INFLUENCE OF PLANTING METHODS AND SPACING ON YIELD AND QUALITY OF RADISH SEED

SHASHANKO SHEKHOR GHOSH

INSTITUTE OF SEED TECHNOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA -1207

JUNE, 2022

INFLUENCE OF PLANTING METHODS AND SPACING ON YIELD AND QUALITY OF RADISH SEED

BY

SHASHANKO SHEKHOR GHOSH

REGISTRATION NO. : 15-06820

Email: shashanko18426@gmail.com

Mobile: 01719-029779

A Thesis

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 (MS)
IN

SEED TECHNOLOGY

SEMESTER: JANUARY- JUNE, 2022

Approved by:

Dr. Tahmina Mostarin	**Dr. Khaleda Khatun**
Professor	**Professor**
Department of Horticulture	Department of Horticulture
SAU, Dhaka	SAU, Dhaka
Supervisor	**Co-Supervisor**

Prof. Dr. Md. Ismail Hossain
Chairman, Examination Committee
&
Director, Institute of Seed Technology
Sher-e-Bangla Agricultural University

INSTITUTE OF SEED TECHNOLOGY

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

CERTIFICATE

This is to certify that the thesis entitled **"INFLUENCE OF PLANTING METHODS AND SPACING ON YIELD AND QUALITY OF RADISH SEED"** 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 (M.S.)** in **SEED TECHNOLOGY**, embodies the result of a piece of bonafide research work carried out by **SHASHANKO SHEKHOR GHOSH**, Registration No. 15-06820 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.

June, 2022

Dhaka, Bangladesh

Prof. Dr. Tahmina Mostarin
Department of Horticulture
SAU, Dhaka
Supervisor

Dedicated
To
My Beloved Parents

ACKNOWLEDGEMENTS

The author seems it a much privilege to express his enormous sense of gratitude to the almighty Allah for there ever ending blessings for the successful completion of the research work.

The author wishes to express his gratitude and best regards to his respected Supervisor, Dr. Tahmina Mostarin, Professor, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for her continuous direction, constructive criticism, encouragement and valuable suggestions in carrying out the research work and preparation of this thesis.

The author wishes to express his earnest respect, sincere appreciation and enormous indebtedness to his reverend Co-supervisor, Dr. Khaleda Khatun, Professor, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for her scholastic supervision, helpful commentary and unvarying inspiration throughout the research work and preparation of the thesis.

The author feels to express his heartfelt thanks to the honorable Director, Professor Dr. Md. Ismail Hossain, along with all other teachers and staff members of the Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka, for their co-operation during the period of the study.

The author feels proud to express his deepest and endless gratitude to all of his course mates and friends for to cooperate and help him during taking data from the field and preparation of the thesis. The author wishes to extend his special thanks to his lab mates, class mates and friends for their keen help as well as heartiest co-operation and encouragement.

The author expresses his heartfelt thanks to his beloved parents, elder sister and brother and all other family members for their prayers, encouragement, constant inspiration and moral support for his higher study. May Almighty bless and protect them all.

The Author

INFLUENCE OF PLANTING METHODS AND SPACING ON YIELD AND QUALITY OF RADISH SEED

ABSTRACT

An experiment was carried out to study the influence of planting methods and spacing on yield and quality of radish seed at the experimental field of Sher-e-Bangla Agricultural University (SAU), from November 2021 to March 2022. Three planting methods *viz.* M_1 = Direct sowing of seed, M_2 = 1/3 cutting of root and M_3 = 2/3 cutting of root were comprised with plant spacings *viz.*, S_1 = 30 cm × 20 cm, S_2 = 30 cm × 30 cm, S_3 = 30 cm × 40 cm. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Different planting methods showed significant variation for growth, yield contributing parameters, yield and quality parameters of radish. The planting method M_1 (Direct sowing of seed) showed significantly highest seed yield plant^{-1} (10.87 g) and seed yield ha^{-1} (1234.00 kg) compared to M_2 (1/3 cutting of root) and M_3 (2/3 cutting of root) treatment. M_1 (Direct sowing of seed) also showed the best quality seeds considering highest germination percentage (88.43%) and vigor index (1434.57) whereas M_3 (2/3 cutting of root) treatment gave the minimum results. Different plant spacing of radish showed significant variation for growth, yield contributing parameters, yield seed quality parameters. The highest seed yield ha^{-1} (1283.33 kg) was recorded from the plant spacing S_1 (30 cm × 20 cm) while the plant spacing S_3 (30 cm × 40 cm) spacing gave the significantly highest germination percentage (89.00%) and vigor index (1611.74). The treatment combination of M_1S_3 gave the highest number of pods plant^{-1} (82.13), number of seeds pod^{-1} (6.31), dry weight plant^{-1} (153.70 g) and seed yield plant^{-1} (13.81 g) but the highest seed yield ha^{-1} (1386.00 kg) was recorded from the treatment combination of M_3S_1 but the lowest seed yield ha^{-1} (841.90 kg) was recorded from M_3S_3. The treatment combination of M_3S_1 gave the maximum germination percentage (90.40%) and vigor index (1722.12) whereas M_3S_1 gave the minimum results. From the above results, it can be concluded that among the planting methods, M_1 (Direct sowing of seed) performed the best regarding growth, seed yield and seed quality. Considering plant spacing, S_1 (30 cm × 20 cm) performed the highest seed yield whereas S_3 (30 cm × 40 cm) was the best for quality seeds production.

