75 DAS, the CGR increased with increasing seed tuber weight where as NAR increased with increasing seed tuber weight till 30 ± 2 g followed by a decline. The RGR showed no sequence like CGR and NAR. At 60-75 DAS, the highest CGR was recorded in the larger tuber weight of 40 ± 2 g while at 75-90 DAS, it was the highest in the tuber weight of 20 ± 2g. The highest NAR was observed in the tuber weight of 30 ± 2 g followed by the tuber weight of 40 ± 2 g.

The effect of seed tuber weight on yield attributes such as tubers hill^{-1} and single tuber weight and tuber yield (gross, marketable and non-marketable yield) was significant. Results revealed that tubers hill^{-1}, single tuber weight, seed weight hill^{-1}, gross tuber yield ha^{-1} and marketable tuber yield ha^{-1} increased with increasing seed tuber weight till the tuber weight of 30 ± 2 g followed by a slide decline. The highest gross and marketable tuber yield was observed in the tuber weight of 30 ± 2 g due to increased bearing of tubers hill^{-1} and larger tuber. In contrast, the lowest tuber yield of both gross and marketable was recorded in smaller weight seed tuber of 10 ± 2 g due to production of fewer tubers hill^{-1} as well as smaller weight tubers. Non-marketable tuber yield had shown no regularity like gross and marketable tuber yield due to variation in seed tuber weight.

There was significant variation in size grade of tubers due to different seed tuber weight. The highest number of Grade-A and Grade-B tuber was recorded in the seed tuber weight of 40 ± 2 g (18.4% and 38.83% for grade-A and grade-B, respectively). The highest number of Grade-C and Grade-D tuber was recorded in the seed tuber weight of 10 ± 2 g (45.04% and 37.37% for grade-C and grade-D, respectively). The lowest number of grade-C and grade-D tubers were recorded in the seed tuber weight of 40 ± 2 g (31.13%% and 11.68% for grade-C and grade-D, respectively).

Variation in cost of production was noticed due to the varied cost of seed tuber and different plant spacing. The cultivation cost increased with increasing seed tuber weight and decreasing plant spacing. The highest cost of production was involved when used 40 ± 2 g seed tuber with closer spacing of 60 cm × 15 cm (279121 Tk./ha). The lowest cost of production was involved when used 10 ± 2 g seed tuber with wider spacing of 60 cm × 25 cm (142681 Tk./ha). However, the highest net profit was obtained from the treatment combination of 30 ± 2 g seed tuber with wider spacing of 60 cm × 25 cm (513979 Tk./ha) that was apparently similar to the treatment combination of 30 ± 2 g seed tuber with plant spacing of 60 cm × 20 cm (501959 Tk./ha). Again, the maximum benefit-cost ratio was observed in those two treatment combination (2.41-2.47). But cost involvement was lower in latter treatment combination than the earlier treatment combination.

The effect of plant spacing on morpho-physiological, growth, yield attributes and tuber yield was significant except CGR at 75-90 DAP, RGR at 60-75 DAP and NAR at 60-75 DAP. Results showed that stems and leaves hill^{-1}, leaf length and breadth, LA, TDM plant^{-1}, tubers hill^{-1}, single tuber weight and tuber weight hill^{-1} increased with increasing plant spacing while reverse trend was observed in plant height, LAI, TDM m^{-2} and CGR. The tallest plant, the highest LAI, TDM m^{-2} and CGR were recorded in closer spacing of 60 cm × 15 cm while the shortest plant, the lowest LAI, TDM m^{-2} and CGR were recorded in thw wider spacing of 60 cm × 25 cm. The highest stems and leaves $hill^{-1}$, leaf length and breadth, LAI, TDM $plant^{-1}$, tubers $hill^{-1}$, single tuber weight and tuber weight $hill^{-1}$ were observed in the wider spacing of 60 cm × 25 cm and the lowest of the above parameters was observed in the closer spacing of 60 cm × 15 cm. The highest gross and marketable tuber yield ha^{-1} was observed in the plant spacing of 60 cm × 20 cm and the lowest was recorded in the closer spacing of 60 cm × 15 cm due to lower tubers $hill^{-1}$, smaller tuber weight and tuber weight $hill^{-1}$. However, the larger tuber by number was greater in wider spacing than the narrower spacing.

The interaction effect of seed tuber size and plant spacing on all the studied parameters such as morpho-physiological, growth, yield attributes and yield was significant whereas the effect of seed tuber size and plant spacing had no significant influence on LAI at 60 DAP and RGR at 60-75 DAP. The highest gross and marketable tuber yield was observed in the treatment combination of 40 ± 2 g seed tuber with the plant spacing of 60 cm × 25 cm. But economic point of view, the seed tuber weight of 30 ± 2 g with plant spacing of 60 cm × 20 cm was more profitable than the other treatment combination.

