EFFECT OF PLANTING DATES AND SPACING ON YIELD AND EXPORT QUALITY OF POTATO

SUSHMITA SEN TULY

INSTITUTE OF SEED TECHNOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

JUNE, 2020

EFFECT OF PLANTING DATES AND SPACING ON YIELD AND EXPORT QUALITY OF POTATO

BY

SUSHMITA SEN TULY

REGISTRATION NO. : 13-05255

A Thesis

Submitted to the Institute of Seed Technology,
Sher-e-Bangla Agricultural University, Dhaka-1207,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)

IN

SEED TECHNOLOGY

SEMESTER: JANUARY-JUNE, 2020

Approved by:

Prof. Dr. Tuhin Suvra Roy
Supervisor
Department of Agronomy
Sher-e-Bangla Agricultural University
Dhaka-1207

Dr. Bimal Chandra Kundu
Co-supervisor
Principle Scientific Officer
Tuber Crops Research Centre
Bangladesh Agricultural Research Institute

Prof. Dr. Md. Ismail Hossain
Director
Institute of Seed Technology
& Chairman
Examination Committee

INSTITUTE OF SEED TECHNOLOGY

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled '**Effect of Planting Dates and Spacing on Yield and Export Quality of Potato**' submitted to the Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in SEED TECHNOLOGY**, embodies the results of a piece of bona fide research work carried out by **SUSHMITA SEN TULY**, Registration No. **13-05255** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Dhaka, Bangladesh

Prof. Dr. Tuhin Suvra Roy
Supervisor
Department of Agronomy
Sher-e-Bangla Agricultural University
Dhaka-1207

DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises are due to the "Omnipotent Creator" for His never-ending blessing, the author deems it a prodigious pleasure to express her profound gratefulness to her respected parents, who entiled much hardship and inspiring for prosecuting her studies and as well as receiving proper education.

The author feels delighted to express her heartiest sence of gratitude, sincere appreciation and immense obligation to her Supervisor Dr. Tuhin Suvra Roy, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Dhaka, for his continuous scholastic and intellectual guidance, cooperation, constructive criticism and suggestions in carrying out the research work and preparation of thesis, without his passionate co-operation this work would not have been possible.

The author feels proud to express her deepest respect, sincere appreciation and immense gratitude to her Co-supervisor Dr. Bimal Chandra Kundu, Principle Scientific Officer, Tuber Crops Research Centre-TCRC, Bangladesh Agricultural Research Institute (BARI), Joydebpur Gazipur, for his scholastic and continuous guidance, constructive criticism and valuable suggestions during the entire period of course and research work and preparation of this thesis.

The author expresses her sincere respect and sence of gratitude to Prof. Dr. Mohammed Ali, Director, Institute of Seed Technology, SAU, Dhaka and Honorable Chairman, examination committee for valuable suggestions and cooperation during the study period.

The author also expresses her heartfelt thanks to all the teachers of the Institute of Seed Technology, SAU, for their valuable teaching, suggestions and encouragement during the period of study.

The author expresses her sincere appreciation to her husband, relatives, well wishers and friends for their inspiration, help and encouragement throughout the study.

The Author

EFFECT OF PLANTING DATES AND SPACING ON YIELD AND EXPORT QUALITY OF POTATO

ABSTRACT

The experiment was conducted during the period of October 2018 to March 2019 in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to find out the effect of planting dates and spacing on yield and export quality of potato and their economy. The potato variety Lady Rosetta (BARI Alu-28) was used as test crop for this experiment. The experiment consisted of two factors: Factor A: Planting dates (4 levels) as- D_1: October 20, D_2: November 01, D_3: November 10, D_4: November 20, and Factor B: Spacing (4 levels) as- S_1: 60 cm × 25 cm, S_2: 60 cm × 30 cm, S_3: 70 cm × 25 cm, S_4: 70 cm × 30 cm. The two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded on different growth, yield parameters, yield and quality of potato tubers and significant variation was observed for most of the studied characters due to different planting dates, spacing and their combined effects. In consideration of planting dates, the highest yield of tubers (27.69 t ha^{-1}), dry matter content (19.19%), specific gravity (1.08), starch content (17.11 mg g^{-1} FW) and vitamin C content in potato tubers (23.62 mg 100 g^{-1}) was recorded from D_2, while the lowest was observed from D_4. But the highest reducing sugar content (0.30 mg g^{-1} FW) and TSS of potato (6.35 ^{0}brix) was found from D_4, while the lowest from D_2. For different spacing, the highest yield of tubers (27.81 t ha^{-1}), dry matter content (19.46%), specific gravity (1.09), starch content (17.13 mg g^{-1} FW) and vitamin C content in potato tubers (23.68 mg 100 g^{-1}) was found from S_1, whereas the lowest was recorded from S_4. On the other hand, the highest reducing sugar content in potato tubers (0.29 mg g^{-1} FW) and TSS (6.32 ^{0}brix) was found from S_4, whereas the lowest from S_1. Due to the combined effect of different planting dates and spacing, the highest yield of tubers (31.56 t ha^{-1}), dry matter content (20.94%), specific gravity (1.13), starch content (18.60 mg g^{-1} FW) and highest vitamin C content in potato tubers (26.11 mg 100 g^{-1}) was recorded from D_2S_1, while the lowest from D_4S_4. So, November 01 planting date and 60 cm × 25 cm spacing showed best performance when considered the growth, yield parameters, yield and quality of potato tubers.

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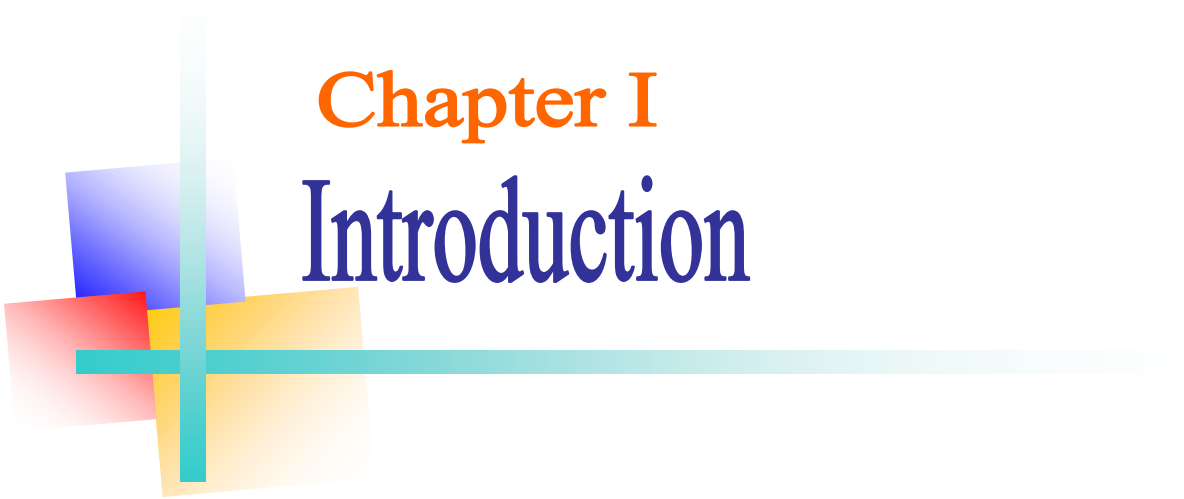
SOME COMMONLY USED ABBREVIATIONS

FULL WORD	ABBREVIATION
Agro-Ecological Zone	AEZ
and others	*et al.*
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Co-efficient of variation	Cv
Days After Planting	DAP
Etcetera	Etc
Food and Agriculture Organization	FAO
Journal	J.
Least Significance Difference	LSD
Muriate of Potash	MoP
Non significant	NS
Sher-e-Bangla Agricultural University	SAU
Soil Resources Development Institute	SRDI
Triple Superphosphate	TSP
viz.	Namely



Chapter I
Introduction

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a tuber crop belonging to the family Solanaceae is one of the world's most important non-cereal food crop and widely cultivated after wheat, rice and maize (Chakraborty *et al*., 2010; Chandra, 2018). Potato is the rich source of starch, vitamins C and B, and minerals. It contains about 20.6% carbohydrates, 2.1% protein, 0.3% fat, 1.1% crude fiber and 0.9% ash. It contains a good amount of essential amino acids like leucine, tryptophan and isoleucine (Khurana and Naik, 2003). Potato also contains a variety of phytonutrients that have antioxidant activity. Among these, some important health-promoting compounds are carotenoids, flavonoids, caffeic acid and tuber storage proteins (such as patatin) which exhibit activity against free radicals (Breithaupt and Bamedi, 2002). It is a carbohydrate rich crop, and is consumed almost absolutely as a vegetable in Bangladesh. It contributes as much as 55% of the total vegetable demand in Bangladesh (BBS, 2018).

Vegetables production is considered to be particularly important in satisfying world food demand (Kumar *et al*., 2019). Although per capita production of vegetable in Bangladesh is very low as per actual standard requirements and also production as compared to that of other countries of the world (DAE, 2016). In 2016-2017, total vegetable (summer and winter season) production area was 645.04 thousand hectares of land with total production of 1.87 million tons (BBS, 2018). Bangladesh is the 8th potato producing country in the world, 3rd biggest in Asia; it ranks 2nd after rice in production. The total acreage, production and yield of Bangladesh is 0.48 million hectares, 0.974 crore MT and 20.41 t ha^{-1}, respectively (FAOSTAT, 2018). The potato yield is increasing day by day in Bangladesh but very much low compared to other major potato producing countries *viz*., USA (47.15 t ha^{-1}), France (54.19 t ha^{-1}) (FAOSTAT, 2018). The main reasons for the low yield include the use of poor quality seed tubers and inefficient management practices including planting time and spacing.

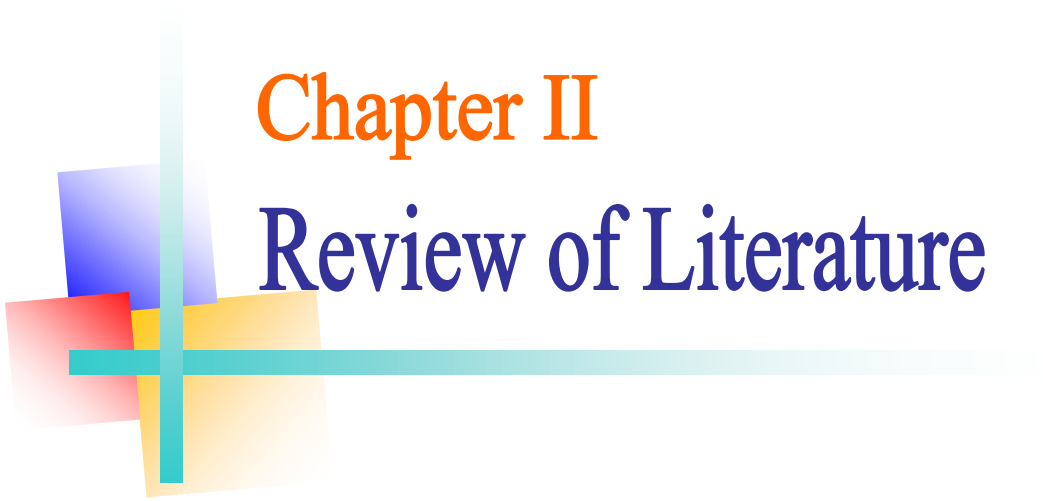
Planting dates may affect crop growth and yield of potato, where high temperature and drought stress are common during late crop development and maturation during Rabi season (Thongam *et al*., 2017). In Bangladesh, the optimum time of sowing of potato is the second week of November, but in many cases the potato crops are planted under late sown condition due to delayed harvesting of transplanted aman. Plant growth at delayed planting significantly reduced the vegetable growth of potato plant because of lower temperatures in the end of October and November and subsequently reduced the yield (Ahmed *et al*., 2017). On the other hand, sub-optimal planting geometry, wider rows and plant spacing lead to low population which in turn fail to compensate the yield obtained in optimum plant stand while narrower row and plant spacing increase the inter-and intra-plant competition leading to poor growth and development and dry matter accumulation resulting in poor yield of potato (Pandey *et al*., 2015).

Various researchers have reported the importance of effect of planting dates on the crop yield of potatoes (Arab *et al*., 2011; Muthuraj and Ravichandran, 2014; Srivastava *et al*., 2016). Tuber development requires a temperature of 20^0C (Khan *et al.*, 2011). Potato crop growth is not possible below 2^0C and above 30^0C, however, for net photosynthesis minimum (0-7^0C), optimum (16-25^0C) and maximum temperature (40^0C) are required (Singh and Lal, 2009). The crop productivity is affected by the climate thus, optimum planting date is considered as an important aspect of crop production (Kalbarczyk, 2000 and Gomma, 2014). Appropriate and proper planting time is basic requirement for obtaining maximum yield and high-profit returns of potato (Kar, 2003). The crop management practices, such as changing planting date modifying plant duration will affect potential yield (Kumar *et al*., 2019). Performance of potato crop highly depends upon planting time for each region in the country, where each stage of growth should coincide with appropriate environmental conditions, type of soil and cropping systems (Pandey, 2013). Hence, it is necessary to determine planting time for different climatic conditions according to characteristics of cultivars (Ahmed *et al.*, 2017).

The optimizing of plant density is one of the most important agronomic practices of potato production, because it affects seed cost, plant development, yield and quality of the crop (Bussan *et al*., 2007). Appropriate plant population per unit area to have high yield, marketable tuber size, good quality seed tuber and appropriate agronomic practices (Arega *et al*., 2018). As plant density increases, there is a marked decrease in plant size and yield plant^{-1}. This effect is due to increased inter-plant competition for water, light and nutrients (Masarirambi *et al*., 2012). The absence of optimal intra-row spacing practices could significantly reduce total tuber yield up to 50% (Endale and Gebremedhin, 2001). Therefore, optimization of intra-row spacing is the one of most important agronomic practices of potato production as it affects the seed cost, plant development and potato tuber yield (Gulluoglu and Arioglu, 2009). Any intra row spacing variation could influence biomass accumulation and subsequently tuber number (Santos and Gilreath, 2004). Still many potato producer farmers in the area frequently give less attention to optimal plant population due lack of sufficient land and high planting density supposedly yields more tuber number (Getie, *et al*., 2015).

Considering the above mentioned facts to find out the optimum planting date and spacing to maximize the better economic return export quality potato tubers this experiment was undertaken with the following objectives:

- To select the appropriate planting date for export quality potato tubers;
- To find out the proper spacing for better yield for export quality potato tubers, and
- To select the suitable combination of planting dates and spacing for producing good quality of potato with higher yield.



Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Potato is one of the most widely grown tuber crops in the world and contributes immensely to human nutrition and food security. The potential yield of potato is determined by appropriate husbandry practices and the surrounding environment that was provided to the cultivation of this crop. Among the husbandry practices, planting dates and spacing may play an important role although very limited studies on the growth, yield and quality of potato have been carried out in our at home and also abroad. The research work so far done in these aspects is not adequate and conclusive. However, some of the important and informative works and research findings related to planting dates and spacing on potato so far been done at home and abroad have been reviewed under the following headings-

2.1. Effect of planting dates on growth, yield and quality of potato

Patel *et al.* (2000) carried out a field experiment at Gujarat, India to evaluate the effect of planting date on the yield and quality of two potato cultivars. The planting dates were 3rd week of November-D_1, 1st week of December-D_2 and 3rd week of December-D_3. The highest tuber yield and number of large-sized (>50 g) potato tubers were produced under D_1. Based on tuber yield and its quality, D_1 was found to be the superior planting date. They also observed the highest number (10.89) of large sized (>100 g) tubers from planting on 3rd week of November followed by 1st week of December (6.76) and 3rd week of December (3.88).

Lakra (2003) carried out a field experiment to study the effect of five planting dates (1st October, 16 October, 1st November, 16 November and 1st December) on yield and yield attributes of five potato cultivars in Haryana conditions for two years and reported that planting on 1st November resulted in maximum tuber yield in all the cultivars.

Baljeet *et al*. (2005) conducted an experiment to study the influence of planting time on black scurf development at potato cv. Kufri Chandramukhi at the research

Farm area of Department of vegetable crops, CCSHAU, Hisar, Haryana, India. Seed tubers were planted on 1st October, 15th October, 1st November, 15 November and 1st December. Findings of their study revealed that number of stem plant^{-1} was decreased with delay planting time up to 1st December. Maximum yields were recorded in crop planted before 15th October with delay in planting.

Sandhu *et al*. (2008) carried out an experiment consisting of combinations of four each of planting dates (22 October, 1, 11, and 21 November) and fertilizer doses to find out their effect on growth and yield of potato and reported that Stems m^{-2} increased with delay in planting. Plant height, leaf weight and stem weight were highest in 1st November planting and lowest in 21st November planting. Maximum number and yield of total as well as A and B grade tubers was obtained from 1st November planted crop, while planting on 21st November recorded lowest number and yield of total as well as A and B grade tubers.

Field trial was conducted by Khan *et al*. (2011) to optimize the sowing date and crop growth period of potato at the Agricultural Research Institute, Dera Ismail Khan, NWFP. The tubers were planted on four dates with one-week interval starting from September and reported that total number of stems increased with the delay in planting. Total numbers of tubers per unit area and percentage of large sized tubers (>55 mm) were the highest at the earliest planting of September 24 and smaller tubers (<35 mm) increased with delay in planting. Total tuber yield was higher at earlier planting as compared to planting at later dates. However, dry matter of potato was higher at the planting of optimum time. Plant dry bio-mass was higher by planting the potato earlier.

Sandhu *et al*. (2013) conducted an experiment was with sixteen treatment combination using four planting dates (22nd October, 1st, 11th and 21st November) and four fertilizer doses (75; RFD_1, 100; RFD_2, 125; RFD_3 and 150%; RFD_4) of recommended dose (150:50:100 Kg ha^{-1} of NPK). The highest percentage of A-grade tubers and marketable yield was recorded with 1st November (D_2) planting followed by 22nd October planting (D_1), while the lowest values were recorded

with 21st November (D_4) planting. Percentage of D-grade tubers was highest in 21st November planting, indicating the decrease in tuber size (non-marketable) with delayed planting. Percentage of A and B grades, marketable and total tuber increased with increase in fertilizer dose. However, the percentage of C and D grade tubers decreased with fertilizer dose. Therefore, 1st November planting coupled with higher fertilizer dose may result in improved marketable yield.