CONTENTS

CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

ABBREVIATIONS AND ACRONYMS

AEZ	:	Agro-Ecological Zone
BBS	:	Bangladesh Bureau of Statistics
BCSIR	:	Bangladesh Council of Scientific and Industrial Research
cm	:	Centimeter
CV %	:	Percent Coefficient of Variation
DAS	:	Days After Sowing
DMRT	:	Duncan's Multiple Range Test
et al.,	:	And others
e.g.	:	exempli gratia (L), for example
etc.	:	Etcetera
FAO	:	Food and Agriculture Organization of the United Nations
g	:	Gram (s)
i.e.	:	id est (L), that is
Kg	:	Kilogram (s)
LSD	:	Least Significant Difference
m^2	:	Meter squares
ml	:	MiliLitre
M.S.	:	Master of Science
No.	:	Number
SAU	:	Sher-e-Bangla Agricultural University
var.	:	Variety
^oC	:	Degree Celceous
%	:	Percentage
NaOH	:	Sodium hydroxide
GM	:	Geometric mean
mg	:	Miligram
P	:	Phosphorus
K	:	Potassium
Ca	:	Calcium
L	:	Litre
µg	:	Microgram
USA	:	United States of America
WHO	:	World Health Organization

CHAPTER I

INTRODUCTION

Radish (*Raphanus sativus* L.) is a popular root vegetable of Brassicaceae family grown all over world. Radish is grown for its young tender tuberous root which is consumed either raw as salad or cooked as a vegetable. Radish has cooling effect, prevents constipation and increases appetite. It is recommended for patients suffering from piles, liver troubles and jaundice. The juice of fresh leaves is used as diuretic and laxative.

Radish is a good source of vitamin- C (ascorbic acid), containing 15-40 mg per 100 g of edible portion and supplies a variety of minerals. Trace elements in radish include aluminium, barium, lithium, manganese, silicon, titanium, fluorine and iodine. Beside tender leaves which are used as greens are rich in vitamin-A and C. Roots are also rich in carbohydrate and protein. Pink skinned radish is generally richer in ascorbic acid than the white skinned one. The characteristics pungent flavor of radish is due to the presence of volatile isothiocynates (Bose *et al*., 2000).

Root to seed method is generally followed for breeder seed production where true to type roots are selected and seed so produced is of high quality. Mild temperature and prevalence of dry condition at the time of seed maturity and ripening, is favorable for high quality and excellent vigour seed production (Dev, 2010). In Bangladesh, farmers generally cultivate radish in large scale in the field but urban farmers generally cultivate the crop in their homesteads. Production statistics of radish in Bangladesh is covering an area of 22052 ha and producing 200840 tones of edible roots. It ranks second both in acrage and among the major vegetables crop of Bangladesh (BBS, 2018). The maintenance of optimum plant population and methods of planting offers ample scope for increasing the flowering, fruiting and seed yield of radish (Kumar *et al*., 2012).

One of the factors responsible for reduced growth and lower seed yield of radish is cultural practices like methods of plantation (direct seed sowing, cutting of root etc.) and plant spacing. The scientific vegetable seed production reveals the significance and importance of sowing time, methods of plantation and plant population to be used for raising of crops in order to get higher production and good quality. For good quality and better root production, radish requires suitable plantation methods and plant density regarding proper sowing time (Lavanya *et al*., 2014).

The choice of sowing method can significantly influence the growth and seed yield of radish. Different sowing methods, such as direct sowing of seeds, cutting of root and transplanting etc. have been explored to optimize radish production. These methods offer variations in seed placement and root development, which can affect plant establishment, nutrient uptake, and ultimately seed yield (Kwon, 2014; Lee, 2018 and Naik and Saha, 2017). Ogata (2020) and Naik and Saha (2017) observed the effect of different planting methods (eg. direct seed sowing, cutting ratios) on growth and seed yield components of spring radish and found signification variation on seed yield among the planting methods.

Among different factors of seed production, plant spacing is very important that affects the ambient environment of the seed crop field, which in turn modifies the crop phenology (Singh *et al*., 2013), ultimately affecting yield (Baumhardt *et al*., 2018) and seed quality (Ashraf *et al*., 2016). Optimum plant population is of prime importance to get higher yield (Kang *et al*., 2015). Optimized plant spacing can increase nutritional availability and biomass production of plants (Horbe *et al*., 2016) and ultimately affect seed quality. Optimal row spacing avoids competition for nutrient elements and soil moisture among the crop plants (Chaudhary *et al*., 2015) as well as with weeds (Ashraf *et al*., 2016), rather suppresses weeds (Champion *et al*., 1998). Moreover, appropriate plant spacing allows a larger proportion of incident radiation to be intercepted by the crop canopy (Pandey *et*

al., 2013) and thus affects photosynthetic efficiency and seed yield (Hussain *et al*., 2012).

Keeping the above facts in view, an experiment entitled "influence of planting methods on growth, seed yield and quality of radish (*Raphanus sativus* L) seed as influenced by plant spacing" was conducted with the following objectives:

1. To study the effect of planting method on growth, yield and quality of radish seed;
2. To evaluate the effect of spacing on growth, yield and quality of radish seed; and
3. To assess the combined effect of planting method and spacing on yield and quality of radish seed.