Based on the experimental results, it may be concluded that-

i) The effect of seed tuber weight and plant spacing had positive effect on morphological and growth characters, yield attributes and yield in potato; and

ii) The tuber size of 30 ± 2 g with plant spacing of 60 cm × 20 cm seemed to be more suitable for getting higher tuber yield which reflected better in economic analysis.

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APPENDICES

Appendix I. Physical and chemical properties of soil of the experimental plots

A. Physical properties of soil	
% sand (0.2-.02 mm)	21.75
% silt (0.02-.002 mm)	66.60
% clay (< 0.002 mm)	11.65
Textural class	Silty loam
Consistency	Granular
B. Chemical properties of soil	
Soil pH	6.53
Organic carbon (%)	1.68
Organic matter (%)	1.28
Total nitrogen (%)	0.17
Available phosphorus (ppm)	8.05
Exchangeable potassium (me/100 g soil)	0.16
Available sulphur (ppm)	11.43

Appendix II. Average monthly rainfall, air temperature and relative humidity during the experimental period between November 2008 to March, 2009 at the SAU area, Dhaka

Month	Monthly average air temperature (^{0}C)			Average rainfall (mm)	Average relative humidity (%)	Average daily sunshine (hrs)
	Maximum	Minimum	Average			
October	31.27	24.14	27.71	18.0	86.2	8.65
November	29.49	19.55	24.52	00.0	84.3	8.45
December	26.52	13.19	19.85	00.0	80.8	6.67
January	23.43	12.93	18.18	00.0	78.0	7.20
February	27.34	16.41	21.87	06.6	73.9	8.18
March	29.61	20.57	25.09	13.6	80.6	7.66
April	30.56	22.14	26.35	96.6	78.57	7.42

Source: Weather Yard, SAU, Dhaka

Appendix III. Analysis of variance (mean square) on plant height and stem number hill^{-1} of potato at different days after planting

Source of variation	df	Plant height (cm)			Stems hill^{-1}
		60 DAP	75 DAP	90 DAP	90 DAP
Replication	2	15.19	2.08	1.76	0.034
Seed tuber weight (A)	3	244.71 **	330.9 **	493.9 **	18.26 **
Plant spacing (B)	2	17.16 *	32.17 *	54.08 **	1.44 **
A×B	6	8.97 *	13.94 *	15.24 *	0.11 *
Error	22	4.74	6.08	7.04	0.031

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix IV. Analysis of variance (mean square) on leaf production and leaf characters of potato at different days after planting

Source of variation	df	Leaves hill^{-1}			Leaf characters at 75 DAP	
		60 DAP	75 DAP	90 DAP	Leaf length (cm)	Leaf breadth (cm)
Replication	2	1.75	1.08	0.63	0.231	0.035
Seed tuber weight (A)	3	1898.4	1927.4*	1712.7*	48.83 **	4.872 **
Plant spacing (B)	2	**	*	*	3.26 *	0.327 *
A×B	6	82.69 **	104.16*	426.1**	1.55 *	0.159 *
Error	22	16.19 *	*	52.64 **	0.89	0.075
		7.93	15.52 *	7.87		
			7.27			

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix V. Analysis of variance (mean square) on leaf area of potato at different days after planting

Source of variation	df	Leaf area plant^{-1} (cm^2)		
		60 DAP	**75 DAP**	**90 DAP**
Replication	2	3939.6	8025.3	2700.0
Seed tuber weight (A)	3	1598262.2 **	2042814.2 **	1313037.7 **
Plant spacing (B)	2	94017.0 **	368269.8 **	216072.2 **
A×B	6	39395.0 *	128547.8 *	35093.9 *
Error	22	15635.0	51374.4	16809.1

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix VI. Analysis of variance (mean square) on leaf area index of potato at different days after planting

Source of variation	df	Leaf area index		
		60 DAP	**75 DAP**	**90 DAP**
Replication	2	0.014	0.008	0.010
Seed tuber weight (A)	3	1.243 **	1.50 **	1.011 **
Plant spacing (B)	2	1.646 **	1.623 **	0.794 **
A×B	6	0.008 ^{ns}	0.044 *	0.063 *
Error	22	0.029	0.020	0.025

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix VII. Analysis of variance (mean square) on total dry mass plant^{-1} of potato at different days after planting