Gomaa (2014) conducted an experiment at Siwa Oasis Research Station, Matrooh Governorate, Desert Research Center to determine the effects of four planting dates (1st of January, mid of January, 1st of February and mid of February) and three potato seed tuber sources of spunta cultivar on growth and yield under Siwa conditions. The results showed that planting on mid of January and 1st of February, generally produced the highest growth and total yield and its components values. On the other hand, 1st of January and mid of February gave the lowest values.

An experiment was conducted by Sandhu *et al*. (2014) with four planting dates (22nd October, 1st, 11th and 21st November) and four fertilizer rates viz. 75, 100, 125and 150% of recommended fertilizer dose (RFD; 150:50:100 kg ha^{-1} of NPK) in the region for optimum productivity. They observed that planting date had significant effect on all vegetative characteristics and recorded the highest values at 1st November planting date and lowest in 21st November planting date. Thus, the results of this study suggested that optimum planting time (1st November) is very critical to the potato crop under semi-arid conditions.

Jamro *et al*. (2015) carried out an experiment to determine the proper planting dates for true potato seed (TPS) nursery at Agriculture Research Institute, Tandojam, Pakistan. Comparison of three planting dates i.e. October 15, October 30 and November 15 and reported that plant height (46.94 cm) average number of micro (1-9 mm) tubers (196.1), small (10-19 mm) tubers (42.15), medium(20-39 mm) tubers (26.56), large(>40 mm) tubers (7.57), weight of micro tubers (1302 g), small tubers (480.3 g), medium tubers (340 g) and large tubers (468.5 g) were observed when TPS-9804 was planted on 30th October. The overall results for

tuber yield showed that TPS-9804 genotype planted on 30th October produced maximum tuber yield (29.46 t ha^{-1}) as compared to rest of genotypes.

Thongam *et al*. (2017) carried out an experiment to assess the effect of planting dates on growth and yield response of potato Cv. Kufri Pukhraj at the Instructional Farm, Department of Horticulture, College of Agriculture, Latur, Maharashtra with eight planting times (September 30, October 10, October 20, October 30, November 10, November 20, November 30 and December 10). Data revealed that the maximum height (52.93 cm and 70.23 cm) at 45 and 75 DAP, respectively and maximum number of leaves at both 45 and 75 DAP was recorded in the tuber planted on 10th October, while the minimum values were observed in tuber planted on 10th December. Further, the maximum number of tubers plant^{-1} (8.20) was recorded in planting date of October 10th which was at par with planting on 30th October and 10th November, while the minimum number of tubers (4.00) per plant was obtained in planting date of 10th December. The highest yield (27.74 t ha^{-1}) was recorded in planting date of 10th October which was statistically at par with 20th October planting, while the lowest yield (10.77 t ha^{-1}) in planting date of 10th December. Study conclusively revealed that the potato crop planted on 10th October recorded maximum plant height, number of leaves and yield.

An experiment was conducted by Ahmed *et al*. (2017) to assess the effect of planting dates on growth and yield performance of three potential varieties of potato at Plant Physiology research field, Bangladesh Agricultural Research Institute, Gazipur. Three planting dates (November 20, December 5 and December 29) and three varieties (var. BARI Alu-35, BARI Alu-40 and BARI Alu-41) were the treatment variables. Maximum plant height (42.3 cm) was observed in 5 December sowing in var. BARI Alu-40. Highest number of tuber plant^{-1} (13) was recorded from December 5 sowing in var. BARI Alu-41. The highest leaf area was found in December 5 sowing of BARI Alu-40 while the lowest leaf area in November 20 sowing in var. BARI Alu-35. The highest tuber weight plant^{-1} (97.25 g) was observed in var. BARI Alu-5 at December 5 sowing and the lowest tuber

weight plant^{-1} (25.58 g) in var. BARI Alu-35 at November 20 sowing. The maximum potato yield (42.12 t ha^{-1}) was obtained at December 5 sowing of BARI Alu-35 followed by same date of var. BARI Alu-41. From the experiment it was revealed that the first decade of December is the optimum date for planting of potato due to the physiological maturity and tuber yield.

Dash *et al*. (2018) conducted a field experiment at the experimental plots of All India Coordinated Research Project on Potato, Orissa University of Agriculture and Technology, Bhubaneswar with five dates of planting (25th October, 5th November, 15th November, 25th November and 5th December and four varieties. They observed that 15th November emerged as the best planting date with a maximum tuber yield of 24.019 t ha^{-1} and low tuber yield of 19.635 t ha^{-1} was obtained under the late planting of 5th December.

Teweldemedhin *et al*. (2018) conducted an experiment with four planting dates (September-20, October-02, October-14 and October-26) and three potato varieties Ajiba, Cosmos and Zafira under irrigated condition at the experimental farm of Hamelmalo Agricultural College to evaluate and find suitable potato variety and planting time. The data on yield and yield attributing parameters were recorded at harvesting. The tuber numbers and average tuber weight were found to be significantly affected by planting dates and it has been observed that delay in planting decreased the potato tuber yield.

Sadawarti *et al*. (2019) carried out an experiment with five planting dates, i.e.10 October, 17 October, 24 October, 31 October and 7 November and varieties, viz., Kufri Chandramukhi, Kufri Sindhuri and Kufri Chipsona at ICAR-Central Potato Research Station, Gwalior, Madhya Pradesh, India and reported that 7 November planting recorded higher growth attributes like number of stems, compound leaves except plant height. Delayed planting resulted in the reduction of plant height. Higher seed size and total tuber number and yield ha^{-1} were recorded in 17 October onward plantings over other 10 October planting and highest was in 7 November

planting (355 and 634 thousand ha^{-1} and 19.33 and 24.63 t ha^{-1} seed size and total tuber number and weight, respectively).

An experiment was conducted by Haile *et al*. (2019) to assess the effect of planting date and variety on growth and yield of potato at Anderacha district, Western Zone of SNNPRS. Five planting times (October 20, October 30, November 9, November 19 and November 29) and three varieties were used as treatments. Data were collected on growth and yield parameters and the result showed that early planting (October 20) delayed flowering by about 4 and 15 days, respectively and increased plant height by 10.68 cm than the latest planting on November 29. The number of stems $plant^{-1}$ increased with delayed plantings however tuber number decreased in late plantings. Early planting produced significantly heavier tuber weight (83.80 g) which progressively reduced in subsequent plantings, whereas delay in planting resulted in higher unmarketable yield.

A field trial was conducted by Gogoi and Ray (2019) with four different dates of planting, viz. D_1-1st November, D_2-11th November, D_3-21st November and D_4-1st December and observed that tubers planted on D_2 date of sowing showed higher results for number of leaves $plant^{-1}$, dry matter accumulation (g), number of tubers $plant^{-1}$, weight of tubers $plant^{-1}$ (g) and tuber yield (t ha^{-1}). The highest recorded tuber yield was 15.30 t ha^{-1} for D_2 over other three planting dates.

Kumar *et al*. (2019) carried out a field experiments at research farm of Department of Agricultural Meteorology, CCSHAU, Hisar to quantify crop weather relationship and the effect of different planting dates on growth and yield of potato cultivars. The main plots treatments consisted four date of sowing viz. D_1-8th October, D_2-22th October, D_3- 5th November and D_4- 23rd November. The sub-plots treatment consisted of three varieties. The results revealed that various growth and yield observations were recorded higher in second sown crop (22th October) as followed by other planting dates. The maximum tuber yield were produced in D_2 (20810.45 kg ha^{-1}) and it was least in D_4 (14525.46 kg ha^{-1}).

2.2. Effect of spacing on growth, yield and quality of potato

Ahire *et al.* (2000) carried out an experiment at Rahuri, Maharashtra, India with the treatments consisted of 2 row spacings (60 and 45 cm), 2 planting systems (normal and paired row) and 2 irrigation methods (trickle and surface) and reported that the wider spacing of 60 cm increased plant growth and tuber yield (20.29 t ha^{-1}) compared with the narrow spacing of 45 cm (17.86 t ha^{-1}).

The effects of intra-row spacing (15, 25 and 35 cm) and seed size on the growth and yield of potato were investigated by Khalafalla (2001) at Shambat and Shehainab in Sudan and observed that yield decreased with increase in spacing at both locations. The findings also revealed that plant spacing had significant effect on marketable tubers $plant^{-1}$, marketable tuber weight but have no significant effect on number of stems $plant^{-1}$.

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

Sonawane and Dhoble (2004) carried out an experiment at Maharashtra, India, to find out suitable and economical combination of inter and intra row spacing with seedling tuber size of potato and recorded the significant increase in the tuber yields 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.

An experiment was conducted by Yenagi *et al.* (2004) 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 and nitrogen rate 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.

An experiment was carried out by Mahmood (2005) at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh to investigate the effect of planting method and spacing on the yield of potato using Cv. BARI TPS-2. The experiment consisted of (a) two planting methods (b) two planting systems and (c) three spacing viz., 50×5, 50×10 and 50×15 cm. Plant spacing 50×5 cm produced the maximum yield 42.32 t ha^{-1}. The combination of planting method, planting system and spacing produced marked effect on all parameters studied, being the highest yield (52.62 t ha^{-1}) in the combination of transplanting, double row and 50×5 cm spacing.

Kumar and Lal (2006) carried out a field experiment to evaluate the effects of planting geometry (60×15 and 60×10 cm), N and P levels and haulm cutting on the production of small size tubers of potato at the Central Potato Research Station, Patna (Bihar). From the study they reported that number of stems m^{-2} decreased significantly with the increase in plant spacing from 60×10 cm to 60×15 cm. Yield of small sized tubers (up to 40 g) and total tubers increased significantly with closer plant spacing, while the yield of bigger size tubers (>40 g) increased with wider planting geometry. Number of small sized tubers (up to 40 g) as well as total tubers increased significantly at closer planting geometry, while the number of larger size tubers (>40 g) increased with wider planting geometry. Multiplication rate on the basis of yield decreased from 7.8 times to 4.21 times with a decrease in plant spacing.

Bayorbor and Gumah (2007) conducted an experiment to study the effects of four different 'seed' tuber weights and three intra-row spacing (20 cm, 30 cm and 40 cm) on the yield and yield components of 'Frafra' potato and reported that spacing had significant effect on number of branches at 3 weeks after planting (WAP) and 6WAP, number of tubers and tuber weight. 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.

Kumar *et al.* (2009) carried out an experiment to study the growth (plant height, number of stem hill^{-1}, leaf area and total dry matter production, yield and quality (reducing sugar content) of potato cv. 'Kufri Pukraj' for different intra-row spacings (60×15, 60×20 and 60×25 cm) and fertilizer levels and 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^{-1}.

Gulluoglu and Aroglu (2009) conducted an experiment to find out the effects of different in-row spacing (20, 25, 30 and 35 cm) and seed size on yield components and tuber yield of potato. They observed that closer spacing reduced tubers hill^{-1}, average tuber weight, tuber yield hill^{-1} and percentages of large and medium weight tubers. Total yields increased as increasing planting density up to 20 cm.

Islam *et al*. (2012) studied the effect of tuber size and plant spacing on tuber yield and yield attributes of potato. Number of tubers per plant increased with increasing intra-row spacing and tuber size. Narrow spacing increased the hectare yield in the use of under (19-27 mm), A (28-35 mm) and B (36-45 mm) size seed tubers. The yield for C grade (46-55 mm) and over size (> 55 mm) seed tubers were lowest in closer spacing due to insufficient light interception by an over populated crop canopy. Income may be optimized if the seed tubers are sorted according to size and planted in 60×20 cm using under size tubers and in 60×25 cm with A, B, C and over size seed tubers.

Roy *et al.* (2014) conducted an experiment to observe the response of seedling tuber weight and plant spacing (60×25 cm, 60×20 cm and 60×15 cm) on yield and economic analysis of potato. Results revealed that tubers hill^{-1}, single tuber weight

and tuber weight hill^{-1} increased with increasing plant spacing. The highest gross and marketable tuber yield ha^{-1} was observed in the plant spacing of 60×20 cm and the lowest from closer spacing of 60×15 cm.

A field study was carried out by Kumar *et al*. (2014) with two processing varieties Kufri Himsona and Kufri Chipsona-3 in main plot and five crop intra-row spacing treatments (67.5×20, 67.5×22.5, 67.5×25, 67.5×27.5 and 67.5×30 cm) sub-plots. Growth traits, processing grade tuber number and yield and processing quality parameters were not influenced by crop intra-row spacing. Tuber number plant^{-1}, percent processing grade tuber and average processing grade tuber weight steadily increased with increased intra-intra-row spacing from 22 to 30 cm.

A study was conducted by Akassa *et al*. (2014) to determine the effect of inter and intra row spacing on potato seed and ware tuber emergence and subsequent growth with six levels of inter: 60, 65, 70, 75, 80 and 85 cm and three levels of intra row spacings: 20, 30 and 40 cm. Most of the recorded variables were significantly affected by inter, intra and/or their interactions except the number of main stem. Though most of the variables considered require wider spacing, it was observed that an indefinite increase in the space between plants and rows did not result to an increase in any of the variables apart from extending days to flowering and maturity. For the optimum emergence and successful growth of potato tubers for both seed and ware, spacing of 70-75 and 20-30 cm between plants and rows, respectively were identified as the best combination.

Getie *et al*. (2015) carried out a field experiment to investigate the effect of nitrogen fertilizer and planting density on yield and yield components of potato crop (Bubu variety) in Haramaya, Eastern Ethiopia. Treatments included quantity of nitrogen fertilizer and planting density (4.17 plant m^{-2} (80×30 cm), 4.44 plant m^{-2} (75×30 cm), 5.56 plant m^{-2} (60×30 cm), 6.67 plant m^{-2} (60×25 cm) and 8 plant m^{-2} (50×25 cm). Increasing planting density resulted in higher tuber yield, total tuber number, total dry biomass yield (%), marketable tuber yield and small-sized tuber yield (16.92%).

Alam *et al*. (2016) carried out an experiment to develop suitable crop spacing for the production of higher processing grade yield and quality of potato tuber with three levels of inter intra-row spacing (60, 67.5 and 75 cm) and four levels of intra intra-row spacing (20, 25, 30 and 35 cm) and reported that intra-row spacing had great influence on economically important characteristics such as total yield, processing grade yield, tuber size distribution and tuber quality. The highest total potato tuber yield, chips and canned grade tubers were found in 67.5×25 cm spacing without affecting processing quality but all were in the highly acceptable range. Intra-row spacing of 25 cm showed the maximum processing quality tubers closely followed by 30 cm spacing. Therefore, 67.5×25 cm crop spacing can be recommended for higher potato tuber yield and processing grade tubers as well as higher economic return.

A study was designed Dagne *et al*. (2019) to elucidating the effect of varied plant spacing and seed tuber sizes on yield and quality of potato and reported that average tuber weight was significantly affected by plant spacing. Total tuber yield and marketable tuber yield significantly affected by different plant spacing, where the maximum marketable tuber yield (33.68 t ha^{-1}) and total tuber yields (34.38 t ha^{-1}) were obtained at spacing of 60×30 cm and 50×20 cm, respectively. The yield of starch was significantly affected by spacing but did not influenced significantly on specific gravity and tuber dry matter content of potato.

A study was conducted by Dawinder *et al*. (2020) to determine the effect of tuber size and intra row spacing on potato yield and subsequent growth. The experiment was designed three levels of tuber size and four levels of intra row spacing's (8, 12, 16 and 20 cm) and intra row 60 cm. For the optimum emergence and successful growth of potato tubers for process able yield, a size of 40-50 mm and spacing of 20 cm between plants, respectively were identified as the best treatments. They recorded that Intra row spacing, the given data showed that (60×20 cm) plant spacing produced maximum yield of 163.3 q ha^{-1}, while minimum yield (132.4 q ha^{-1}) was recorded in plant spacing of (60×8 cm).

2.3. Combined effect of planting dates and spacing on growth, yield and quality of potato

Yenagi *et al*. (2002) conducted an experiment during the Kharif season 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 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 150 kg N ha^{-1}.

Field experiment conducted by Yenagi *et al*. (2004) with two row spacings allotted to main plots (60 cm and 45 cm), three dates of planting to sub plots (June 18th, June 25th and July 10th) and four N levels to sub-sub plots (0, 50, 100 and 150 kg N ha^{-1}) at MARS, Dharwad and revealed that higher tuber yield (12.21 t ha^{-1}) was recorded with narrow row spacing (45 cm) although more number of A grade tubers were recorded with wider row spacing. Planting on June 3rd week recorded significantly highest total tuber yield (12.76 t ha^{-1}). A, B and C grade tuber yield was highest when potato was planted on June 3rd week.

Yenagi *et al.* (2005) carried out an experiment 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, tubers per plant and tuber yield was highest with 45 cm row spacing, 18 June planting and 150 kg N ha^{-1} supplementation. Tuber weight was highest with 60 cm row spacing, 18 June planting and 150 kg N ha^{-1} supplementation.

A field experiment was conducted by Sen *et al*. (2010) at Potato Research and Seed Multiplication Farm, Anandapur, West Midnapore, West Bengal to study the effect of dates of transplanting and spacing on yield attributing character, productivity and economics of potato cultivation through true potato seed (TPS) technology. The highest number of tubers $plant^{-1}$ was recorded in early transplanted (December 3) crop, while, crop spacing did not produce any

significant differences in recording tuber number plant^{-1}. Early established crop also produced significantly higher tuber weight plant^{-1} as compared to intermediate (December 11) and late (December 19) transplanted crops and widely spaced (60×15 cm) crop recorded higher weight of tuber plant^{-1} as compared to the narrowly spaced crop. As such, early transplanted and densely planted crops produced significantly higher yield of seedling tuber, marketable tuber and total tuber than their counterparts.

Arab *et al*. (2011) carried out an experiment in Shahrood (Iran) to study the effect of planting date, depth of sowing and planting density on yield and yield components of potato. The first treatment was three planting date (11, 21 and 31 May 2010), the second treatment was planting density including 8 and16 plants per square meter and the third treatment was depth of sowing (10, 20 and 30 cm). Results showed that tuber yield was affected by experimental factors. Planting date, depth of sowing and planting density significantly affected tuber yield. Planting date, depth of sowing and planting density significantly affected all traits except protein percentage which was not significantly influenced by plant density factor. Planting date (11 May) and plant density (8 plants m^2) and depth of sowing (20 cm) treatment produced 31.800 t ha^{-1} and was maximum yield in comparison to other treatments.