CHAPTER II

REVIEW OF LITERATURE

A lot of information has been accumulated on the effect of spacing and productivity of different annual crop in different parts of the world. A considerable amount of such research works have been reported on vegetable crops but regarding reports on radish is meager. Experimental reports on the influence of planting methods and plant spacing on soil condition and crop productivity are also available to a considerable extent but such report on radish is lacking. However, some of the available literatures related to the present investigation have been presented below:

2.1 Effect of planting methods

Kim *et al*. (2021) carried out an experiment aimed to evaluate the effects of sowing methods and harvest time on the seed yield and quality of radish for mechanical harvesting. The researchers compared direct seeding and transplanting methods and assessed different harvest times. They found that direct seeding resulted in higher seed yield compared to transplanting. Early harvest showed higher seed yield and better seed quality compared to late harvest. The researchers recommended direct seeding with early harvest as an effective approach for maximizing seed yield and quality in radish cultivation intended for mechanical harvesting.

Ogata (2020) conducted an experiment to study the effect of cutting ratios on growth and yield components of spring radish (*Raphanus sativus* L.). They reported that different cutting ratios (1/3 cutting and 2/3 cutting of the root) significantly affected the growth and yield components of spring radish. 1/3 cutting of the root resulted in higher leaf number and total weight compared to 2/3 cutting. 2/3 cutting of the root showed delayed maturity and reduced yield

compared to 1/3 cutting. 1/3 cutting is recommended for maximizing growth and yield in spring radish production.

Kim *et al*. (2020) carried out a study to investigate the influence of planting methods on the yield and quality of radish seeds in organic farming. The researchers compared direct seeding, transplanting, and mixed planting methods. They found that direct seeding resulted in higher yield contributing characters (dry matter accumulation, pods number per plant, seeds/pod) and higher seed yield compared to transplanting and mixed planting. Direct seeding also showed better seed quality in terms of germination percentage and vigor index. The researchers concluded that direct seeding can be a suitable planting method for maximizing seed yield and quality in organic radish seed production.

Liu *et al*. (2020) carried out an experiment aimed to determine the effect of different planting methods on seed yield and quality of radish under field conditions. Four planting methods, namely direct seeding, transplanting, dibbling, and broadcasting, were compared. The results showed that direct seeding and transplanting methods significantly outperformed dibbling and broadcasting in terms of seed yield and quality. Direct seeding resulted in the highest seed yield and exhibited superior seed quality in terms of germination percentage and vigor index. Transplanting also yielded satisfactory seed quantities and showed good seed quality. These findings highlight the importance of selecting appropriate planting methods to optimize seed production in radish cultivation under field conditions.

Chen *et al*. (2019) conducted a study aimed to evaluate the effect of different planting methods on radish seed production. Four planting methods, including direct seeding, transplanting, dibbling, and furrow sowing, were examined. The results indicated that direct seeding and transplanting methods yielded significantly higher seed quantities compared to dibbling and furrow sowing.

Direct seeding also showed better seed quality in terms of germination rate and seedling vigor. These findings highlight the importance of selecting appropriate planting methods to enhance radish seed production.

Islam *et al*. (2019) investigated the effects of planting methods on the growth, yield, and quality of radish. They conducted experiments in the field and compared direct seeding and transplanting. Parameters such as root weight, root length, root diameter, and seed quality were evaluated. The results indicated that direct seeding resulted in higher root weight, root length, and yield compared to transplanting. However, transplanting showed better root diameter and seed quality due to enhanced nutrient availability and controlled establishment conditions. The researchers recommended direct seeding as a suitable method for maximizing radish yield, while transplanting could be beneficial for enhancing root quality.

Mwai *et al*. (2018) conducted a study to compare the effects of transplanting and direct seeding methods on the growth, yield, and seed quality of radish. The researchers conducted experiments in the field and evaluated parameters such as plant height, root weight, germination percentage, and seed quality. They found that transplanting resulted in higher plant height, root weight, and seed yield compared to direct seeding. However, direct seeding exhibited better germination percentage and seed quality due to reduced transplanting shock. The researchers concluded that the choice of planting method should consider the specific objectives of radish production, such as maximizing yield or optimizing seed quality.

Lee (2018) conducted an experiment to study the comparison of root characteristics and seed yield in radish (*Raphanus sativus* L.) using different sowing methods. Results revealed that different sowing methods (direct sowing, different ratios of cutting of root) significantly influenced root characteristics and

seed yield of radish. Direct sowing method resulted in the highest root weight, root yield and seed yield compared to the cutting methods. The cutting methods showed reduced root weight and seed yield, likely due to the disturbances caused during root cutting. Direct sowing is recommended for maximizing root and seed yield in radish cultivation.

Lim *et al*. (2018) investigated the effects of planting depth and method on the growth, yield, and seed quality of radish. They conducted experiments comparing different planting depths and methods, including direct seeding and transplanting. The results revealed that shallow planting depths resulted in higher seed yield and better seed quality. Direct seeding showed better seed yield compared to transplanting, while transplanting exhibited better seed quality. The researchers concluded that selecting an appropriate planting depth and method can optimize seed yield and quality in radish seed production.

Johnson *et al*. (2018) conducted this experiment aimed to investigate the effect of different planting methods on seed production of radish. Three planting methods, namely direct seeding, transplanting, and broadcast sowing, were compared. The results showed that direct seeding and transplanting methods resulted in significantly higher seed yields compared to broadcast sowing. Additionally, direct seeding exhibited better seed quality in terms of germination percentage and vigor index. The findings suggest that direct seeding and transplanting are suitable methods for optimizing seed production in radish.