Source of variation	df	Total dry mass plant^{-1} (g)		
		60 DAP	75 DAP	90 DAP
Replication	2	5.26	12.23	1.083
Seed tuber weight (A)	3	1844.2 **	6768.28 **	7453.2 **
Plant spacing (B)	2	55.09 **	222.59 **	643.31 **
A×B	6	19.23 *	31.43 *	159.04 *
Error	22	7.827	13.97	73.08

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix VIII. Analysis of variance (mean square) on total dry mass m^{-2} of potato at different days after planting

Source of variation	df	Total dry mass m^{-2} (g)		
		60 DAP	75 DAP	90 DAP
Replication	2	102.62	918.75	0.750
Seed tuber weight (A)	3	144392.1 **	530846.2 **	615423.7 **
Plant spacing (B)	2	43642.1 **	147161.8 **	156934.8 **
A×B	6	1289.51 *	2763.51 *	4009.0 *
Error	22	598.4	983.6	1915.5

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix IX. Analysis of variance (mean square) on growth parameters of potato at different days after planting

Source of variation	df	Crop growth rate (g m^{-2} d^{-1})		Relative growth rate (mg g^{-1} d^{-1})		Net assimilation rate (mg cm^{-2} d^{-1})
		60-75 DAP	75-90 DAP	60-75 DAP	75-90 DAP	60-75 DAP
Replication	2	1.17	0.281	0.58	0.106	11.08
Seed tuber weight (A)	3	558.4**	84.08**	89.75	225.7**	3913.4**
Plant spacing (B)	2	136.1**	1.83^{ns}	**	37.89**	22.09 ns
A×B	6	5.11 *	29.43**	4.89^{ns}	41.34**	122.61 *
Error	22	2.39	0.701	2.67^{ns}	2.00	74.63
				8.67		

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix X. Analysis of variance (mean square) on yield attributes and yield in potato.

Source of variation	df	Tubers $hill^{-1}$ (no.)	Single tuber weight (g)	Tuber weight $hill^{-1}$ (g)
Replication	2	0.187	7.964	31.21
Seed tuber weight (A)	3	4.280 **	964.2 **	54572.8 **
Plant spacing (B)	2	4.116 **	167.1 **	21799.6 **
A×B	6	0.754 **	24.10 *	3656.4 **
Error	22	0.189	10.29	569.6

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix XI. Analysis of variance (mean square) on yield in potato.

Source of variation	df	Gross tuber yield (t ha^{-1})	Marketable tuber yield (t ha^{-1})	Non-marketable tuber yield (t ha^{-1})
Replication	2	4.781	3.676	0.283
Seed tuber weight (A)	3	225.21 **	185.30 **	5.380 **
Plant spacing (B)	2	10.97 **	32.22 **	4.616 **
A×B	6	12.87 **	11.55 **	0.884 **
Error	22	3.31	2.66	0.200

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix XII. Analysis of variance (mean square) on the grade of tubers by number in potato.

Source of variation	df	Grade of tubers (%) by number			
		< 20 mm	20-35 mm	35-55 mm	> 55 mm
Replication	2	8.689	4.34	6.938	0.964
Seed tuber weight (A)	3	1064.1 **	323.7 **	846.82 **	513.6 **
Plant spacing (B)	2	117.7 **	269.07 **	289.7 **	104.4 **
A×B	6	9.49 *	89.50 **	24.628 **	22.945 **
Error	22	4.13	8.88	5.756	0.458

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix XIII. Production cost of potato per hectare

A. Input cost

1. Labour	300 labours × 150/-	= 45000/-
2. Land preparation		= 3400/-
3. Fertilizer		
(a) Cowdung 10 t ha^{-1} @ 700/- per ton		= 7000/-
(b) Urea 300 kg ha^{-1} @ 11.00/- per kg		= 3300/-
(c) TSP 220 kg ha^{-1} @ 25.0/- per kg		= 5500/-
(d) MP 250 kg ha^{-1} @ 22.0/- per kg		= 5500/-
(e) Gypsum 100 kg ha^{-1} @ 10.0/- per kg		= 1000/-
(f) Zinc sulphate 25 kg ha^{-1} @ 80.0/- per kg		= 2250/-
(g) Boric acid 15 kg ha^{-1} @ 100.0/- per kg		= 1500/-
(h) Irrigation three times @ 1000/- per kg		= 3000/-
(i) Pesticides		= 5400/-
(j) Seed cost variable (Seed rate 40.0/- per kg)		---
(k) Land leez		= 25000/-
Total		= 107850/-

* Seed tuber sell Tk. 30.0 ha^{-1}