Al-Mamun *et al*. (2016) conducted an experiment at the Horticultural Research Farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University to evaluate the performance of top-shoots as planting material and to determine the optimum time of planting and the optimum spacing for top-shoot cuttings as planting material for breeder seed production. Significant variations were found among the treatment combinations for plant height at 45 and 60 days after planting (DAP), foliage coverage at 45 and 60 DAP, number of branches plant^{-1}, number of tubers plant^{-1}, individual tuber weight, tuber yields plant^{-1} and yield hectare^{-1}. The highest mean yield (46.57 t ha^{-1}) was produced by whole tubers planted on 10 November with 50×10 cm spacing which was similar to whole tubers planted on

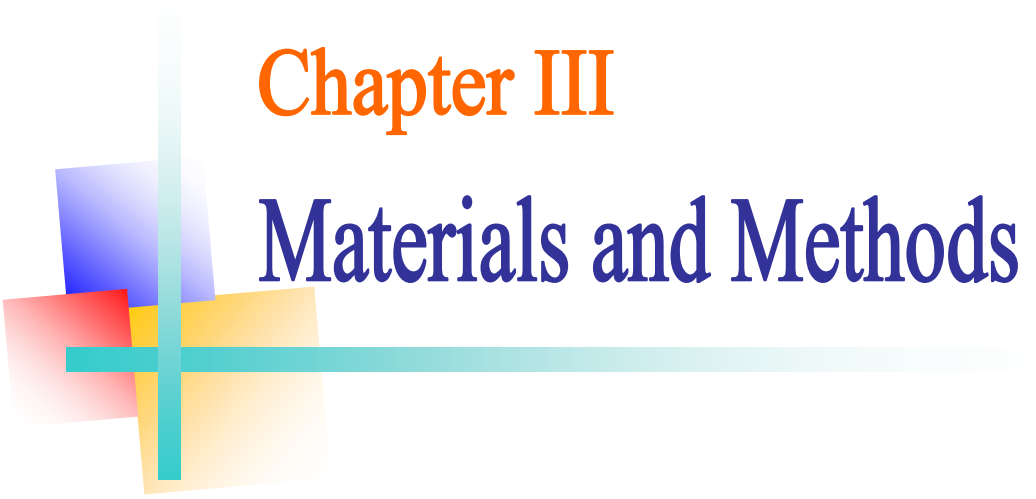
1 November with 50×10 cm spacing. Early planting of top-shoot cuttings with closer spacing (50×10 cm and 50×15 cm) is recommended for the multiplication of breeder seed potato.

An experiment was conducted by Thongam *et al*. (2017) to assess the effect of planting dates on growth and yield response of potato Cv. Kufri Pukhraj at the Instructional Farm, Department of Horticulture, College of Agriculture, Latur, Maharashtra. Eight planting times (September 30, October 10, October 20, October 30, November 10, November 20, November 30 and December 10) with a spacing of 60×15 cm. Data revealed that the maximum height (52.93 cm and 70.23 cm) at 45 and 75 DAP respectively and maximum number of leaves at both 45 and 75 DAP was recorded in the tuber planted on 10th October while the minimum values were observed on tuber planted on 10th December. Further, the maximum number of tubers (8.20) per plant was recorded in planting date of October 10 which was at par with planting on 30th October and 10th November, while the minimum number of tubers (4.00) per plant was obtained in planting date of 10th December. The highest yield (44.93 kg/plot and 27.74 t/ha) was recorded in planting date of 10th October which was statistically at par with 20th October planting, while, the lowest yield (17.45 kg/plot and 10.77 t/ha) was observed in planting date of 10th December) with a spacing of 60×15 cm.

Above cited reviews revealed that planting dates and spacing greatly influences the growth and as well as yield and quality of potato. Optimizing planting dates and spacing are the most important subjects of potato production systems due to their effects on plant development, yield and quality of the potato. But the cited literature revealed that the effects of planting dates and spacing have not been yet studied well and have no definite conclusion for the production of potato under the agro climatic condition of Bangladesh.

Chapter III

Materials and Methods



CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the effect of planting dates and spacing on yield and export quality of potato and their economy. The materials and methods that were used for conducting the experiment have been presented in this chapter. It generally includes a short description of the location of experimental site, soil and climate condition of the experimental plot, materials used, treatment and design of the experiment, growing of crops, data collection procedure and subsequently also analysis procedure of the recorded data.

3.1 Experimental site

3.1.1 Experimental period

The field experiment was conducted during the period of October 2018 to February 2019 and subsequently laboratory analysis was done on March, 2019.

3.1.2 Experimental location

The present study was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^0 74^/$N latitude and $90^0 35^/$E longitude with an elevation of 8.2 meter from sea level. A map of the experimental location presented in Appendix I.

3.1.3 Soil characteristics

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28) and the General Soil Type is Deep Red Brown Terrace Soils (FAO, 1988). Top soil was Silty Clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental area having available irrigation and drainage system and situated above flood level. The soil having a texture of sandy loam with organic matter 1.15% and was composed of 26% sand, 43% silt and 31% clay particles. Details morphological, physical and chemical properties of the soil of experimental field are presented in Appendix II.

3.1.4 Climatic condition of the experimental site

Experimental area is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the month of April to September. The monthly average temperature, humidity, rainfall and sunshine hour during crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix III. During this period the maximum temperature (27.9^0C) was recorded in the month of February 2019, whereas the minimum temperature was (12.5^0C) in January 2019. The highest related humidity (84%) was recorded in the month of October, 2018, while the highest rainfall (43 mm) in February 2019 and the highest sunshine hour (7.1 hour) in October, 2018.

3.2 Experimental details

3.2.1 Planting materials

The potato variety Lady Rosetta (BARI Alu-28) were used as test crop for this experiment and the seeds of potato were collected from Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.

3.2.2 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Planting dates (4 levels) as

i D_1: October 20, 2018
ii. D_2: November 01, 2018
iii. D_3: November 10, 2018
iv. D_4: November 20, 2018

Factor B: Spacing (4 levels) as

i. S_1: 60 cm × 25 cm
ii. S_2: 60 cm × 30 cm
iii. S_3: 70 cm × 25 cm
iv. S_4: 70 cm × 30 cm

There were 16 (4×4) treatments combination such as D_1S_1, D_1S_2, D_1S_3, D_1S_4, D_2S_1, D_2S_2, D_2S_3, D_2S_4, D_3S_1, D_3S_2, D_3S_3, D_3S_4, D_4S_1, D_4S_2, D_4S_3 and D_4S_4.

3.2.3 Design and layout of the experiment

The two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 167.2 m^2 which were divided into three equal blocks. Each block was divided into 16 plots where 16 treatments combination allotted at random. There were 48 unit plots and the size of each plot was 2.0 m × 2.0 m. The distance between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

3.3 Growing of crops

3.3.1 Preparation of the main field

The selected experimental plot was opened in the 5th October 2018 with a power tiller and left exposed to the sun for a week. Subsequently cross ploughing was done five times followed by laddering to make the land suitable for planting the seed tubers. All weeds, stubbles and residues were eliminated from the field. Finally, a good tilth was achieved. The soil was treated with insecticides (Cinocarb 3G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

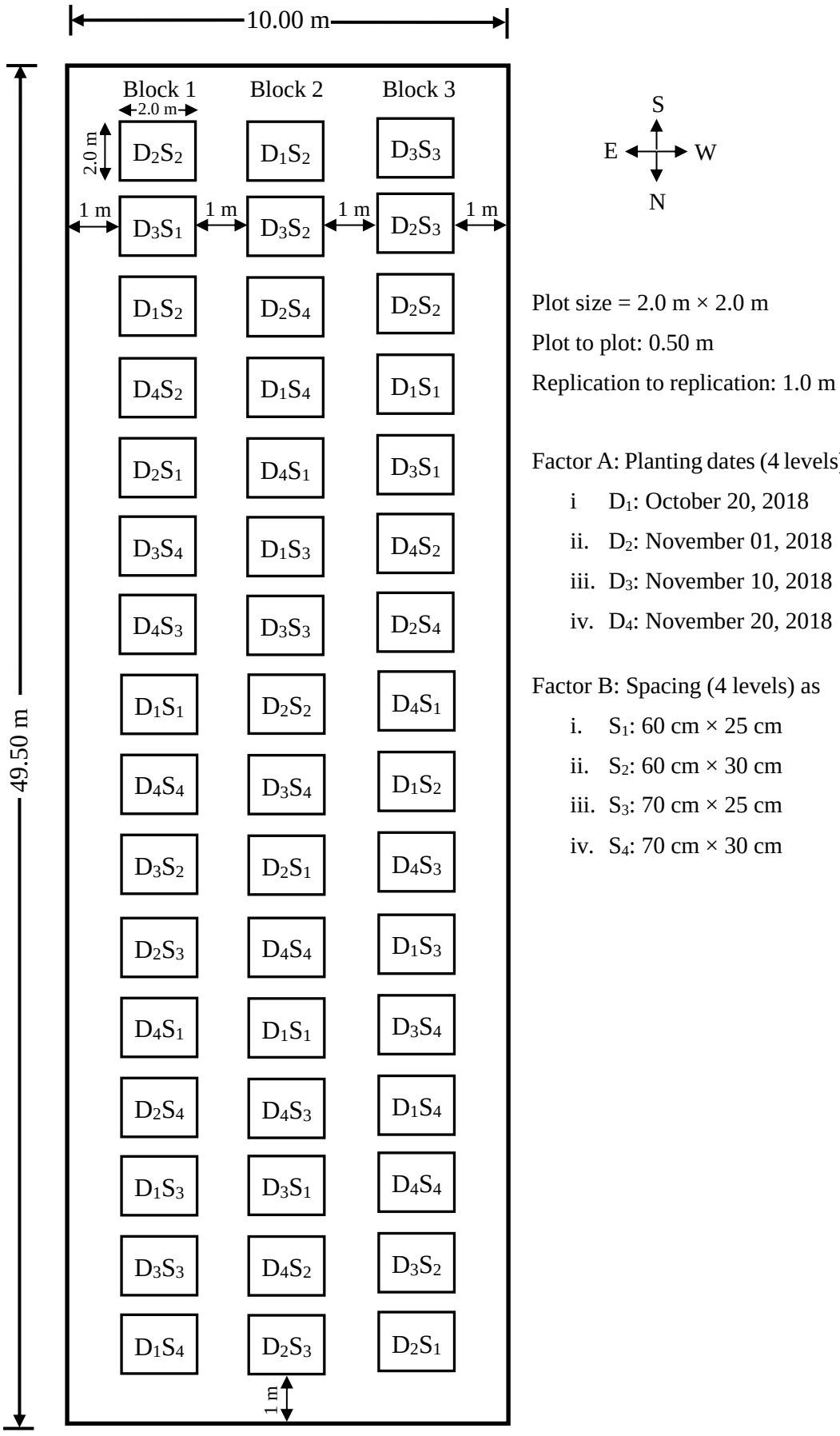
3.3.2 Application of manure and fertilizer

Manures and fertilizers were applied to the experimental plot considering the recommended fertilizer doses of potato and presented in Table 1.

Table 1. Doses and methods of application of manure and fertilizers in potato field

Manures and fertilizers	Dose ha^{-1}	Application (%)	
		Basal	40 DAP
Cowdung	10 ton	100	--
Urea	325 kg	50	50
TSP	200 kg	100	--
MoP	250 kg	100	--
Zypsum	100 kg	100	--
Zinc	8 kg	100	--

Source: BARI, 2019



Plot size = 2.0 m × 2.0 m

Plot to plot: 0.50 m

Replication to replication: 1.0 m

Factor A: Planting dates (4 levels) as

i D_1: October 20, 2018

ii. D_2: November 01, 2018

iii. D_3: November 10, 2018

iv. D_4: November 20, 2018

Factor B: Spacing (4 levels) as

i. S_1: 60 cm × 25 cm

ii. S_2: 60 cm × 30 cm

iii. S_3: 70 cm × 25 cm

iv. S_4: 70 cm × 30 cm

Figure 1. Field layout of the experimental plot

The entire amount of all manures and fertilizers and half amount of urea were applied during final land preparation. Rest amount of urea was applied during 2nd earthing up at 40 days after planting (DAP).

3.3.3 Planting of potato tubers

The seed tubers were planted at a depth of 5 cm in the experimental plots as per the treatments of planting dates and spacing. The soil along the rows of seed tubers were ridged up immediately after planting.

3.3.4 Intercultural operations

When the seedlings started to emerge in the beds mulch materials were clean up for easy growth and development of potato seedlings. The crop was always kept under careful observation. After emergence of potato seedlings, various intercultural operations were accomplished for better growth and development.

3.3.4.1 Weeding and mulching

Weeding was done at 30 and 50 DAP (days after planting) to remove the unwanted weeds and mulching was done to conserve soil moisture. Manual weeding was done as and when necessary to keep the plots free from weeds. The soil was mulched by breaking the crust of the soil for easy aeration and to conserve soil moisture as and when needed. Mulching also helped to disturb the emergence of Bathua plants *(Chenopodium album)* and other weeds. These two operations were done carefully without hampering the luxurious crop health.

3.3.4.2 Earthing-up

Two times earthing up was done at 25 and 40 DAP. The soil along the rows of seed tubers were ridged up immediately after planting. The earthing which was preceded by top dressing of the remaining half of urea and also it was treated as a final earthing-up.

3.3.4.3 Irrigation

Pre emergence irrigation was done seven days after planting as because moisture was not optimum for germination before emergence, light irrigation was done for

even emergence of seed tuber. After emergence, only one irrigation was given throughout the growing period and the irrigation was given just after earthing-up.

3.3.4.4 Pests and diseases control

Except cutworm, no other insects were found harmful for potato in growing season. To protect the soil borne insects Furadan 5G was applied @10kg ha^{-1} during the final land preparation for both 1st and 2nd planting. Dithane M-45 was applied @ 2 g L^{-1} at 10 days interval as a preventive measure against late blight *(Phytophthora infestans)* of potato for both 1st and 2nd planting. This time was very cold so Dithane M 45 and Rovral 50 wp were applied alternatively at 3 days interval.

3.4 Harvesting

The maturity of the crop was determined by the appearance of the yellowish color of the leaves, falling of the stems on the ground and finally drying of leaves. The tubers from each plot were harvested manually.

3.5 Data collection

Five plants were randomly selected from the middle rows of each unit plot for avoiding border effect and tagged with a sample card, which was done in plot wise. Data were collected in respect of the following parameters to assess plant growth; yield attributes, yields and quality of tubers as affected by different treatments of this experiment. Data on plant height, number of leaves $plant^{-1}$, number of stems $plant^{-1}$ were collected at 30, 45, 60, 75 DAP and at harvest. All other yield contributing characters and yield parameters were recorded during harvest and after harvest.

3.5.1 Growth, yield parameters and yield of potato

3.5.1.1 Days required for1st emergence

Each plot of the experiment was kept under close observation to count days required for 1st emergence of potato seedlings. Total number of days from the date of planting to the visible emergence was recorded.

3.5.1.2 Days required for 1st to 80% emergence

Each plot of the experiment was kept under close observation to count days required for 1st to 80% emergence of potato seedlings. Total number of days from the 1st emergence to 80% emergence was recorded.

3.5.1.3 Days required for 1st emergence to stolen initiation

Each plot of the experiment was kept under close observation to count days required for 1st emergence to stolen initiation from potato plants. Total number of days from the 1st emergence to stolen initiation was recorded.

3.5.1.4 Days required for planting to harvest

Each plot of the experiment was kept under close observation to count days required for planting to maturity of potato plants. Total number of days from the date of planting to the harvesting was recorded.

3.5.1.5 Plant height

Plant height was measured from sample plants in centimeter from the ground level to the tip of the longest leaf and mean value was calculated. Plant height was also recorded at 15 days interval starting from 30 DAP upto 75 DAP and also at harvest to observe the growth rate of the potato plants.

3.5.1.6 Number of leaves plant^{-1}

The total number of leaves plant^{-1} was counted from each selected potato plants. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot at 15 days interval starting from 30 DAP upto 75 DAP and also at harvest.

3.5.1.7 Number of stems plant^{-1}

The total number of stems plant^{-1} was counted from each selected potato plants. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot at 15 days interval starting from 30 DAP upto 75 DAP and also at harvest.

3.5.1.8 Number of tubers hill^{-1}

Total number of potato tubers hill^{-1} was recorded as the average of 5 plants selected at random from each unit plot at harvest. The total number of tubers were recorded by counting the entire potato hill^{-1}.

3.5.1.9 Weight of tubers hill^{-1}

Five earlier tagged hills from middle row was selected from each unit plot, and the yield of potato tubers obtained from the hills was collected and weighted and recorded according with expressed in g hill^{-1}.

3.5.1.10 Average weight of single tubers

Average weight of single tubers were estimated by dividing the weight of tubers hill^{-2} with the number of tubers hill^{-1} as the average of 5 plants selected at random from each unit plot at harvest.

3.5.11 Dry matter content of potato tubers

At first selected tubers were collected, cut into pieces and was dried under sunshine for a 3 days and then dried in an oven at 70^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken. The dry matter contents in potato tubers were computed by simple calculation from the weight recorded using the following formula:

$$\text{Dry matter content in stem (\%)} = \frac{\text{Dry weight of potato tubers}}{\text{Fresh weight of potato tubers}} \times 100$$

3.5.1.12 Yield of tubers hectare^{-1}

Tubers yield per hectare of potato was calculated by converting the weight of individual tubers yield from a plot and converted yield of tubers into hectare and was expressed in t ha^{-1}.

3.5.2 Quality of potato

3.5.2.1 Grading of potato

The harvested potato tubers from 1 m^2 area of each unit plot were graded in to four size grades (<28 mm, 28-45 mm, 45-55 mm and >55 mm) and expressed in percentage.

3.5.2.2 Marketable quality of potato

The harvested potato tubers from 1 m^2 area of each unit plot were graded a marketable (25 to >75 mm) and non-marketable (<25 mm) size and marketable tubers again classified for different purposive uses i.e. Chips (45-75 mm) and Canned (25-45 mm) potato and expressed in percentage.

3.5.2.3 Estimation of firmness score of potato tubers

Firmness score was estimated by using pressure gauge. For the estimation of firmness firstly the potato tubers was divided into two then created pressure using pressure gauge and recorded the reading from pressure gauge.