Gonzalez *et al*. (2017) carried out a study to compare the effects of direct seeding and transplanting methods on the yield and quality of radish. They conducted experiments in the field and found that direct seeding resulted in higher seed yield and better quality compared to transplanting. Direct seeding allowed for better root development and minimized transplanting shock. However, transplanting showed better plant growth and uniformity due to controlled conditions during

establishment. The researchers concluded that direct seeding can be a preferred method for radish cultivation to optimize seed production, especially for small-scale farmers.

Lee *et al*. (2017) conducted in a greenhouse experiment to examine the effects of planting methods on the yield and quality of radish seeds. They compared direct seeding and transplanting methods. The results showed that direct seeding resulted in higher seed yield compared to transplanting. However, transplanting exhibited better seed quality in terms of germination percentage, vigor index, and uniformity. The researchers suggested that direct seeding can be an effective method for maximizing seed yield, while transplanting can be beneficial for obtaining superior seed quality in greenhouse cultivation of radish seeds.

Khaliq *et al*. (2017) conducted an experiment aimed to determine the influence of sowing methods on the yield and quality of radish roots under temperate conditions in Pakistan. The researchers conducted experiments in the field and compared direct seeding and transplanting. They evaluated parameters such as root weight, root diameter, root length, and quality traits. The results revealed that direct seeding resulted in higher root weight, root diameter.

Naik and Saha (2017) carried out a study to investigate the effect of different planting methods on the growth, yield, and quality of radish (*Raphanus sativus* L.). Results revealed that different planting methods, including direct sowing, transplanting, and dibbling, had significant effects on the growth, yield, and quality of radish. Direct sowing method resulted in higher plant height, leaf area, and root and seed yield compared to transplanting and dibbling. Transplanting method showed delayed maturity and lower yield compared to direct sowing. Direct sowing is recommended for higher root and seed yield and better growth in radish cultivation.

Perez *et al*. (2017) carried out a study to investigate the influence of planting methods on seed production of radish in a Mediterranean environment. Four planting methods, including direct seeding, transplanting, furrow sowing, and ridge planting, were examined. The results indicated that direct seeding and transplanting methods resulted in significantly higher seed yields compared to furrow sowing and ridge planting. Furthermore, direct seeding exhibited better seed quality in terms of germination rate and seedling vigor. These findings emphasize the importance of selecting appropriate planting methods for radish seed production in Mediterranean regions.

Suthar *et al*. (2016) conducted an experiment to assess the effects of planting methods on the growth, yield, and quality of radish. The researchers observed that direct seeding resulted in higher root weight, root length, and yield compared to transplanting. However, transplanting exhibited better root diameter and quality. They recommended direct seeding for commercial production and transplanting for obtaining superior root quality in radish cultivation.

Park (2016) investigated the growth, yield, and quality of radish (*Raphanus sativus* L.) affected by different sowing methods and nitrogen fertilization. Different sowing methods (direct sowing and transplanting) and nitrogen fertilization significantly influenced the growth, yield, and quality of radish. Direct sowing combined with nitrogen fertilization resulted in higher plant height, shoot weight, root weight, and yield compared to transplanting. Nitrogen fertilization enhanced the growth and yield parameters in both sowing methods. Direct sowing with nitrogen fertilization is recommended for improving growth, yield, and quality in radish cultivation.

Hong *et al*. (2016) conducted this experiment aimed to determine the effects of planting density and method on seed yield and quality of radish. The researchers compared different planting densities and methods, including direct seeding and

transplanting. They found that higher planting densities resulted in increased seed yield per unit area. Direct seeding exhibited higher root weight and seed yield compared to transplanting. However, transplanting showed better seed quality in terms of germination percentage and vigor index. The researchers suggested selecting an optimal planting density and method based on the desired balance between seed yield and quality in radish seed production.

Kim *et al*. (2016) conducted an experiment aimed to determine the effects of planting density and depth on radish growth, yield, and quality in greenhouse conditions. The researchers conducted experiments with different planting densities and depths and measured parameters such as individual root weight and total yield per unit area. They found that higher planting density led to reduced individual root weight but increased total yield per unit area due to the higher number of plants. Planting depth did not significantly affect yield or quality parameters. Based on the findings, the researchers recommended an optimal planting density to achieve the desired yield and quality in radish cultivation, considering the specific growing conditions.

Gupta *et al*. (2016) carried out a study to aimed to assess the impact of planting techniques on seed yield and quality of radish. Three planting techniques, namely direct seeding, transplanting, and seedling plug transplanting, were compared. The results revealed that direct seeding and seedling plug transplanting methods resulted in significantly higher seed yields compared to transplanting. Direct seeding also exhibited better seed quality in terms of germination percentage and seedling vigor. The findings suggest that direct seeding and seedling plug transplanting are effective techniques for enhancing radish seed production.

Salehi *et al*. (2015) carried out an experiment to investigate the effect of planting methods and planting date on the yield and yield components of radish in a cold semi-arid region. The researchers found that direct seeding resulted in higher root

weight, root length, and yield compared to transplanting. They also observed that early planting significantly increased the yield and quality parameters. They suggested adopting direct seeding with early planting as an effective method for radish production in similar climatic conditions.

Kim *et al*. (2015) carried out a study to investigate the effects of different planting methods on the growth, yield, and seed quality of radish. They compared direct seeding, transplanting, and dibbling methods. The results showed that direct seeding resulted in higher root weight and seed yield compared to transplanting and dibbling. However, transplanting exhibited better seed quality in terms of germination percentage and vigor index. The researchers concluded that direct seeding can be a suitable method for maximizing seed yield, while transplanting can improve seed quality in radish cultivation.

Sanjari *et al*. (2014) evaluated different sowing methods and their impact on the growth, yield, and quality of radish. The researchers conducted experiments in the field and compared transplanting and direct seeding. They measured parameters such as plant height, root weight, and quality traits. The results showed that transplanting resulted in higher plant height, root weight, and yield compared to direct seeding. However, direct seeding exhibited better root quality due to reduced root damage during transplanting. The researchers suggested that the selection of sowing method should be based on the desired outcome of radish cultivation, considering factors such as yield and root quality.

Kwon (2014) carried out an experiment to study the effects of direct sowing and transplanting on the growth, root yield and seed yield of radish (*Raphanus sativus* L.). They reported that direct sowing and transplanting methods significantly influenced the growth and yield of radish. Direct sowing resulted in better root length, diameter, and weight compared to transplanting. Transplanting method exhibited higher shoot length and weight compared to direct sowing. Both direct

sowing and transplanting methods can be utilized to optimize radish production based on specific goals and growing conditions.

Suh *et al*. (2014) conducted a study aimed to evaluate the effect of planting density and method on the yield and seed quality of radish. The researchers compared different planting densities and methods, including direct seeding and transplanting. They found that higher planting density resulted in increased seed yield per unit area. Direct seeding exhibited higher root weight and seed yield compared to transplanting. However, transplanting showed better seed quality in terms of germination percentage and vigor index. The researchers suggested selecting an optimal planting density and method based on the desired balance between seed yield and quality in radish seed production.

2.2 Effect of plant spacing

Husnain *et al*. (2020) conducted an experiment to standardize the plant spacing (row and plant spacing) of radish for seed production. Stecklings of two radish cultivars (Forty Days and Mino Early) were planted at 30 or 45 cm plant-to-plant and 45, 60 or 75 cm row-to-row spacing. Results showed that branch length, number of branches, plant height, silique length, silique weight, number of seeds per silique, number of siliques per plant, seed yield per plant, 1000-seed weight, and nitrogen, phosphorus and potash (NPK) contents of seeds were higher for the plant and row spacing of 45 × 75 cm. However, seed yield per plot was (10.47 and 5.36%) higher at closer spacing (30 × 45 cm) during the both years. The two cultivars did not differ significantly for most of the studied traits except, branch length, lodging index, insertion height of first silique and silique weight per plant, which were higher for cultivar Mino Early than Forty Days. In conclusion, seed companies and growers can grow radish seed crop at 45 × 75 cm spacing for obtaining high yield of good quality seed.

Khan *et al*. (2016) conducted an experiment to study the effect of different spacing on the performance of radish under the agro-climatic conditions. Radish seeds were sown at different plant spacing of 6 (control), 12 and 18 centimeter (cm). There was a significant effect of plant-to-plant spacing on number of leaves, petiole width (cm), leaf blade width (cm), petiole length, root weight plant^{-1}, root width (mid), biomass and root length. Maximum number of leaves (41.66), petiole width (1.34), leaf blade width (17.38), petiole length (4.16), root weight plant^{-1} (1625 g), root length (43.36 cm) root width (mid) (7.34 cm) and biomass (1726 g) were recorded in plants with spacing of 18 cm, while minimum number of leaves (29.31), petiole width (0.68), leaf blade width (12.35 cm), petiole length (2.7 cm), root weight plant^{-1} (810.3 g) root length (31.75 cm) root width (mid) (5.10 cm) and biomass (1076 g) were recorded in plants with plant-to-plant distance of 6 cm. Based on the results, it is recommended that plant spacing of 18 cm should be kept for optimum growth and maximum production of radish in agro-climatic conditions of Swabi region.

Detroja and Davara (2016) carried out an experiment to study the response of radish (*Raphanus sativus* L.) cv. Pusa Chetaki to comprising three levels of spacing (15×10, 30×10, 45×10 cm) and four levels of potash (0, 25, 50, 75 kg K_2O) were laid out in factorial randomized block design with three replications. The growth parameters of radish *viz*., fresh weight of shoot, dry weight of shoot, number of leaves per plant, shoot length and weight of root, root girth, root length were significantly higher under the spacing of 45×10 and 30×10 cm over that 15×10 cm.

Sudhavani *et al*. (2015) conducted an experiment to study the effect of sowing dates (1st October, 15th October, 1st November and 15th November) and spacings (45 × 10 cm, 45 × 20 cm and 45 × 30 cm) on root yield of radish cv. Pusa Chetki. Highest yield was recorded in D_1S_1 (closely spaced crop and 1st October sowing) (13.88 t ha^{-1}).

Lavanya *et al*. (2014) conducted an experiment to study the effect of sowing dates and spacing on growth and yield of radish. The seeds sown on four different dates *viz*., 1st October, 15th October, 1st November and 15th November at different plant spacings of 45 × 10 cm, 45 × 20 cm and 45 × 30 cm. The closer spacing (45 × 10 cm) resulted in maximum plant height, whereas all other vegetative parameters like number of leaves, leaf area, root-shoot ratio and plant weight were found maximum with wider spacing (45 × 30 cm). Decreasing plant density significantly reduced the total yield (5.66 t/ha).