3.5.2.4 Estimation of specific gravity of potato tubers

Specific gravity of potato tubers was measured by using the following formula (Gould, 1995). Five tubers were taken from each plot after harvest of treatment and then the means were taken.

$$\text{Specific Gravity} = \frac{Wa}{Ww} \times 100$$

Where,

Wa= Weight of tuber (g) in air and

Ww= Weight of tubers (g) in fresh water at 4^0C

3.5.2.5 Estimation of starch content of potato tubers

Starch content of potato tubers was determined after harvest by Somogyi-Nelson method (Nelson, 1944). Phosphate buffer solution was prepared through diluted 0.74g $NaH_2PO_4 \cdot 2H_2O$ and 0.09g $Na_2HPO_4 \cdot 12H_2O$ into 100 ml Distilled water.

Then 0.1 g Enzyme (Amyloglucosidase) was added and mixed well, kept at 20^0C for the preservation. The residue remained after extraction for sugar was washed for several times with water to ensure that there was no more soluble sugar in the residues. After that using tap water and mark up to 250 ml beaker. Stirred well on a magnetic stirrer. Then 0.5 mL solution was taken from the beaker during stirring into 3 test tubes. The test tubes was boiled for 10 min at 100^0C. Add 1 ml Amyloglucosidase solution, mix well, and heat at 50-60^0C for 2 hours in hot water. After cooling, add 0.5 ml Copper solution, mix well, heat at 100^0C for 10 min., cool in tap water, add 0.5 ml Nelson solution, mix well, add 7 ml distilled water, mix well (Final volume = 9.5 ml), and measure the absorbance at 660 nm (Abs). Starch content was calculated using the glucose standard curve.

3.5.2.6 Estimation of reducing sugar content of potato tubers

For the analysis of sugar content like reducing sugar glucose potato flesh was extracted. For each extraction, 1 g fresh sample of chopped potato was taken from uniform tuber samples and smashed well in a motor. Sugar was extracted using 5 ml of 80% ethanol heat at 80^0C for 30 min using a dry block heat bath and the extracts was centrifuged at 5000 rpm for 10 min and decanted the supernatant. 8 mL 80% EtOH, was added and it was repeated 4 and 5 times in total. All the supernatants were mixed well and the final volume was made up to 25 mL using 80% EtOH. The residue is used for sugar analysis. Reducing sugar was estimated by the photometric adaptation of the Somogyi method (Nelson, 1944) with some modification. Copper solution and Nelson reagent and standard glucose solution (0.5 ml) were used. 3 mL sample solution was put into a small glass container. Then it was completely dried up on an electric heater, 3 mL distilled water was added and then mixed well.

Then 0.5 ml solution was taken from that, two times and was put in different test tubes. In one test tube, 0.5 ml Copper solution was added and was boiled (100^0C) for 10 min. After boiling, immediately the test tube was cooled in tap water. 0.5 mL Nelson reagent in the test tube was added, and mixed them well. After 20 min,

8 mL distilled water was added and mixed well (Total volume = 9.5 ml). After that the absorbance at 660 nm (Abs1) was measured and the reducing sugar content was calculated.

3.5.2.7 Estimation of Total Soluble Solids (TSS) in potato tubers

TSS of harvested tubers was determined after harvest in a drop of potato juice by using Hand Sugar Refractometer "ERMA" Japan, Range: 0-32% according to (AOAC, 1990) and recorded as obrix from direct reading of the instrument.

3.5.2.8 Estimation of ascorbic acid (vitamin C) content in potato tubers

Quantitative determination of ascorbic acid content of potato tubers from different treatment was estimated (AOAC, 1990) at Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka. The applied method was as follows:

Reagents

i) Metaphosphoric acid solution (3% HPO_3): Prepared by dissolving pellets of HPO_3 in glass distilled water.

ii) Standard ascorbic acid solution: 100 mg of ascorbic acid was weighted, dissolved and made up to 100 ml with 3% HPO_3 and diluted to 0.1 mg/ml (10 ml HPO_3 of 1 mg/ml) immediately before use.

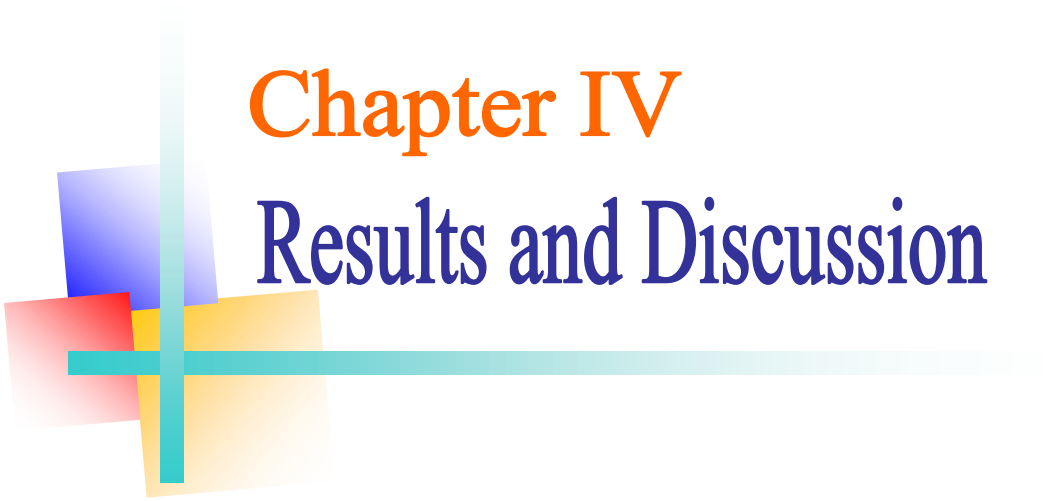
iii) Dye solution: Fifty milligram of 2, 6-Dichlorophenol indophenol was dissolved in approximately 150 ml of hot glass distilled water containing 42 mg of sodium bicarbonate. The mixture was cooled, diluted with distilled water upto 200 ml, stored in a refrigerator and standardizes every day before use.

Procedure

Five (5) grams of fresh potato tuber sample was crushed in a mortar and mixed well with 3% HPO_3 upto 100 ml in a volumetric flask. It was filtered with whatman filter paper 40. Then 5 ml aliquot of HPO_3 extract of the sample was taken and titrated with dye solution.

3.6 Statistical analysis

The data obtained for different characters were statistically analyzed to find out effect and the significance of the difference for planting date and spacing on yield, yield contributing characters and quality of potato. The mean values of all the recorded parameters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test using MSTAT-C software. The significance of the difference among the treatment and treatment combinations of means under the experiment was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).



Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of planting dates and spacing on yield and export quality of potato and their economy. Analyses of variance (ANOVA) of the data on different growth, yield parameters, yield and quality of potato are presented in Appendix IV-XI. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Growth, yield parameters and yield of potato

4.1.1 Days required for 1st emergence

Days required for 1st emergence showed statistically significant differences was recorded due to the different planting dates (Table 2). The highest days required for 1st emergence (18.83) was observed from D_1 (October 20, 2018) planting date which was followed (17.83, 17.25 and 17.08 days, respectively) by D_3 (November 10, 2018), D_2 (November 01, 2018) and D_4 (November 20, 2018) planting date, respectively and they were statistically similar, whereas the lowest (17.08 days) was found from D_4. The higher days required for 1st emergence in planting date of D_1 as compared to the other planting date may be attributed to climatic conditions in general and temperature in particular. Similar findings were in agreement with the earlier reported by Gopalakrishnan (2007).

Different spacing showed statistically non-significant differences on days required for 1st emergence (Table 2). The maximum days required for 1st emergence (18.17) was recorded from S_4 (70 cm × 30 cm) spacing, while the minimum (17.42 days) was observed from S_1 (60 cm × 25 cm) spacing. Data revealed that there were spacing did not influences on days required of 1st emergence of potato. From earlier experiment Akassa *et al.* (2014) reported the optimum days for 1st emergence was in spacing of 70-75 and 20-30 cm between plants and rows. Similar findings also reported earlier by Kumar and Lal (2006).

Table 2. Effect of different planting dates and spacing on days required for 1st emergence, 80% emergence, stolen initiation and harvest of potato

Treatments	Days required for			
	1st emergence	80% emergence	1st emergence to stolen initiation	Planting to harvest
Planting dates				
D_1	18.83 a	7.83 a	38.83 a	96.83 a
D_2	17.25 b	7.25 b	36.42 b	94.00 b
D_3	17.83 b	7.25 b	35.58 b	95.00 ab
D_4	17.08 b	6.50 c	32.08 c	92.67 b
Sx	0.283	0.113	0.746	0.885
Level of significance	**	**	*	**
Spacing				
S_1	17.42	7.08	38.92 a	92.83 b
S_2	17.50	7.17	35.50 b	94.00 ab
S_3	17.92	7.25	36.25 b	95.17 ab
S_4	18.17	7.33	32.25 c	96.50 a
Sx	0.283	0.113	0.746	0.885
Level of significance	NS	NS	*	**
CV(%)	5.52	5.45	7.23	3.24

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_1: October 20, 2018 S_1: 60 cm × 25 cm

D_2: November 01, 2018 S_2: 60 cm × 30 cm

D_3: November 10, 2018 S_3: 70 cm × 25 cm

D_4: November 20, 2018 S_4: 70 cm × 30 cm

NS = Non-significant; * = Significant at 5% level; ** = Significant at 1% level

Combined effect of different planting dates and spacing varied significantly variation was recorded in terms of days required for 1st emergence (Table 3). The highest days required for 1st emergence (20.67) was found from D_1S_4 (October 20, 2018 and 70 cm × 30 cm) and the lowest (16.33 days) was recorded from D_2S_1 (November 01, 2018 and 60 cm × 25 cm) treatment combination.

4.1.2 Days required for 1st to 80% emergence

Statistically significant variation was observed due to the different planting dates in terms of days required for 1st to 80% emergence (Table 2). The highest days required for 1st to 80% emergence (7.83) was recorded from D_1 which was followed (7.25 days) by D_2 and D_3, respectively and they were statistically similar, while the lowest (6.50 days) from D_4. Haile *et al*. (2019) observed that as planting date was delayed, the number of days from 1st to 80% emergence was shortened.

Days required for 1st to 80% emergence showed statistically non-significant differences due to different spacing (Table 2). The maximum days required for 1st to 80% emergence (7.33) was recorded from S_4 and the minimum (7.08 days) from S_1. These results were also in conformity with finding of Firman and Daniels (2011).Statistically significant variation was recorded due to the combined effect of different planting dates and spacing in terms of days required for 1st to 80% emergence (Table 3). The highest days required for 1st to 80% emergence (8.00) was observed from D_1S_2, D_1S_3 and D_1S_4, whereas the lowest (6.00 days) was found from D_4S_2 treatment combination.

4.1.3 Days required for 1st emergence to stolen initiation

Different planting dates showed statistically significant differences in terms of days required for 1st emergence to stolen initiation (Table 2). The highest days required for 1st emergence to stolen initiation (38.83) was found from D_1 which was followed (36.42 and 35.58 days) by D_2 and D_3, respectively and they were statistically similar, while the lowest (32.08 days) was recorded from D_4. The results were in agreement with those of Dubey *et al*. (2011) and Darabi, (2013).

Table 3. Combined effect of different planting dates and spacing on days required for 1st emergence, 80% emergence, stolen initiation and harvest of potato

Treatments	Days required for			
	1st emergence	80% emergence	1st emergence to stolen initiation	Planting to harvest
D_1S_1	18.33 bc	7.33 a-c	41.00 a	97.00 ab
D_1S_2	18.67 b	8.00 a	37.67 a-d	97.33 ab
D_1S_3	17.67 b-d	8.00 a	37.67 a-d	94.67 a-d
D_1S_4	20.67 a	8.00 a	39.00 ab	98.33 a
D_2S_1	16.33 d	7.33 a-c	41.67 a	90.67 de
D_2S_2	17.33 b-d	7.67 ab	38.67 a-c	96.33 a-d
D_2S_3	17.67 b-d	7.00 b-d	36.00 b-e	94.67 a-d
D_2S_4	17.67 b-d	7.00 b-d	29.33 f	94.33 a-d
D_3S_1	18.33 bc	7.33 a-c	40.67 ab	96.67 a-c
D_3S_2	17.33 b-d	7.00 b-d	34.00 c-f	91.00 c-e
D_3S_3	18.33 bc	7.00 b-d	38.00 a-d	97.33 ab
D_3S_4	17.33 b-d	7.67 ab	29.67 f	95.00 a-d
D_4S_1	16.67 cd	6.33 de	32.33 ef	87.00 e
D_4S_2	16.67 cd	6.00 e	31.67 ef	91.33 b-e
D_4S_3	18.00 b-d	7.00 b-d	33.33 d-f	94.00 a-d
D_4S_4	17.00 b-d	6.67 c-e	31.00 f	98.33 a
Sx	0.566	0.227	1.491	1.770
Level of significance	*	**	**	*
CV(%)	5.52	5.45	7.23	3.24

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_1: October 20, 2018 S_1: 60 cm × 25 cm

D_2: November 01, 2018 S_2: 60 cm × 30 cm

D_3: November 10, 2018 S_3: 70 cm × 25 cm

D_4: November 20, 2018 S_4: 70 cm × 30 cm

* = Significant at 5% level; ** = Significant at 1% level

Statistically significant variation was recorded due to different spacing in terms of days required for 1st emergence to stolen initiation (Table 2). The highest days required for 1st emergence to stolen initiation (38.92) was observed from S_1 which was followed (36.25 and 35.50 days) by S_3 and S_2, respectively and they were statistically similar, whereas the lowest (32.25 days) was found from S_4.

Days required for 1st emergence to stolen initiation varied significantly due to the combined effect of different planting dates and spacing (Table 3). The highest days required for 1st emergence to stolen initiation (41.67) was found from D_2S_1, while the lowest (31.00 days) was recorded from D_4S_4 treatment combination.

4.1.4 Days required for planting to harvest

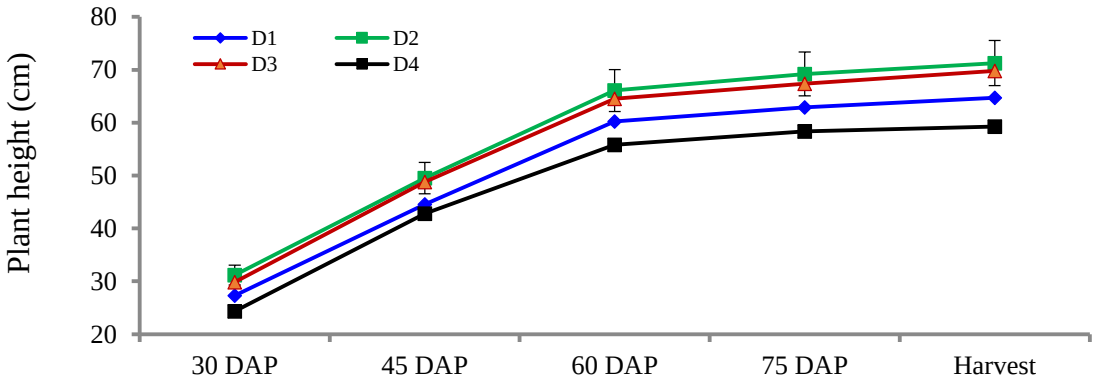
Statistically significant variation was observed due to the different planting dates in terms of days required for planting to harvest (Table 2). The highest days required for planting to harvest (96.83) was recorded from D_1 which was statistically similar (95.00 days) to D_3 and followed (94.00 and 92.67 days) by D_2 and D_4, respectively and they were statistically similar, whereas the lowest (92.67 days) was observed from D_4. The maturity is a varietal characteristic which of course can be influenced by planting date, climatic condition and adopted cultivation practices (Musa *et al*., 2007).

Different spacing showed statistically significant differences on days required for planting to harvest (Table 2). The highest days required for planting to harvest (96.50) was recorded from S_4 which was statistically similar (95.17 and 94.00 days) to S_3 and S_2, respectively, while the lowest (92.83 days) was found from S_1. Akassa *et al*. (2014) observed that an indefinite increase in the plant space did not result to an increase in any of the variables apart from extending days to maturity.

Combined effect of different planting dates and spacing varied significantly in terms of days required for planting to harvest (Table 3). The highest days required for planting to harvest (98.33) was recorded from D_1S_4 that identical to D_4S and the lowest (87.00 days) was observed from D_4S_1 treatment combination.

4.1.5 Plant height

Plant height of potato at 30, 45, 60, 75 DAP (days after planting) and at harvest varied significantly due to the different planting dates (Figure 2). At 30, 45, 60, 75 DAP and harvest, the tallest plant (31.16, 49.50, 66.09, 69.20 and 71.26 cm, respectively) was recorded from D_2 which was statistically similar (29.83, 48.80, 64.55, 67.36 and 69.79 cm, respectively) to D_3. On the other hand, the shortest plant (24.36, 42.77, 55.81, 58.35 and 59.26 cm, respectively) was found from D_4 which was followed (27.32, 44.56, 60.23, 62.89 and 64.72 cm, respectively) by D_1. Plant height is a genetical character but it may differ due to prevailing different biotic and abiotic factors. Thongam *et al*. (2017) recorded the maximum height (52.93 cm and 70.23 cm) at 45 and 75 DAP, respectively in the tuber planted on 10th October, while the minimum values in tuber planted on 10th December.

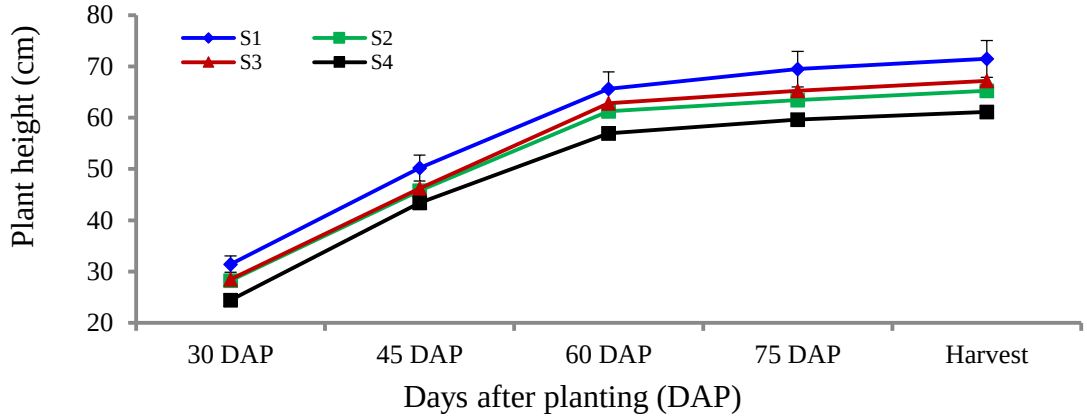


D_1: October 20, 2018; D_2: November 01, 2018
D_3: November 10, 2018; D_4: November 20, 2018

Figure 2. Effect of planting dates on plant height of potato. Vertical bars represent Sx value.

Different spacing showed statistically significant differences on plant height of potato at 30, 45, 60, 75 DAP and harvest (Figure 3). At 30, 45, 60, 75 DAP and harvest, the tallest plant (31.46, 50.19, 65.64, 69.46 and 71.47 cm, respectively) was recorded from S_1 which was followed by (28.50, 46.23, 62.82, 65.27 and 67.20 cm, respectively) and (28.25, 45.80, 61.27, 63.46 and 65.22 cm, respectively) by S_3 and they were statistically similar, whereas the shortest plant

(24.46, 43.42, 56.96, 59.62 and 61.14 cm, respectively) was found . The variation in plant height due to the influences of plant spacing may have been due to the variation in temperature and light during the growing periods. That also reported by Yasmin (2008).



S_1: 60 cm × 25 cm; S_2: 60 cm × 30 cm

S_3: 70 cm × 25 cm; S_4: 70 cm × 30 cm

Figure 3. Effect of spacing on plant height of potato. Vertical bars represent Sx value.

Statistically significant variation was recorded due to the combined effect of different planting dates and spacing in terms of plant height of potato at 30, 45, 60, 75 DAP and harvest (Table 4). At 30, 45, 60, 75 DAP and harvest, the tallest plant (35.91, 55.76, 75.78, 79.49 and 81.79 cm, respectively) was observed from D_2S_1, while the shortest plant (22.34, 39.83, 51.90, 54.12 and 55.42 cm, respectively) was recorded from D_4S_4 treatment combination.

4.1.6 Number of leaves plant^{-1}

Different planting dates varied significantly in terms of number of leaves plant^{-1} of potato at 30, 45, 60, 75 DAP and at harvest (Table 5). At 30, 45, 60, 75 DAP and harvest, the maximum number of leaves plant^{-1} (36.40, 57.13, 63.55, 65.83 and 66.77, respectively) was found from D_2 which was statistically similar (35.95, 55.72, 62.30, 63.27 and 64.10, respectively) to D_3, whereas the minimum number (31.55, 45.65, 53.90, 56.35 and 57.35, respectively) was recorded from D_4 which was followed (33.70, 51.93, 58.13, 59.80 and 60.53, respectively) by D_1.

Table 4. Combined effect of different planting dates and spacing on plant height of potato at different days after planting (DAP) and harvest

Treatments	Plant height (cm) at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
D_1S_1	30.53 c-e	47.02 c-e	59.46 d-f	64.73 c-e	67.73 d-f
D_1S_2	28.37 d-f	45.86 c-g	59.12 d-f	60.39 d-f	62.38 f-i
D_1S_3	28.05 d-g	45.54 d-g	56.48 ef	58.60 ef	59.60 g-i
D_1S_4	23.64 hi	40.58 fg	65.88 b-d	67.86 b-d	69.19 c-f
D_2S_1	35.91 a	55.76 a	75.78 a	79.49 a	81.79 a
D_2S_2	32.41 a-c	51.60 a-c	70.83 a-c	73.40 ab	76.03 a-c
D_2S_3	29.75 c-e	46.54 c-f	65.85 b-d	69.81 bc	71.78 b-e
D_2S_4	26.58 e-h	44.12 d-g	53.66 ef	55.47 f	56.13 hi
D_3S_1	34.46 ab	53.82 ab	72.98 ab	75.30 ab	77.06 ab
D_3S_2	28.01 d-g	43.77 d-g	62.36 c-e	64.54 c-e	65.63 d-g
D_3S_3	31.56 b-d	48.46 b-d	66.48 b-d	68.57 b-d	72.67 b-d
D_3S_4	25.27 f-i	49.15 b-d	56.38 ef	61.04 d-f	63.80 f-h
D_4S_1	24.95 f-i	44.17 d-g	54.34 ef	58.31 ef	59.30 g-i
D_4S_2	24.22 g-i	41.96 e-g	52.76 f	55.51 f	56.83 hi
D_4S_3	24.63 f-i	44.37 d-g	62.47 c-e	64.10 c-e	64.76 e-g
D_4S_4	22.34 i	39.83 g	51.90 f	54.12 f	55.42 i
Sx	1.221	1.811	2.725	2.514	2.365
Level of significance	*	*	**	**	**
CV(%)	7.51	6.76	7.65	6.76	6.18

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_1: October 20, 2018 S_1: 60 cm × 25 cm

D_2: November 01, 2018 S_2: 60 cm × 30 cm

D_3: November 10, 2018 S_3: 70 cm × 25 cm

D_4: November 20, 2018 S_4: 70 cm × 30 cm

* = Significant at 5% level; ** = Significant at 1% level

Table 5. Effect of different planting dates and spacing on number of leaves plant^{-1} of potato at different days after planting (DAP) and harvest

Treatments	Number of leaves plant^{-1} at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
Planting dates					
D_1	33.70 b	51.93 b	58.13 b	59.80 b	60.53 b
D_2	36.40 a	57.13 a	63.55 a	65.83 a	66.77 a
D_3	35.95 a	55.72 a	62.30 a	63.27 a	64.10 a
D_4	31.55 c	45.65 c	53.90 c	56.35 c	57.35 c
Sx	0.556	0.679	1.208	1.047	1.143
Level of significance	**	**	**	**	**
Spacing					
S_1	36.20 a	57.40 a	64.48 a	66.05 a	66.75 a
S_2	34.25 b	52.55 c	60.47 b	62.07 b	62.98 b
S_3	35.30 b	54.82 b	61.00 b	62.67 b	63.73 b
S_4	31.85 c	45.67 d	51.93 c	54.47 c	55.28 c
Sx	0.556	0.679	1.208	1.047	1.143
Level of significance	**	**	**	**	**
CV(%)	5.60	4.47	7.03	5.92	6.37

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_1: October 20, 2018
D_2: November 01, 2018
D_3: November 10, 2018
D_4: November 20, 2018

S_1: 60 cm × 25 cm
S_2: 60 cm × 30 cm
S_3: 70 cm × 25 cm
S_4: 70 cm × 30 cm

** = Significant at 1% level

Number of leaves plant^{-1} of potato at 30, 45, 60, 75 DAP and harvest showed statistically significant differences due to different spacing (Table 5). At 30, 45, 60, 75 DAP and harvest, the maximum number of leaves plant^{-1} (36.20, 57.40, 64.48, 66.05 and 66.75, respectively) was observed from S_1 which was followed by (35.30, 54.82, 61.00, 62.67 and 63.73, respectively) and (34.25, 52.55, 60.47, 62.07 and 62.98, respectively) by S_3 and S_2 and they were statistically similar, while the minimum number (31.85, 45.67, 51.93, 54.47 and 55.28, respectively) was found from S_4. Gulluoglu and Aroglu (2009) reported that closer spacing produced the highest number of leaves plant^{-1}. Probably it was occurred due to intra plant competition and also the variation in temperature and light induced for suitable spacing between plants.

Combined effect of different planting dates and spacing showed statistically significant variation in terms of number of leaves plant^{-1} at 30, 45, 60, 75 DAP and harvest (Table 6). At 30, 45, 60, 75 DAP and harvest, the maximum number of leaves plant^{-1} (40.00, 64.40, 71.07, 72.33 and 73.20, respectively) was observed from D_2S_1 and the minimum number (28.40, 42.20, 50.67, 52.00 and 52.93, respectively) was found from D_4S_4 treatment combination.

4.1.7 Number of stems plant^{-1}

Statistically significant variation was observed due to the different planting dates in terms of number of stems plant^{-1} of potato at 30, 45, 60, 75 DAP and at harvest (Figure 4). At 30, 45, 60, 75 DAP and harvest, the maximum number of stems plant^{-1} (4.72, 5.28, 5.55, 5.67 and 5.78, respectively) was found from D_2 which was statistically similar (4.62, 5.20, 5.45, 5.60 and 5.70, respectively) to D_3, while the minimum number (3.78, 4.23, 4.67, 4.85 and 4.93, respectively) was recorded from D_4 which was followed (4.35, 4.90, 5.30, 5.42 and 5.53, respectively) by D_1. Data revealed that planting of potato in early November produced the highest number of stems plant^{-1}. These results were also in conformity with finding of Firman and Daniels (2011) and Khan *et al*. (2011) who obtained increased number of stem plant^{-1} in early November planting.

Table 6. Combined effect of different planting dates and spacing on number of leaves plant^{-1} of potato at different days after planting (DAP) and harvest

Treatments	Number of leaves plant^{-1} at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
D_1S_1	33.40 de	54.20 de	60.73 c-f	63.73 b-d	64.07 bc
D_1S_2	34.60 b-e	51.47 ef	58.73 d-g	59.87 de	60.60 cd
D_1S_3	35.20 b-e	54.13 de	58.73 d-g	59.20 de	60.40 s-e
D_1S_4	31.60 ef	47.93 fg	54.33 fg	56.40 ef	57.07 c-e
D_2S_1	40.00 a	64.40 a	71.07 a	72.33 a	73.20 a
D_2S_2	38.20 ab	59.87 bc	67.40 a-c	69.07 a-c	69.87 ab
D_2S_3	34.60 b-e	57.20 cd	63.73 a-d	66.73 a-c	67.87 ab
D_2S_4	32.80 de	47.07 g	52.00 g	55.20 ef	56.13 de
D_3S_1	37.60 a-c	62.20 ab	69.40 ab	70.40 ab	71.20 ab
D_3S_2	35.80 b-d	56.07 cd	62.33 b-e	63.27 cd	64.00 bc
D_3S_3	36.40 b-d	59.13 bc	66.73 a-c	67.40 a-c	68.27 ab
D_3S_4	34.00 c-e	45.47 gh	50.73 g	54.27 ef	55.00 de
D_4S_1	33.80 de	48.80 fg	56.73 d-g	57.73 d-f	58.53 c-e
D_4S_2	29.00 f	42.80 h	53.40 fg	56.07 ef	57.47 c-e
D_4S_3	35.00 b-e	48.80 fg	54.80 e-g	57.33 d-f	58.40 c-e
D_4S_4	28.40 f	42.20 h	50.67 g	52.00 f	52.93 e
Sx	1.112	1.358	2.415	2.094	2.286
Level of significance	**	**	*	*	*
CV(%)	5.60	4.47	7.03	5.92	6.37

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

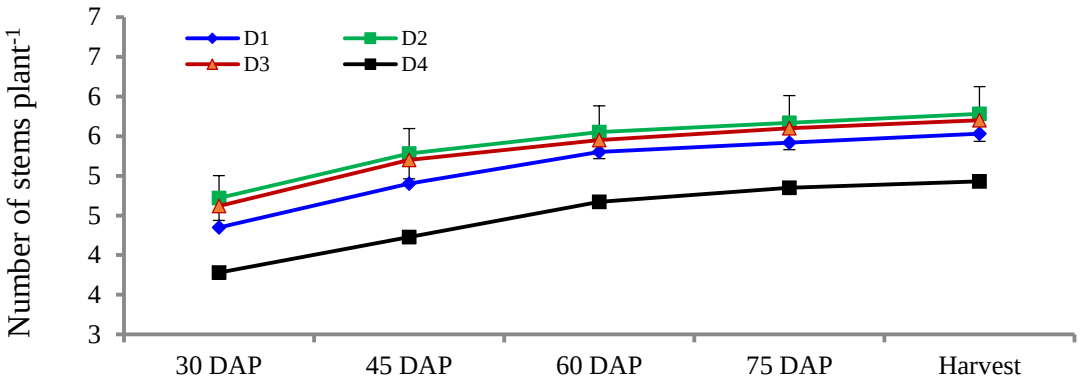
D_1: October 20, 2018 — S_1: 60 cm × 25 cm

D_2: November 01, 2018 — S_2: 60 cm × 30 cm

D_3: November 10, 2018 — S_3: 70 cm × 25 cm

D_4: November 20, 2018 — S_4: 70 cm × 30 cm

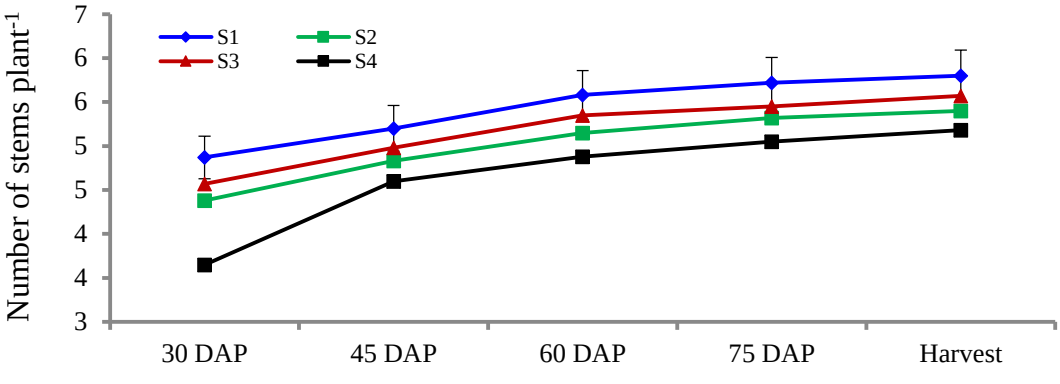
* = Significant at 5% level; ** = Significant at 1% level



D_1: October 20, 2018; D_2: November 01, 2018
D_3: November 10, 2018; D_4: November 20, 2018

Figure 4. Effect of planting dates on number of leaves plant^{-1} of potato. Vertical bars represent Sx value.

Different spacing varied significantly on number of stems plant^{-1} of potato at 30, 45, 60, 75 DAP and harvest (Figure 5). At 30, 45, 60, 75 DAP and harvest, the maximum number of stems plant^{-1} (4.87, 5.20, 5.58, 5.72 and 5.80, respectively) was recorded from S_1 which was followed by (4.57, 4.98, 5.35, 5.45 and 5.57, respectively) and (4.38, 4.83, 5.15, 5.32 and 5.40, respectively) by S_3 and S_2 and they were statistically similar, whereas the minimum number (3.65, 4.60, 4.88, 5.05 and 5.18, respectively) from S_4. Khalafalla (2001) reported that spacing have no significant effect on number of stems plant^{-1}.



S_1: 60 cm × 25 cm; S_2: 60 cm × 30 cm
S_3: 70 cm × 25 cm; S_4: 70 cm × 30 cm

Figure 5. Effect of spacing on number of stems plant^{-1} of potato. Vertical bars represent Sx value.

Number of stems plant^{-1} at 30, 45, 60, 75 DAP and harvest varied significantly due to the combined effect of different planting dates and spacing (Table 7). At 30, 45, 60, 75 DAP and harvest, the maximum number of stems plant^{-1} (5.47, 5.80, 6.07, 6.20 and 6.27, respectively) was recorded from D_2S_1, while the minimum number (3.40, 4.07, 4.27, 4.53 and 4.67, respectively) from D_4S_4 treatment combination.

4.1.8 Number of tubers hill^{-1}

Different planting dates varied significantly in terms of number of tubers hill^{-1} (Table 8). The maximum number of tubers hill^{-1} (9.02) was observed from D_2 which was statistically similar (8.85) to D_3 and followed (8.43) by D_1, whereas the minimum number (7.90) was recorded from D_4. Thongam *et al*. (2017) recorded the maximum number of tubers plant^{-1} (8.20) in planting date of October 10th, while the minimum number (4.00) in planting date of 10th December.

Statistically significant variation was recorded for different spacing in terms of number of tubers hill^{-1} (Table 8). The maximum number of tubers hill^{-1} (9.00) was found from S_1 which was followed (8.58 and 8.52) by S_3 and S_2, respectively and they were statistically similar, while the minimum number (8.10) from S_4. Kumar and Lal (2006) reported that total tubers increased at closer planting geometry.

Combined effect of different planting dates and spacing showed statistically significant differences in terms of number of tubers hill^{-1} (Table 9). The maximum number of tubers hill^{-1} (9.73) was recorded from D_2S_1 and the minimum number (7.60) was found from D_4S_4 treatment combination.

4.1.9 Weight of tubers hill^{-1}

Weight of tubers hill^{-1} showed statistically significant variation due to the different planting dates (Table 8). The highest weight of tubers hill^{-1} (425.93 g) was recorded from D_2 which was statistically similar (413.67 g) to D_3 and followed (405.79 g) by D_1, while the lowest weight (381.06 g) was observed from D_4. Ahmed *et al*. (2017) reported the highest tuber weight plant^{-1} (97.25 g) at December 5 sowing and the lowest (25.58 g) in November 20 sowing.