Asil *et al*. (2013) observed the effect of seed density and plant distance on yield and growth parameters of radish. Treatments consisted of factorial arrangement of three seed density levels (5, 10 and 15 kg/ha) and plant spacing (20 and 30 cm). Measurements comprising of total production in hectare, weight of one shrub, weight of tuber, weight of foliage, shrub height, leaf number, length of leaf, length and diameter of tuber. Results showed that seed density of 5 kg in hectare in plant distance of 20 cm with yield of 45.38 ton in hectare was most performance and recommendable for this region.

Desuki *et al*. (2005) investigated the interactive effect of different plant densities and N fertilizer rates on yield and quality attributes. On radish plants were spaced at 2 (10 and 20 cm) interrow and 2 (5 or 10 cm) intrarow distances (plants thinned when leaves were 5-8 cm tall) and received N fertilizer (ammonium sulfate) at rates of 40, 60 and 80 kg/fed. The roots were harvested 35 days after sowing. Decreasing plant density significantly reduced the total yield but markedly enhanced root quality.

Bilekudari *et al*. (2005) evaluated the effect of spacing and fertilizer levels on growth yield and quality of radish revealed that wider spacing (60 × 45 cm) significantly increased the number of branches per plant (9.25). Higher fertilizer level (130:55:55 NPK/ha) significantly increased the plant height (124 cm),

number of branches per plant (9.47), pods per plant (61.2), seed yield per plant (12.3 g), per hectare (5.13 q) and test weight (9.9 g) compared to recommended dose of fertilizer. Though the seed yield per plant was significantly higher (11.7 g) in wider spacing, but the closer spacing recorded significantly higher seed yield per hectare (5.07 q). The interaction due to spacing and fertilizer levels was non-significant. Significantly higher germination (93.3 and 97.1%), field emergence (86.92 and 90.4%), seedling vigour index (1628 and 1853) and lower electrical conductivity for seed leachate (0.48 and 0.43 dSm^{-1}) were recorded by seeds produced with wider spacing and higher fertilizer dose respectively.

Pervez *et al*. (2004) observed the effect of various nitrogen levels (0, 100, 150 & 200 kg ha^{-1}) and spacing (5, 10 and 15 cm) on growth and yield of radish. The experiment was laid out according to randomized complete block design in factorial arrangement with three replications. Application of 200 kg N ha^{-1} planted at 10 cm plant to plant distance was found the best treatment than others in relation to growth and yield of radish.

Gonge *et al*. (2004) conducted an experiment to study the performance of three varieties viz., Pusa Chetki, Pusa Reshmi and Japanese White and four plant spacings *viz*., 60 × 60, 60 × 45, 60 × 30 and 60 × 15 cm on seed yield and quality of radish. The results indicated that maximum seed yield of 13.47 and 14.01 q/ha was harvested from Pusa Chetki variety and the closer plant spacing treatment 60 × 15 cm, respectively. Among quality characters, test weight and graded seed yield were observed maximum in wider spacing of 60 × 60 cm whereas, the variety Pusa Chetki recorded highest test weight and germination percentage of radish seed. The interaction of varieties x spacings was non-significant for all the characters.

Warade *et al*. (2004) studied the effect of time of planting and spacing on seed yield and quality of radish var. Pusa Chetki. Forty five days old stecklings were

transplanted on five dates of transplanting *viz*., 1st October, 15th October, 1st November, 15th November and 30th November with four plant spacings *viz*., 60 × 60 cm, 60 × 45 cm, 60 × 30 cm and 60 × 15 cm were tested in seed crop of radish var. Pusa Chetki during rabi season of 2000-2001. The result indicated that maximum seed yield (17.49 q/ha) was harvested from steckling planted on 1st October. Among plant spacing, the closest spacing of 60 × 15 cm produced highest seed yield (17.96 q/ha). The interaction of time of planting × spacing was significant for number of pods per plant, seed yield per plant and per hectare, which indicated that 1st October planting with close spacing 60 × 15 cm produced highest seed yield (25.59 q/ha).

Albayral *et al*. (2004) conducted an experiment to find out the effect of four row spacing (20, 30, 40 and 50 cm) on root and leaf yields and yield components of forage turnips. The root yield, root dry matter yield, root crude protein yield, root diameter, root length, leaf dry matter yield and leaf crude protein yield were determined. Row spacing significantly affected most the yield components determined on forage turnip cultivars. Root and leaf yield and their components increased along with increase of row spacing. The highest root and leaf dry matter yields were obtained from the 40cm row spacing.

Bilgili *et al*. (2003) conducted an experiment to evaluate the effects of four row spacing (17.5, 35.0, 52.5 and 70 cm) and live seeding rate on seed yield and some yield components of forage turnip. Plant height, stem diameter, pods/terminal raceme, total pods/plant, seeds/pod and primary branches/plant were measured individually. The number of plants per unit area was counted and the lodging arte of the plots was scored. The seed yield and 1000-seed weight were also determined. Row spacing and seeding rate significantly affected most yield components measured. The number of plants per unit area increased with increasing seeding rate and decreasing row spacing. Plant height was not greatly influenced by row spacing and seeding rate. Also, the number of pods/main stem

was affected by either the row spacing or the seeding rate. In contrast, the number of pods per plant clearly increase with increasing row spacing, but decreased with increasing seeding rate. The plots seeded at narrow row spacing and st high seeding rates were more sensitive to lodging. Seeding rate had no significant effect on seed yield. However, row spacing was associated with seed yield.