Table 7. Combined effect of different planting dates and spacing on number of stems plant^{-1} of potato at different days after planting (DAP) and harvest

Treatments	Number of stems plant^{-1} at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
D_1S_1	4.60 cd	4.93 d-g	5.40 d-f	5.53 b-d	5.60 b-d
D_1S_2	4.40 de	4.67 f-h	5.20 d-g	5.40 c-e	5.53 c-e
D_1S_3	4.40 de	4.87 e-g	5.20 d-g	5.27 c-f	5.40 c-e
D_1S_4	4.00 ef	5.13 c-f	5.40 d-f	5.47 b-e	5.60 b-d
D_2S_1	5.47 a	5.80 a	6.07 a	6.20 a	6.27 a
D_2S_2	4.80 cd	5.40 a-d	5.60 b-d	5.73 a-c	5.80 a-c
D_2S_3	4.87 b-d	5.27 b-e	5.47 c-e	5.53 b-d	5.67 bc
D_2S_4	3.73 fg	4.67 f-h	5.07 e-h	5.27 c-f	5.40 c-e
D_3S_1	5.33 ab	5.73 ab	5.93 ab	6.13 a	6.20 a
D_3S_2	4.67 cd	5.00 d-g	5.20 d-g	5.33 c-f	5.47 c-e
D_3S_3	5.00 a-c	5.53 a-c	5.87 a-c	6.00 ab	6.07 ab
D_3S_4	3.47 g	4.53 g-i	4.80 gh	4.93 e-g	5.07 ef
D_4S_1	4.07 ef	4.33 hi	4.93 f-h	5.07 d-g	5.13 d-f
D_4S_2	3.67 fg	4.27 hi	4.60 hi	4.80 fg	4.80 f
D_4S_3	4.00 ef	4.27 hi	4.87 gh	5.00 d-g	5.13 d-f
D_4S_4	3.40 g	4.07 i	4.27 i	4.53 g	4.67 f
Sx	0.159	0.153	0.148	0.171	0.157
Level of significance	**	**	**	*	*
CV(%)	6.32	5.39	4.88	5.51	4.96

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_1: October 20, 2018 S_1: 60 cm × 25 cm

D_2: November 01, 2018 S_2: 60 cm × 30 cm

D_3: November 10, 2018 S_3: 70 cm × 25 cm

D_4: November 20, 2018 S_4: 70 cm × 30 cm

* = Significant at 5% level; ** = Significant at 1% level

Table 8. Effect of different planting dates and spacing on number and weight of tubers hill^{-1}, average weight of single tuber and yield of tubers hectare^{-1} of potato

Treatments	Number of tubers hill^{-1}	Weight of tubers hill^{-1} (g)	Average weight of single tuber (g)	Dry matter content in potato tubers (%)	Yield of tubers (t ha^{-1})
Planting dates					
D_1	8.43 b	391.53 c	46.46 a	18.32 ab	25.01 b
D_2	9.02 a	429.93 a	47.84 a	19.19 a	27.69 a
D_3	8.85 a	413.67 b	46.80 a	19.13 a	26.96 a
D_4	7.90 c	351.98 d	44.66 b	17.51 b	22.88 c
Sx	0.105	4.456	0.537	0.330	0.457
Level of significance	**	**	**	**	**
Spacing					
S_1	9.00 a	405.04 a	45.01 b	19.46 a	27.81 a
S_2	8.52 b	397.36 a	46.65 a	18.35 b	25.73 b
S_3	8.58 b	401.01 a	46.68 a	18.61 ab	26.16 b
S_4	8.10 c	383.69 b	47.42 a	17.73 b	22.85 c
Sx	0.105	4.456	0.537	0.330	0.457
Level of significance	**	**	*	**	**
CV(%)	4.24	3.89	4.01	6.17	6.17

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_1: October 20, 2018
D_2: November 01, 2018
D_3: November 10, 2018
D_4: November 20, 2018

S_1: 60 cm × 25 cm
S_2: 60 cm × 30 cm
S_3: 70 cm × 25 cm
S_4: 70 cm × 30 cm

** = Significant at 1% level

Table 9. Combined effect of different planting dates and spacing on number and weight of tubers hill^{-1}, average weight of single tuber and yield of tubers hectare^{-1} of potato

Treatments	Number of tubers hill^{-1}	Weight of tubers hill^{-1} (g)	Average weight of single tuber (g)	Dry matter content in potato tubers (%)	Yield of tubers (t ha^{-1})
D_1S_1	8.73 c-e	396.47 de	45.42 b-d	18.80 a-e	25.91 d-f
D_1S_2	8.27 d-g	384.89 e	46.57 b-d	17.48 ef	25.04 e-g
D_1S_3	8.20 e-g	390.79 de	47.71 a-c	17.93 d-f	24.57 e-h
D_1S_4	8.53 c-f	393.99 de	46.16 b-d	19.06 a-e	24.55 e-h
D_2S_1	9.73 a	444.32 a	45.68 b-d	20.94 a	31.56 a
D_2S_2	9.40 ab	437.07 ab	46.53 b-d	19.91 a-d	29.42 a-c
D_2S_3	8.93 b-d	431.21 a-c	48.26 a-c	18.33 c-f	27.43 c-e
D_2S_4	8.00 fg	407.12 c-e	50.88 a	17.58 ef	22.37 gh
D_3S_1	9.53 ab	429.13 a-c	45.02 b-d	20.88 ab	30.53 ab
D_3S_2	8.53 c-f	414.66 b-d	48.62 ab	18.76 b-e	26.22 d-f
D_3S_3	9.07 bc	427.03 a-c	47.10 b-d	20.37 a-c	28.41 b-d
D_3S_4	8.27 d-g	383.86 e	46.44 b-d	16.50 f	22.71 gh
D_4S_1	8.00 fg	350.24 f	43.91 d	17.20 ef	23.24 f-h
D_4S_2	7.87 fg	352.83 f	44.87 cd	17.23 ef	22.26 gh
D_4S_3	8.13 e-g	355.03 f	43.66 d	17.81 d-f	24.23 f-h
D_4S_4	7.60 g	349.80 f	46.19 b-d	17.78 d-f	21.78 h
Sx	0.209	8.913	1.074	0.660	0.914
Level of significance	**	*	*	**	**
CV(%)	4.24	3.89	4.01	6.17	6.17

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_1: October 20, 2018 S_1: 60 cm × 25 cm

D_2: November 01, 2018 S_2: 60 cm × 30 cm

D_3: November 10, 2018 S_3: 70 cm × 25 cm

D_4: November 20, 2018 S_4: 70 cm × 30 cm

* = Significant at 5% level; ** = Significant at 1% level

Different spacing showed statistically significant differences on weight of tubers hill^{-1} (Table 8). The highest weight of tubers hill^{-1} (415.12 g) was recorded from S_1 which was statistically similar (410.76 g and 407.20 g) to S_3 and S_2, respectively, whereas the lowest weight (393.36 g) was found from S_4. Gulluoglu and Aroglu (2009) reported that closer spacing reduced tuber yield hill^{-1}.

Statistically significant variation was recorded due to the combined effect of different planting dates and spacing in terms of weight of tubers hill^{-1} (Table 9). The highest weight of tubers hill^{-1} (440.32 g) was observed from D_2S_1, while the lowest (378.47 g) was recorded from D_4S_4 treatment combination.

4.1.10 Average weight of single tubers

Statistically significant variation was observed due to the different planting dates in terms of average weight of single tuber (Table 8). The highest average weight of single tuber (47.84 g) was observed from D_2 which was statistically similar (46.80 g and 46.46 g) to D_3 and D_1, whereas the lowest weight (44.66 g) was found from D_4. Teweldemedhin *et al*. (2018) reported earlier that the average tuber weight significantly affected by planting dates and it has been observed that delay in planting decreased the average weight of single tuber.

Average weight of single tuber showed statistically significant differences due to different spacing (Table 8). The highest average weight of single tuber (47.42 g) was found from S_4 which was statistically similar (46.68 g and 46.65 g) to S_3 and S_2, respectively, while the lowest weight (45.01 g) was recorded from S_1. Gulluoglu and Aroglu (2009) reported that closer spacing reduced average tuber weight.

Combined effect of different planting dates and spacing varied significantly in terms of average weight of single tuber (Table 9). The highest average weight of single tuber (50.88 g) was observed from D_2S_4 and the lowest (43.66 g) was recorded from D_4S_3 treatment combination.

4.1.11 Dry matter content in potato tubers

Different planting dates varied significantly in terms of dry matter content in potato tubers (Table 8). The highest dry matter content (19.19%) was observed from D_2 which was statistically similar (19.13% and 18.32%) to D_3 and D_1, whereas the lowest (17.51%) was recorded from D_4. Khan *et al*. (2011) reported that the dry matter of potato was higher at the planting of optimum time.

Statistically significant variation was recorded for different spacing in terms of dry matter content in potato tubers (Table 8). The highest dry matter content (19.46%) was found from S_1 which was statistically similar (18.61%) to S_3, respectively, while the lowest (17.73%) from S_4 which was statistically similar (18.35%) to S_2. Dagne *et al*. (2019) reported the similar findings in earlier.

Combined effect of different planting dates and spacing showed statistically significant differences in terms of dry matter content in potato tubers (Table 9). The highest dry matter content (20.94%) was recorded from D_2S_1 and the lowest (16.50%) was found from D_3S_4 treatment combination.

4.1.12 Yield of tubers hectare^{-1}

Yield of tubers hectare^{-1} showed statistically significant differences due to the different planting dates (Table 8). The highest yield of tubers (27.69 t ha^{-1}) was recorded from D_2 which was statistically similar (26.96 t ha^{-1}) to D_3 and followed (25.01 t ha^{-1}) by D_1, while the lowest yield (22.88 t ha^{-1}) was observed from D_4. Lakra (2003) reported that planting on 1st November resulted in maximum tuber yield in all the cultivars. Thongam *et al*. (2017) recorded the highest yield (27.74 t ha^{-1}) in planting date of 10th October which was statistically at par with 20th October planting, while the lowest yield (10.77 t ha^{-1}) in 10th December.

Different spacing showed statistically significant differences on yield of tubers hectare^{-1} (Table 8). The highest yield of tubers (27.81 t ha^{-1}) was found from S_1 which was followed (26.16 t ha^{-1} and 25.73 t ha^{-1}) by S_3 and S_2, respectively and they were statistically similar, whereas the lowest yield (22.85 t ha^{-1}) was observed

from S_4. Roy *et al.* (2014) reported the highest marketable tuber yield ha^{-1} in the plant spacing of 60×20 cm and the lowest from closer spacing of 60×15 cm.

Statistically significant variation was recorded due to the combined effect of different planting dates and spacing in terms of yield of tubers $hectare^{-1}$ (Table 9). The highest yield of tubers (31.56 t ha^{-1}) was recorded from D_2S_1, while the lowest yield (21.78 t ha^{-1}) was observed from D_4S_4 treatment combination.

4.2 Quality of potato tubers

4.2.1 Grading of potato tubers

Statistically significant variation was observed due to the different planting dates in terms of grading of potato tubers (<28 mm, 28-45 mm, 45-55 mm and >55 mm) (Table 10). In consideration <28 mm grade, the highest (29.82%) was found from D_4 which was followed (23.69%) by D_1, whereas the lowest (17.18%) was found from D_2. On the other hand in 28-45 mm, 45-55 mm and >55 mm grade, the highest (45.79%, 28.58% and 8.45%, respectively) was recorded from D_2 which was statistically similar (45.06%, 27.83% and 8.21%, respectively) to D_3, while the lowest (38.51%, 24.47% and 7.20%, respectively) from D_4. Sandhu *et al.* (2008) observed maximum number of A and B grade tubers from 1st November planted crop, while 21st November recorded lowest number.

Grading (<28 mm, 28-45 mm, 45-55 mm and >55 mm) of potato tubers showed statistically significant differences due to different spacing (Table 10). For <28 mm grade, the highest (29.42%) was observed from S_4 which was followed (22.08%) by S and the lowest (17.79%) was recorded from S_1. On the other hand in 28-45 mm, 45-55 mm and >55 mm grade, the highest (45.62%, 28.19% and 8.40%, respectively) was found from S_1 which was statistically similar (44.06%, 27.53% and 8.10%, respectively) to S_3, whereas the lowest (38.85%, 24.55% and 7.18%, respectively) was recorded from S_4. Islam *et al.* (2012) reported that yield for C grade (46-55 mm) and over size (> 55 mm) seed tubers were lowest in closer spacing due to insufficient light interception by an over populated crop canopy.

Table 10. Effect of different planting dates and spacing on different grading of potato tubers

Treatments	Grading of potato tubers (%)			
	<28 mm	28-45 mm	45-55 mm	>55 mm
Planting dates				
D_1	23.69 b	42.14 b	26.41 b	7.76 b
D_2	17.18 c	45.79 a	28.58 a	8.45 a
D_3	18.91 c	45.06 a	27.83 a	8.21 a
D_4	29.82 a	38.51 c	24.47 c	7.20 c
Sx	1.033	0.644	0.322	0.126
Level of significance	**	**	**	**
Spacing				
S_1	17.79 c	45.62 a	28.19 a	8.40 a
S_2	22.08 b	42.97 b	27.02 b	7.93 b
S_3	20.31 bc	44.06 ab	27.53 ab	8.10 ab
S_4	29.42 a	38.85 c	24.55 c	7.18 c
Sx	1.033	0.644	0.322	0.126
Level of significance	**	**	**	**
CV(%)	15.98	5.21	4.15	5.51

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_1: October 20, 2018
D_2: November 01, 2018
D_3: November 10, 2018
D_4: November 20, 2018

S_1: 60 cm × 25 cm
S_2: 60 cm × 30 cm
S_3: 70 cm × 25 cm
S_4: 70 cm × 30 cm

** = Significant at 1% level

Combined effect of different planting dates and spacing varied significantly in terms of grading (<28 mm, 28-45 mm, 45-55 mm and >55 mm) of potato tubers (Table 11). For <28 mm grade, the highest (33.81%) was recorded from D_4S_4, whereas the lowest (10.62%) was observed from D_2S_1 treatment combination. On the other hand in 28-45 mm, 45-55 mm and >55 mm grade, the highest (49.51%, 30.65% and 9.22%, respectively) was recorded from D_2S_1 and the lowest (36.21%, 23.13% and 6.85%, respectively) was found from D_4S_4 treatment combination.

4.2.2 Category of potato tubers for different uses

Category (Chips: 45-75 mm, Canned: 25-45 mm and non-marketable) of potato tubers varied significantly due to the different planting dates (Table 12). In consideration of Chips and Canned potato, the highest (40.50% and 42.07%, respectively) was recorded from D_2 which was statistically similar (39.21% and 41.01%, respectively) to D_3, while the lowest (33.92% and 37.64%, respectively) was found from D_4. On the other hand in non-marketable potato, the highest (28.44%) was recorded from D_4 which was followed (23.33%) by D_1 and the lowest (17.43%) was found from D_2. Haile *et al*. (2019) reported that the delay in planting of potato tubers resulted in higher unmarketable yield.

Different spacing showed statistically significant differences on category (Chips: 45-75 mm, Canned: 25-45 mm) and non-marketable of potato tubers (Table 12). For Chips and Canned potato, the highest (40.45% and 41.27%, respectively) was recorded from S_1, whereas the lowest (33.55% and 38.59%, respectively) was found from S_4. On the other hand in non-marketable potato, the highest (27.86%) was observed from S_4 which was followed (22.05% and 20.79%) by S_2 and S_3 and they were statistically similar, whereas the lowest (18.28%) from S_1. Kumar and Lal (2006) reported that yield of bigger size tubers (>40 g) increased with wider planting geometry. Alam *et al*. (2016) reported the highest chips grade tubers in 67.5×25 cm spacing without affecting processing quality.

Table 11. Combined effect of different planting dates and spacing on different grading of potato tubers

Treatments	Grade of potato tubers (%)			
	<28 mm	28-45 mm	45-55 mm	>55 mm
D_1S_1	20.30 e-g	44.02 b-d	27.56 bc	8.11 bc
D_1S_2	23.23 c-f	42.34 c-e	26.83 c-e	7.59 c-f
D_1S_3	22.90 c-f	43.04 c-e	26.64 c-f	7.43 c-f
D_1S_4	28.35 a-c	39.15 e-g	24.60 f-h	7.91 b-e
D_2S_1	10.62 i	49.51 a	30.65 a	9.22 a
D_2S_2	11.67 hi	48.76 a	30.51 a	9.06 a
D_2S_3	17.73 f-h	45.48 a-c	28.14 bc	8.65 ab
D_2S_4	28.69 a-c	39.41 e-g	25.03 e-h	6.87 f
D_3S_1	13.03 hi	48.76 a	29.22 ab	8.99 a
D_3S_2	20.84 d-g	43.68 b-d	27.39 b-d	8.09 b-d
D_3S_3	14.92 g-i	47.18 ab	29.25 ab	8.65 ab
D_3S_4	26.84 b-e	40.62 d-f	25.44 d-f	7.09 ef
D_4S_1	27.22 a-d	40.18 d-g	25.32 d-g	7.29 d-f
D_4S_2	32.57 ab	37.10 fg	23.34 gh	6.99 f
D_4S_3	25.67 c-e	40.56 d-f	26.09 c-f	7.68 c-f
D_4S_4	33.81 a	36.21 g	23.13 h	6.85 f
Sx	2.066	1.289	0.643	0.251
Level of significance	*	*	**	**
CV(%)	15.98	5.21	4.15	5.51

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_1: October 20, 2018 S_1: 60 cm × 25 cm

D_2: November 01, 2018 S_2: 60 cm × 30 cm

D_3: November 10, 2018 S_3: 70 cm × 25 cm

D_4: November 20, 2018 S_4: 70 cm × 30 cm

* = Significant at 5% level; ** = Significant at 1% level

Table 12. Effect of different planting dates and spacing on potato for the uses as chips, canned and non-marketable potato tubers

Treatments	Category of potato tubers (%) for different uses		
	Chips (45-75 mm)	Canned (25-45 mm)	Non-marketable
Planting dates			
D_1	36.58 b	40.09 b	23.33 b
D_2	40.50 a	42.07 a	17.43 c
D_3	39.21 a	41.01 ab	19.79 c
D_4	33.92 c	37.64 c	28.44 a
Sx	0.550	0.376	0.843
Level of significance	**	**	**
Spacing			
S_1	40.45 a	41.27 a	18.28 c
S_2	37.71 b	40.24 a	22.05 b
S_3	38.50 b	40.71 a	20.79 b
S_4	33.55 c	38.59 b	27.86 a
Sx	0.550	0.376	0.843
Level of significance	**	**	**
CV(%)	5.07	3.24	13.13

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_1: October 20, 2018
D_2: November 01, 2018
D_3: November 10, 2018
D_4: November 20, 2018

S_1: 60 cm × 25 cm
S_2: 60 cm × 30 cm
S_3: 70 cm × 25 cm
S_4: 70 cm × 30 cm

** = Significant at 1% level

Statistically significant variation was recorded due to the combined effect of different planting dates and spacing in terms of category (Chips: 45-75 mm, Canned: 25-45 mm and non-marketable) of potato tubers (Table 13). For Chips and Canned potato, the highest category (45.20% and 43.82%, respectively) was recorded from D_2S_1, while the lowest (31.82% and 37.11%, respectively) was found from D_4S_4 treatment combination. On the other hand in non-marketable potato, the highest (31.07%) was recorded from D_4S_4 and the lowest (10.98%) was found from D_2S_1 treatment combination.

4.2.3 Firmness score of potato tubers

Statistically significant variation was observed due to the different planting dates in terms of firmness score of potato tubers (Table 14). The highest firmness score of potato tubers (42.45 N) was found from D_2 which was statistically similar (41.28 N) to D_3 and followed (38.45 N) by D_1, while the lowest firmness score of potato tubers (36.07 N) from D_4.

Firmness score of potato tubers showed statistically significant differences due to different spacing (Table 14). The highest firmness score of potato (42.70 N) was observed from S_1 which was followed (40.06 N and 39.41 N) by S_3 and S_2, respectively and they were statistically similar, whereas the lowest firmness score (36.07 N) was found from S_4.

Combined effect of different planting dates and spacing varied significantly in terms of firmness score of potato tubers (Table 15). The highest firmness score of potato (47.83 N) was observed from D_2S_1, while the lowest firmness score (34.42 N) was recorded from D_4S_4 treatment combination.

4.2.4 Specific gravity of potato tubers

Specific gravity of potato tubers varied significantly due to the different planting dates (Table 14). The highest specific gravity of potato (1.08) was observed from D_2 which was statistically similar (1.07 and 1.06) to D_3 and D_1, whereas the lowest specific gravity (1.02) was found from D_4.

Table 13. Combined effect of different planting dates and spacing for the uses as chips, canned and non-marketable potato tubers

Treatments	Harvested potato tubers (%) for		
	Chips (45-75 mm)	Canned (25-45 mm)	Non-marketable
D_1S_1	38.01 c-f	40.67 b-d	21.32 d-f
D_1S_2	36.73 d-g	39.54 d-f	23.73 c-e
D_1S_3	36.74 d-g	40.14 c-e	23.12 c-e
D_1S_4	34.85 f-i	40.00 c-e	25.15 b-e
D_2S_1	45.20 a	43.82 a	10.98 h
D_2S_2	42.70 ab	42.87 ab	14.43 gh
D_2S_3	40.15 b-d	42.15 a-c	17.69 fg
D_2S_4	33.96 g-i	39.45 d-f	26.59 a-d
D_3S_1	43.38 ab	42.77 ab	13.84 gh
D_3S_2	38.67 c-e	41.09 b-d	20.25 ef
D_3S_3	41.22 bc	42.35 a-c	16.44 fg
D_3S_4	33.56 g-i	37.82 ef	28.62 a-c
D_4S_1	35.21 e-i	37.81 ef	26.99 a-c
D_4S_2	32.75 hi	37.45 f	29.81 ab
D_4S_3	35.90 e-h	38.19 ef	25.91 a-d
D_4S_4	31.82 i	37.11 f	31.07 a
Sx	1.100	0.751	1.686
Level of significance	**	*	**
CV(%)	5.07	3.24	13.13

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_1: October 20, 2018 — S_1: 60 cm × 25 cm

D_2: November 01, 2018 — S_2: 60 cm × 30 cm

D_3: November 10, 2018 — S_3: 70 cm × 25 cm

D_4: November 20, 2018 — S_4: 70 cm × 30 cm

* = Significant at 5% level; ** = Significant at 1% level

Table 14. Effect of different planting dates and spacing on firmness score, specific gravity, starch, reducing sugar, total soluble solids-TSS and vitamin C content of potato tubers

Treatments	Firmness score (N)	Specific gravity	Starch (mg g^{-1} FW)	Reducing sugar (mg g^{-1} FW)	Total soluble solid (TSS ^{0}brix)	Vitamin C (mg 100 $g^{-1\ FW}$)
Planting dates						
D_1	38.45 b	1.06 a	15.84 b	0.28 b	6.19 ab	22.01 b
D_2	42.45 a	1.08 a	17.11 a	0.25 d	6.06 b	23.62 a
D_3	41.28 a	1.07 a	16.63 a	0.27 c	6.09 b	23.15 a
D_4	36.07 c	1.02 b	15.03 c	0.30 a	6.35 a	19.60 c
Sx	0.655	0.010	0.213	0.005	0.070	0.242
Level of significance	**	**	**	**	*	**
Spacing						
S_1	42.70 a	1.09 a	17.13 a	0.26 c	6.06	23.68 a
S_2	39.41 b	1.06 b	16.27 b	0.28 b	6.14	21.90 b
S_3	40.06 b	1.07 b	16.45 b	0.27 b	6.18	22.51 b
S_4	36.07 c	1.03 c	14.77 c	0.29 a	6.32	20.29 c
Sx	0.655	0.010	0.213	0.005	0.070	0.242
Level of significance	**	**	**	**	NS	**
CV(%)	5.74	3.11	4.57	6.78	3.92	3.79

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_1: October 20, 2018
D_2: November 01, 2018
D_3: November 10, 2018
D_4: November 20, 2018

S_1: 60 cm × 25 cm
S_2: 60 cm × 30 cm
S_3: 70 cm × 25 cm
S_4: 70 cm × 30 cm

** = Significant at 1% level

Table 15. Combined effect of different planting dates and spacing on firmness score, specific gravity, starch, reducing sugar, total soluble solids-TSS and vitamin C content of potato tubers

Treatments	Firmness score (N)	Specific gravity	Starch (mg g^{-1} FW)	Reducing sugar (mg g^{-1} FW)	Total soluble solid (TSS ^{0}brix)	Vitamin C (mg 100 $g^{-1\ FW}$)
D_1S_1	40.28 c-e	1.09 a-d	16.47 cd	0.24 h	5.75 e	22.70 de
D_1S_2	38.23 d-f	1.05 c-e	15.85 de	0.29 c-e	6.12 b-e	21.54 e-g
D_1S_3	37.58 ef	1.06 b-e	15.74 d-f	0.26 fg	5.71 e	21.69 ef
D_1S_4	37.73 ef	1.06 b-e	15.30 d-f	0.31 ab	6.40 b	22.11 de
D_2S_1	47.83 a	1.13 a	18.60 a	0.25 gh	6.28 bc	26.11 a
D_2S_2	44.70 ab	1.11 a-c	17.78 a-c	0.27 d-f	6.43 b	24.22 bc
D_2S_3	42.10 b-d	1.08 a-d	17.21 bc	0.24 h	5.68 e	23.56 cd
D_2S_4	35.16 f	1.01 e	14.85 ef	0.25 gh	5.81 de	20.59 f-h
D_3S_1	46.01 ab	1.11 ab	18.18 ab	0.26 fg	6.31 bc	25.57 ab
D_3S_2	39.56 c-e	1.05 b-e	16.48 cd	0.25 gh	5.97 b-e	22.43 de
D_3S_3	42.57 bc	1.10 a-c	17.46 a-c	0.28 d-f	6.22 b-d	24.52 bc
D_3S_4	36.98 ef	1.03 de	14.40 f	0.27 e-g	5.87 c-e	20.10 gh
D_4S_1	36.69 ef	1.02 e	15.27 d-f	0.28 d-f	5.88 c-e	20.34 f-h
D_4S_2	35.16 f	1.02 e	14.95 ef	0.29 cd	6.03 b-e	19.43 hi
D_4S_3	38.01 d-f	1.03 de	15.38 d-f	0.30 bc	7.09 a	20.29 f-h
D_4S_4	34.42 f	1.00 e	14.51 ef	0.32 a	7.20 a	18.34 i
Sx	1.311	0.019	0.426	0.011	0.140	0.483
Level of significance	**	*	**	**	**	**
CV(%)	5.74	3.11	4.57	6.78	3.92	3.79

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_1: October 20, 2018 — S_1: 60 cm × 25 cm

D_2: November 01, 2018 — S_2: 60 cm × 30 cm

D_3: November 10, 2018 — S_3: 70 cm × 25 cm

D_4: November 20, 2018 — S_4: 70 cm × 30 cm

* = Significant at 5% level; ** = Significant at 1% level

Different spacing showed statistically significant differences on specific gravity of potato tubers (Table 14). The highest specific gravity of potato (1.09) was recorded from S_1 which was followed (1.07 and 1.06) by S_3 and S_2, respectively and they were statistically similar, while the lowest (1.03) from S_4. Dagne *et al*. (2019) reported that spacing did not influenced significantly on specific gravity.

Statistically significant variation was recorded due to the combined effect of different planting dates and spacing in terms of specific gravity of potato tubers (Table 15). The highest specific gravity of potato (1.13) was observed from D_2S_1 and the lowest specific gravity (1.00) was found from D_4S_4 treatment combination.

4.2.5 Starch content in potato tubers

Statistically significant variation was observed due to the different planting dates in terms of starch content in potato tubers (Table 14). The highest starch content in potato tubers (17.11 mg g^{-1} FW) was found from D_2 which was statistically similar (16.63 mg g^{-1} FW) to D_3 and followed (15.84 mg g^{-1} FW) by D_1, whereas the lowest starch content (15.03 mg g^{-1} FW) was observed from D_4.

Different spacing showed statistically significant differences on starch content in potato tubers (Table 14). The highest starch content in potato (17.13 mg g^{-1} FW) was observed from S_1 which was followed (16.45 and 16.27 mg g^{-1} FW) by S_3 and S_2, respectively and they were statistically similar, while the lowest starch content (14.77 mg g^{-1} FW) was recorded from S_4.

Statistically significant variation was recorded due to the combined effect of different planting dates and spacing in terms of starch content in potato tubers (Table 15). The highest starch content in potato (18.60 mg g^{-1} FW) was recorded from D_2S_1 and the lowest (14.40 mg g^{-1} FW) was observed from D_3S_4 treatment combination.

4.2.6 Reducing sugar content in potato tubers

Reducing sugar content of potato tubers showed statistically significant differences due to the different planting dates (Table 14). The highest reducing

sugar content in potato tubers (0.30 mg g^{-1} FW) was recorded found from D_4 which was followed (0.28 mg g^{-1} FW) by D_1, while the lowest reducing sugar content in potato tubers (0.25 mg g^{-1} FW) was observed from D_2 which was followed (0.27 mg g^{-1} FW) by D_3.

Statistically significant variation was recorded due to different spacing on reducing sugar content in potato tubers (Table 14). The highest reducing sugar content in potato tubers (0.29 mg g^{-1} FW) was observed from S_4 which was followed (0.28 and 0.27 mg g^{-1} FW) by S_2 and S_3, respectively and they were statistically similar, whereas the lowest reducing sugar content (0.26 mg g^{-1} FW) was recorded from S_1.

Combined effect of different planting dates and spacing showed statistically significant differences in terms of reducing sugar content in potato tubers (Table 15). The highest reducing sugar content in potato tubers (0.32 mg g^{-1} FW) was recorded from D_4S_4 and the lowest (0.24 mg g^{-1} FW) was observed from D_2S_3 treatment combination.

4.2.7 Total soluble solid-TSS

Different planting dates showed statistically significant differences in terms of total soluble solid-TSS of potato (Table 14). The highest TSS of potato (6.35 ^{0}brix) was found from D_4 which was statistically similar (6.19 ^{0}brix) to D_1, while the lowest TSS (6.06 ^{0}brix) was observed from D_2 which was statistically similar (6.09 ^{0}brix) to D_3.

Statistically non-significant variation was recorded due to different spacing in terms of TSS of potato (Table 14). The highest TSS of potato (6.32 ^{0}brix) was found from S_4, whereas the lowest TSS (6.06 ^{0}brix) was recorded from S_1.

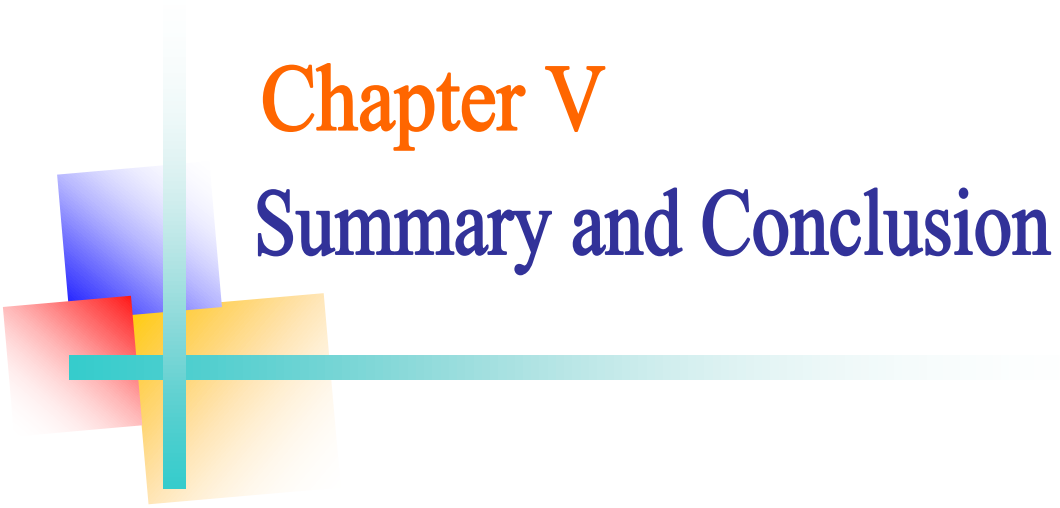
Combined effect of different planting dates and spacing varied significantly in terms of TSS of potato tubers (Table 15). The highest TSS of potato (7.20 ^{0}brix) was found from D_4S_4, while the lowest (5.68 ^{0}brix) from observed from D_2S_3 treatment combination.

4.2.8 Vitamin C content in potato tubers

Vitamin C content in potato tubers showed statistically significant differences due to the different planting dates (Table 14). The highest vitamin C content in potato tubers (23.62 mg 100 g^{-1}) was observed from D_2 which was statistically similar (23.15 mg 100 g^{-1}) to D_3 and followed (22.01 mg 100 g^{-1}) by D_1, while the lowest vitamin C content (19.60 mg 100 g^{-1}) was recorded from D_4.

Statistically significant variation was recorded due to different spacing in terms of vitamin C content in potato tubers (Table 14). The highest vitamin C content in potato tubers (23.68 mg 100 g^{-1}) was found from S_1 which was followed (22.51 and 21.90 mg 100 g^{-1}) by S_3 and S_2, respectively and they were statistically similar, whereas the lowest vitamin C content in potato tubers (20.29 mg 100 g^{-1}) was observed from S_4.

Combined effect of different planting dates and spacing varied significantly in terms of vitamin C content in potato tubers (Table 15). The highest vitamin C content in potato tubers (26.11 mg 100 g^{-1}) was observed from D_2S_1 and the lowest (18.34 mg 100 g^{-1}) was recorded from D_4S_4 treatment combination.



Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period of October 2018 to March 2019 in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to find out the effect of planting dates and spacing on yield and export quality of potato and their economy. The potato variety Lady Rosetta (BARI Alu-28) were used as test crop for this experiment. The experiment consisted of two factors: Factor A: Planting dates (4 levels) as- D_1: October 20, 2018, D_2: November 01, 2018, D_3: November 10, 2018, D_4: November 20, 2018 and Factor B: Spacing (4 levels) as- S_1: 60 cm × 25 cm, S_2: 60 cm × 30 cm, S_3: 70 cm × 25 cm, S_4: 70 cm × 30 cm. The two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded on different growth, yield parameters, yield and quality of potato tubers and significant variation was observed for most of the studied characters due to different planting dates, spacing and their combined effects.

In consideration of different planting dates, the highest days required for 1^{st} emergence (18.83) was observed from D_1, whereas the lowest (17.08 days) from D_4. The highest days required for 1^{st} to 80% emergence (7.83) was recorded from D_1, while the lowest (6.50 days) from D_4. The highest days required for 1^{st} emergence to stolen initiation (38.83) was found from D_1, while the lowest (32.08 days) from D_4. The highest days required for planting to harvest (96.83) was recorded from D_1, whereas the lowest (92.67 days) from D_4. At 30, 45, 60, 75 DAP and harvest, the tallest plant (31.16, 49.50, 66.09, 69.20 and 71.26 cm, respectively) was recorded from D_2 and the shortest plant (24.36, 42.77, 55.81, 58.35 and 59.26 cm, respectively) from D_4. At 30, 45, 60, 75 DAP and harvest, the maximum number of leaves plant^{-1} (36.40, 57.13, 63.55, 65.83 and 66.77, respectively) was found from D_2, whereas the minimum number (31.55, 45.65, 53.90, 56.35 and 57.35, respectively) from D_4. At 30, 45, 60, 75 DAP and harvest,

the maximum number of stems plant^{-1} (4.72, 5.28, 5.55, 5.67 and 5.78, respectively) was found from D_2, while the minimum number (3.78, 4.23, 4.67, 4.85 and 4.93, respectively) from D_4. The maximum number of tubers hill^{-1} (9.02) was observed from D_2, whereas the minimum number (7.90) from D_4. The highest weight of tubers hill^{-1} (425.93 g) was recorded from D_2, while the lowest (381.06 g) from D_4. The highest average weight of single tuber (47.84 g) was observed from D_2, whereas the lowest weight (44.66 g) from D_4. The highest dry matter content (19.19%) was observed from D_2, whereas the lowest (17.51%) from D_4. The highest yield of tubers (27.69 t ha^{-1}) was recorded from D_2, while the lowest (22.88 t ha^{-1}) from D_4.

In <28 mm grade, the highest (29.82%) was found from D_4, whereas the lowest (17.18%) from D_2. On the other hand in 28-45 mm, 45-55 mm and >55 mm grade, the highest (45.79%, 28.58% and 8.45%, respectively) was recorded from D_2, while the lowest (38.51%, 24.47% and 7.20%, respectively) from D_4. In consideration of Chips and Canned potato, the highest (40.50% and 42.07%, respectively) was recorded from D_2, while the lowest (33.92% and 37.64%, respectively) from D_4. On the other hand in non-marketable potato, the highest (28.44%) was recorded from D_4 and the lowest (17.43%) from D_2. The highest firmness score of potato (42.45 N) was found from D_2, while the lowest (36.07 N) from D_4. The highest specific gravity of potato (1.08) was observed from D_2, whereas the lowest (1.02) from D_4. The highest starch content in potato tubers (17.11 mg g^{-1} FW) was found from D_2, whereas the lowest starch content (15.03 mg g^{-1} FW) from D_4. The highest reducing sugar content in potato tubers (0.30 mg g^{-1} FW) was recorded found from D_4, while the lowest reducing sugar content in potato tubers (0.25 mg g^{-1} FW) was observed from D_2. The highest TSS of potato (6.35 ^{0}brix) was found from D_4, while the lowest (6.06 ^{0}brix) from D_2. The highest vitamin C content in potato (23.62 mg 100 g^{-1}) was observed from D_2, while the lowest (19.60 mg 100 g^{-1}) from D_4.