Srivastava *et al*. (1994) studied seed crops of radish cv. Pusa Chetki were grown using 3 spacings (60 × 30, 60 × 45 and 60 × 60 cm) and given 4 rates of nitrogen (zero, 40, 80 and 120 kg N/ha). Various aspects of the seed production and quality (plant height, number of primary branches/plant, number of seeds/g, seed yield in g/plant and q/ha) were determined and found to be significant plant spacing and N doses. The maximum seed yield (3-year mean) of 7.95 q/ha, obtained from the spacing of 120 60 × 30 cm, which was significantly higher than the yield spacings.

Rahman *et al*. (1990) evaluated the effect of time of sowing and spacing on yield, yield components, and quality of radish seeds. Days to flowering and pod maturity which ranged from 41 to 71 days and 98 to 119, days respectively were influenced by time of sowing. With delayed sowing days to flowering and pod maturity were shortened comparatively higher seed yield was obtained from 1st and 15 November sowing at closer spacings. The highest seed yield (1.02 t/ha) was obtained from 15 November sowing at a spacing of 30 × 15 cm which was closely followed by 15 November sowing having 30 × 30 and 15 × 15 cm spacings and 1st November sowings having 30 × 15, 15 × 15 and 45 × 30 cm spacings. There was drastic reduction in per plant seed yield when sown in December.

Maurya *et al*. (1990) worked on the effect of seed sowing dates and planting distances of steckling on growth, yield and quality of radish seed cv. Pusa Chetki: Seeds were sown at distances of 60 × 45, 60 × 60 and 60 × 75 cm. Plant height, numbers of branches/plant, pods/plant and seeds/pod, seed yield/plant and 100 seed weight were recorded. The steckling planting distance of 60 × 75 cm

produced the largest numbers of branches and pods/plant, and highest seed yield/plant, the figures decreasing with increasing plant density. Seed yield/ha was not affected by spacing, but yields from the last sowing date were poor regardless of spacing.

CHAPTER III

MATERIALS AND METHODS

A field experiment was conducted at the research field of Sher-e-Bangla Agricultural University. This chapter provided a brief description on location, climate, soil, crop, fertilizer, experimental design, cultural operations, collection of plant samples and materials used in the experiment and the methods followed and statistical analyses.

3.1 Experimental site

The research work was conducted at the Central Farm of Sher-e-Bangla Agricultural University, Dhaka-1207 to find out the growth, seed yield and quality of radish seed as influenced by planting method and plant spacing during the period from November 2021 to March 2022. Experimental field was located at 90°22′E longitude and 23°41′N latitude and altitude of 8.2 m above the sea level. The experimental site is presented in Appendix I.

3.2 Climate

Experimental area belongs to subtropical climatic zone which is characterized by heavy rainfall, high temperature and relatively long day period during "Kharif-1" season (April-September) and scarce rainfall, low humidity, low temperature and short day period during "Rabi" season (October-March). This climate is also characterized by distinct season, *viz*. the monsoon extending from May to October, the winter or dry season from November to February and per-monsoon period or hot season from March to April (Edris *et al.,* 1979). The meteorological data in respect of temperature, rainfall, relative humidity, average sunshine and soil temperature for the entire experimental period have been shown in Appendix II.

3.3 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract in Agroecological Zone (AEZ)-28 (UNDP, 1988). It was medium high land and the soil series was Tejgaon (FAO, 1988). The soil was having a texture of sandy loam with pH and CEC were 5.6 and 2.64 meq/100 g soil, respectively. The characteristics of the soil under the experimental plot were analyzed in the Soil Testing laboratory, SRDI, Khamarbari, Dhaka and details of the recorded soil characteristics were presented in Appendix III.

3.4 Planting materials

The materials used in the study was radish seeds cv. BARI mula-3(Druti).

3.5 Experimental Treatment

The following treatments were included in the experiment:

Factor A: Planting methods (3 types)

1. M_1 = Direct sowing of seed
2. M_2 = 1/3 cutting of root
3. M_3 = 2/3 cutting of root

Factor B: Plant spacing (3 types)

1. S_1 = 30 cm × 20 cm
2. S_2 = 30 cm × 30 cm
3. S_3 = 30 cm × 40 cm

There were nine (3×3) treatment combinations given below:

M_1S_1, M_1S_2, M_1S_3, M_2S_1, M_2S_2, M_2S_3, M_3S_1, $M_3S_2$and M_3S_3.

3.6 Land preparation

The land was first ploughed by a tractor drawn disc plough and subsequently cross ploughed four times with power tiller and ladder on 17 November, 2021. The corners of the land were spaded. It was then harrowed to bring the soil in a good tilth condition. The land was then thoroughly leveled by a ladder. Weeds and stubbles were removed from the field. All the clods were broken into small pieces. Finally the land preparation was completed on 24 November 2021. The unit plots were also prepared smoothly with spade before sowing.