For different spacing, the highest days required for 1st emergence (18.17) was recorded from S_4, while the lowest (17.42 days) from S_1. The highest days required for 1st to 80% emergence (7.33) was recorded from S_4 and the lowest (7.08 days) from S_1. The highest days required for 1st emergence to stolen initiation (38.92) was observed from S_1, whereas the lowest (32.25 days) from S_4. The highest days required for planting to harvest (96.50) was recorded from S_4, while the lowest (92.83 days) from S_1. At 30, 45, 60, 75 DAP and harvest, the tallest plant (31.46, 50.19, 65.64, 69.46 and 71.47 cm, respectively) was recorded from S_1, whereas the shortest plant (24.46, 43.42, 56.96, 59.62 and 61.14 cm, respectively) from S_4. At 30, 45, 60, 75 DAP and harvest, the maximum number of leaves plant^{-1} (36.20, 57.40, 64.48, 66.05 and 66.75, respectively) was observed from S_1, while the minimum number (31.85, 45.67, 51.93, 54.47 and 55.28, respectively) from S_4. At 30, 45, 60, 75 DAP and harvest, the maximum number of stems plant^{-1} (4.87, 5.20, 5.58, 5.72 and 5.80, respectively) was recorded from S_1, whereas the minimum number (3.65, 4.60, 4.88, 5.05 and 5.18, respectively) from S_4. The maximum number of tubers hill^{-1} (9.00) was found from S_1, while the minimum number (8.10) from S_4. The highest weight of tubers hill^{-1} (415.12 g) was recorded from S_1, whereas the lowest weight (393.36 g) from S_4. The highest average weight of single tuber (47.42 g) was found from S_4, while the lowest weight (45.01 g) from S_1. The highest dry matter content (19.46%) was found from S_1, while the lowest (17.73%) from S_4. The highest yield of tubers (27.81 t ha^{-1}) was found from S_1, whereas the lowest yield (22.85 t ha^{-1}) from S_4.

For <28 mm grade, the highest (29.42%) was observed from S_4 and the lowest (17.79%) from S_1. On the other hand in 28-45 mm, 45-55 mm and >55 mm grade, the highest (45.62%, 28.19% and 8.40%, respectively) was found from S_1, whereas the lowest (38.85%, 24.55% and 7.18%, respectively) from S_4. For Chips and Canned potato, the highest (40.45% and 41.27%, respectively) was recorded from S_1, whereas the lowest (33.55% and 38.59%, respectively) from S_4. On the other hand in non-marketable potato, the highest (27.86%) was observed from S_4, whereas the lowest (18.28%) from S_1. The highest firmness score of potato (42.70

N) was observed from S_1, whereas the lowest (36.07 N) from S_4. The highest specific gravity of potato (1.09) was recorded from S_1, while the lowest (1.03) from S_4. The highest starch content in potato (17.13 mg g^{-1} FW) was observed from S_1, while the lowest (14.77 mg g^{-1} FW) from S_4. The highest reducing sugar content in potato tubers (0.29 mg g^{-1} FW) was observed from S_4, whereas the lowest (0.26 mg g^{-1} FW) from S_1. The highest TSS of potato (6.32 ^{0}brix) was found from S_4, whereas the lowest (6.06 ^{0}brix) from S_1. The highest vitamin C content in potato (23.68 mg 100 g^{-1}) was found from S_1, whereas the lowest (20.29 mg 100 g^{-1}) from S_4.

Due to the combined effect of different planting dates and spacing, the highest days required for 1st emergence (20.67) was found from D_1S_4 and the lowest (16.33 days) from D_2S_1 treatment combination. The highest days required for 1st to 80% emergence (8.00) was observed from D_1S_2, D_1S_3 and D_1S_4, whereas the lowest (6.00 days) from D_4S_2 treatment combination. The highest days required for 1st emergence to stolen initiation (41.67) was found from D_2S_1, while the lowest (31.00 days) from D_4S_4 treatment combination. The highest days required for planting to harvest (98.33) was recorded from D_1S_4 and the lowest (87.00 days) from D_4S_1 treatment combination. At 30, 45, 60, 75 DAP and harvest, the tallest plant (35.91, 55.76, 75.78, 79.49 and 81.79 cm, respectively) was observed from D_2S_1, while the shortest plant (22.34, 39.83, 51.90, 54.12 and 55.42 cm, respectively) from D_4S_4 treatment combination. At 30, 45, 60, 75 DAP and harvest, the maximum number of leaves plant^{-1} (40.00, 64.40, 71.07, 72.33 and 73.20, respectively) was observed from D_2S_1 and the minimum number (28.40, 42.20, 50.67, 52.00 and 52.93, respectively) from D_4S_4 treatment combination. At 30, 45, 60, 75 DAP and harvest, the maximum number of stems plant^{-1} (5.47, 5.80, 6.07, 6.20 and 6.27, respectively) was recorded from D_2S_1, while the minimum number (3.40, 4.07, 4.27, 4.53 and 4.67, respectively) from D_4S_4 treatment combination. The maximum number of tubers hill^{-1} (9.73) was recorded from D_2S_1 and the minimum number (7.60) from D_4S_4 treatment combination. The highest weight of tubers hill^{-1} (440.32 g) was observed from D_2S_1, while the lowest

(378.47 g) from D_4S_4. The highest average weight of single tuber (50.88 g) was observed from D_2S_4 and the lowest (43.66 g) from D_4S_3 treatment combination. The highest dry matter content (20.94%) was recorded from D_2S_1 and the lowest (16.50%) from D_3S_4 treatment combination. The highest yield of tubers (31.56 t ha^{-1}) was recorded from D_2S_1, while the lowest yield (21.78 t ha^{-1}) from D_4S_4 treatment combination.

For <28 mm grade, the highest (33.81%) was recorded from D_4S_4, whereas the lowest (10.62%) from D_2S_1 treatment combination. On the other hand in 28-45 mm, 45-55 mm and >55 mm grade, the highest (49.51%, 30.65% and 9.22%, respectively) was recorded from D_2S_1 and the lowest (36.21%, 23.13% and 6.85%, respectively) from D_4S_4 treatment combination. For Chips and Canned potato, the highest category (45.20% and 43.82%, respectively) was recorded from D_2S_1, while the lowest (31.82% and 37.11%, respectively) from D_4S_4. On the other hand in non-marketable potato, the highest (31.07%) was recorded from D_4S_4 and the lowest (10.98%) from D_2S_1 treatment combination. The highest firmness score of potato (47.83 N) was observed from D_2S_1, while the lowest (34.42 N) from D_4S_4 treatment combination. The highest specific gravity of potato (1.13) was observed from D_2S_1 and the lowest (1.00) was found from D_4S_4 treatment combination. The highest starch content in potato (18.60 mg g^{-1} FW) was recorded from D_2S_1 and the lowest (14.40 mg g^{-1} FW) from D_3S_4 treatment combination. The highest reducing sugar content in potato tubers (0.32 mg g^{-1} FW) was recorded from D_4S_4 and the lowest (0.24 mg g^{-1} FW) from D_2S_3. The highest TSS of potato (7.20 ^{0}brix) was found from D_4S_4, while the lowest (5.68 ^{0}brix) from D_2S_3 treatment combination. The highest vitamin C content in potato (26.11 mg 100 g^{-1}) was observed from D_2S_1 and the lowest (18.34 mg 100 g^{-1}) from D_4S_4 treatment combination.

Conclusion:

It was revealed that planting dates 01 November and the spacing of 60 cm × 25 cm showed best performance when considered the growth, yield parameters, yield and quality of potato tubers.

Considering the results of the present experiment, further studies in the following areas may be suggested:

1. For regional adaptability such study is needed to be repeated in different agro-ecological zones (AEZ) of Bangladesh;
2. Other management practices may be included for further study, and
3. Other planting dates and spacing may be used for further study to specify the specific combination.

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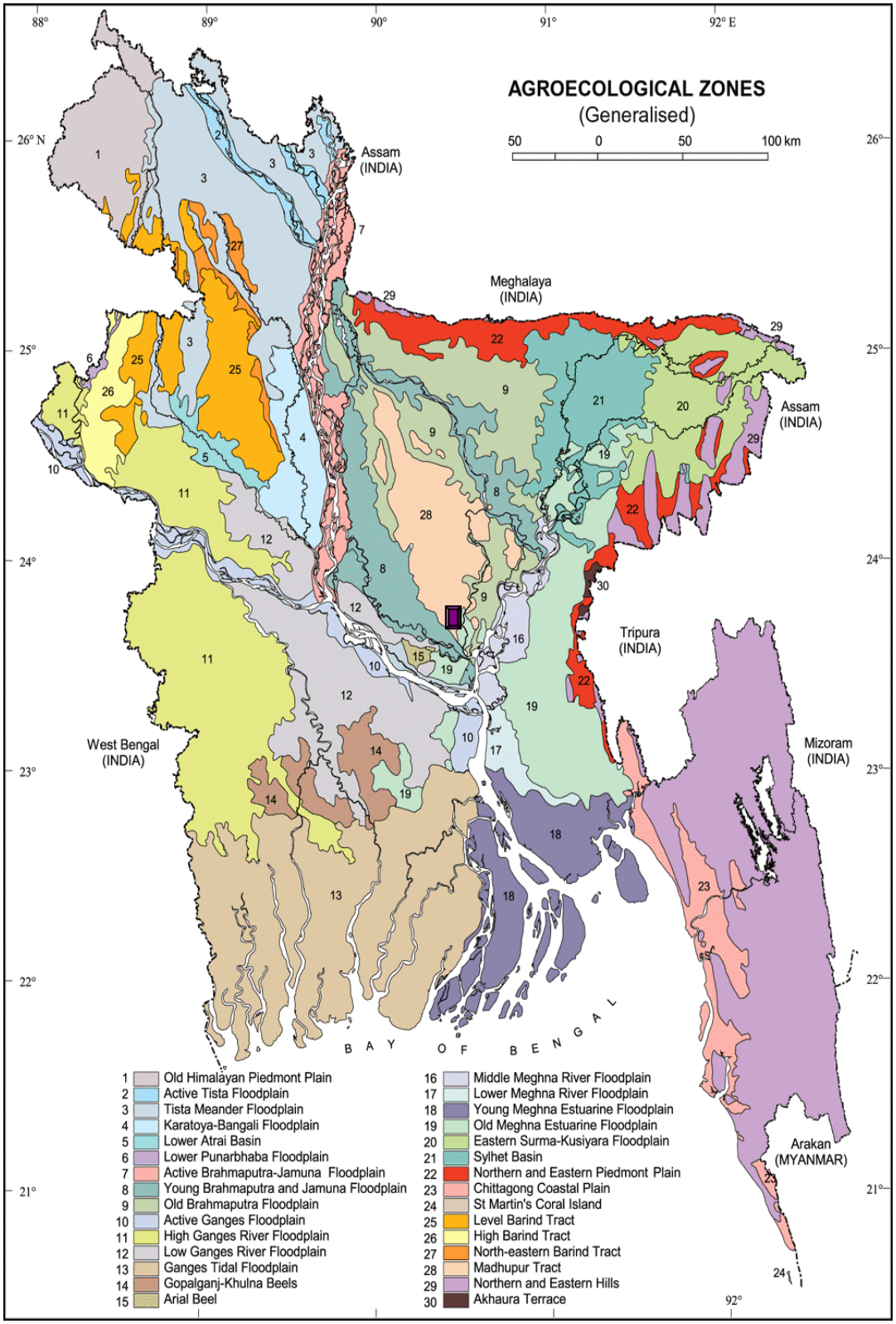
Appendices

APPENDICES

Appendix I. The Map of the experimental site



Appendix II. Soil characteristics of experimental field as per the Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Experimental field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	26
% Silt	43
% clay	31
Textural class	Sandy loam
pH	5.9
Catayan exchange capacity	2.64 meq 100 g/soil
Organic matter (%)	1.15
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Appendix III. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from October 2018 to February 2019

Month	Air temperature (ºC)		Relative humidity (%)	Total Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
October, 2018	26.3	19.1	84	29	7.1
November, 2018	25.6	16.5	77	00	6.9
December, 2018	22.7	13.2	76	08	6.7
January, 2019	25.2	12.5	65	05	6.1
February, 2019	27.9	17.4	67	43	6.8

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka-1212

Appendix IV. Analysis of variance of the data on days required for 1st emergence, 80% emergence, stolen initiation and harvest of potato as influenced by planting dates and spacing

Treatments	Degrees of freedom	Mean square			
		Days required for			
		1st emergence	1st to 80% emergence	1st emergence to stolen initiation	Planting to harvest
Replication	2	0.250	0.021	0.271	1.750
Plating dates (A)	3	7.500**	3.583**	93.688*	36.972**
Spacings (B)	3	1.500	0.139	90.354*	29.639**
Interaction (A×B)	9	2.296*	0.454**	24.076**	28.898*
Error	30	0.961	0.154	6.671	9.394

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix V. Analysis of variance of the data on plant height of potato at different days after planting (DAP) and harvest as influenced by planting dates and spacing

Treatments	Degrees of freedom	Mean square				
		Plant height (cm) at				
		30 DAP	45 DAP	60 DAP	75 DAP	Harvest
Replication	2	0.516	1.130	4.818	6.904	5.284
Plating dates (A)	3	107.666**	127.707**	257.054**	282.969**	355.290**
Spacings (B)	3	98.933**	94.607**	157.761**	200.132**	221.478**
Interaction (A×B)	9	11.444*	26.145*	138.145**	121.934**	128.117**
Error	30	4.475	9.844	22.284	18.967	16.785

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VI. Analysis of variance of the data on number of leaves plant^{-1} of potato at different days after planting (DAP) and harvest as influenced by planting dates and spacing

Treatments	Degrees of freedom	Mean square				
		Number of leaves plant^{-1} at				
		30 DAP	45 DAP	60 DAP	75 DAP	Harvest
Replication	2	0.473	0.976	0.511	0.917	0.692
Plating dates (A)	3	60.060**	316.046**	229.867**	204.683**	203.056**
Spacings (B)	3	42.300**	304.108**	341.076**	286.847**	286.027**
Interaction (A×B)	9	12.600**	27.489**	36.333*	36.446*	34.762*
Error	30	3.713	5.531	17.501	13.153	15.682

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VII. Analysis of variance of the data on number of stems plant^{-1} of potato at different days after planting (DAP) and harvest as influenced by planting dates and spacing

Treatments	Degrees of freedom	Mean square				
		Number of stems plant^{-1} at				
		30 DAP	45 DAP	60 DAP	75 DAP	Harvest
Replication	2	0.006	0.006	0.006	0.001	0.010
Plating dates (A)	3	2.102**	2.725**	1.890**	1.653**	1.768**
Spacings (B)	3	3.216**	0.765**	1.061**	0.923**	0.816**
Interaction (A×B)	9	0.269**	0.309**	0.219**	0.216*	0.205*
Error	30	0.076	0.070	0.065	0.088	0.074

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VIII. Analysis of variance of the data on number and weight of tubers hill^{-1}, average weight of single tuber, dry matter content in tubers and yield of tubers hectare^{-1} of potato as influenced by planting dates and spacing

Treatments	Degrees of freedom	Mean square				
		Number of tubers hill^{-1}	Weight of tubers hill^{-1} (g)	Average weight of single tuber (g)	Dry matter content in potato tubers (%)	Yield of tubers (t ha^{-1})
Replication	2	0.053	30.426	4.783	0.004	0.108
Plating dates (A)	3	2.976**	13676.135**	21.037**	7.541**	55.989**
Spacings (B)	3	1.628**	1031.126**	12.444*	6.156**	50.997**
Interaction (A×B)	9	0.455**	938.584*	16.702*	4.799**	11.177**
Error	30	0.132	238.307	3.462	1.307	2.504

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix IX. Analysis of variance of the data on different grading of potato as influenced by planting dates and spacing

Treatments	Degrees of freedom	Mean square			
		Grading of potato (%)			
		<28 mm	28-45 mm	45-55 mm	>55 mm
Replication	2	0.876	0.466	0.015	0.037
Plating dates (A)	3	384.690**	131.446**	39.258**	3.613**
Spacings (B)	3	300.101**	100.668**	30.277**	3.241**
Interaction (A×B)	9	34.887*	10.067*	3.877**	1.002**
Error	30	12.805	4.984	1.242	0.189

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix X. Analysis of variance of the data on the uses chips, canned and non-marketable potato tubers as influenced by planting dates and spacing

Treatments	Degrees of freedom	Mean square		
		Category of potato (%) for different uses		
		Chips (45-75 mm)	Canned (25-45 mm)	Non-marketable
Replication	2	0.141	0.141	0.344
Plating dates (A)	3	102.294**	42.952**	275.444**
Spacings (B)	3	101.462**	15.911**	197.484**
Interaction (A×B)	9	12.826**	3.682*	28.923**
Error	30	3.631	1.693	8.530

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix XI. Analysis of variance of the data on firmness score, specific gravity, starch, reducing sugar, total soluble solids-TSS and vitamin C content of potato tubers as influenced by planting dates and spacing

Treatments	Degrees of freedom	Mean square					
		Firmness score	Specific gravity	Starch (mg g^{-1} FW)	Reducing sugar (mg g^{-1} FW)	Total soluble solid (TSS ^{0}brix)	Vitamin C (mg/100 g)
Replication	2	0.417	0.0001	0.009	0.0001	0.033	0.078
Plating dates (A)	3	98.781**	0.009**	10.022**	0.004**	0.205*	38.724**
Spacings (B)	3	89.235**	0.008**	11.908**	0.002**	0.144	23.993**
Interaction (A×B)	9	18.604**	0.005*	1.705**	0.001**	0.897**	4.236**
Error	30	5.153	0.001	0.545	0.0001	0.059	0.700

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix XII. Photographs of the experiment

Plate 1. Application of manures and fertilizer during final land preparation

Plate 2. Prepared experimental field for planting of potato tubers

Plate 3. Experimental field visited by Honorable Supervisor

Plate 4. Data collection as per the instruction of my Honorable Supervisor

Plate 5. Harvesting of potato at maturity stage

Plate 6. Preparation of potato for quality analysis in laboratory