3.7 Fertilizer application

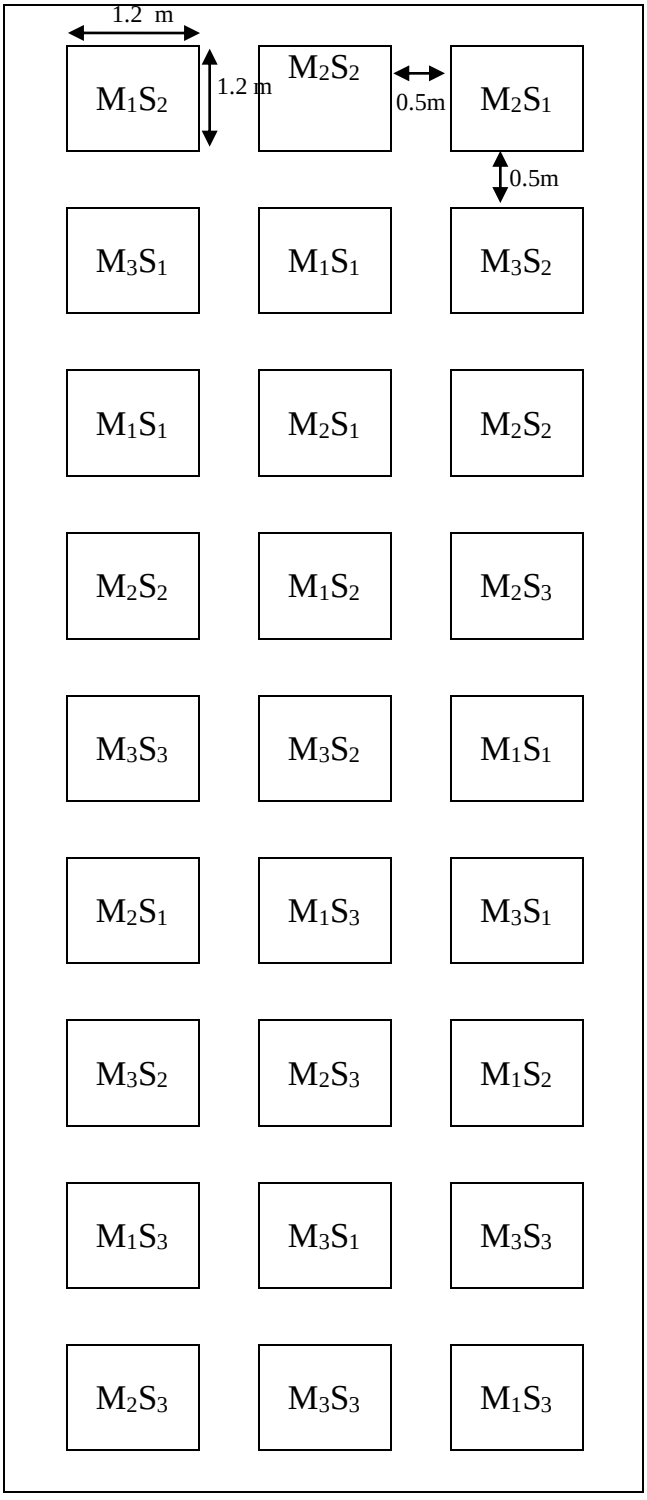
According to Krishi Projukti Hat Boi, BARI, 2019, standard manure and fertilizer doses as follows:

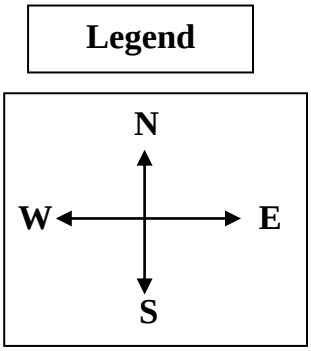
Name of fertilizer and manure	Doses ha^{-1}
Cowdung	8 t
Urea	300 kg
TSP	250 kg
MoP	215 kg

The manures and fertilizers were applied as basal dose at final land preparation but urea was applied in three equal installments. All manures and fertilizers were applied by broadcasting and mixed thoroughly with soil.

3.8 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. There were nine treatment combinations. In total of 27 unit plots and the size of each unit plot was 1.2 m × 1.2 m. The distance maintained between two replications and two plots were 0.5 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.





Treatments

Factor A: Planting methods

1. M_1 = Direct sowing of seed
2. M_2 = 1/3 cutting of root
3. M_3 = 2/3 cutting of root

Factor B: Plant spacing

1. S_1 = 30 cm × 20 cm
2. S_2 = 30 cm × 30 cm
3. S_3 = 30 cm × 40 cm

Fig. 1. Layout of the experimental plot

3.9 Plantation of radish

Plantation was done according to the treatments assigned. Three planting methods were followed *viz*. (i) Direct sowing of seed, (ii) 1/3 cutting of root and (iii) 2/3 cutting of root.

3.10 Intercultural operations

3.10.1 Weed control

The crop was found to be infested with weeds during the early stage of crop establishment. Two hand weddings were done; first weeding was given at 15 days after plantation followed by second weeding at 15 days after first weeding.

3.10.2 Irrigation

The young plants were irrigated by a watering can and at later stage irrigation was done by flooding of each plot whenever necessary.

3.10.3 Plant protection

Preventive measure was taken against soil borne insects. For the prevention of cutworm, Furadan 3G @ 20 kg ha^{-1} was applied. No insect pest infestation was found in the field after pesticide application.

3.11 Harvesting

Harvesting of radish seed at proper stage of maturity is essential to fetch good price in the market. Delay in harvesting deteriorates the quality of the seeds and deteriorate for germination. Radish seed is ready to harvest when about 60 to 70% of the seed pods turn from green yellow to brown and lose their fleshy appearance, becoming papery thin and light. Plants are first cut above the ground by hand with a sickle. After harvesting the entire plants was placed it in a brown bag for avoid shattering. Hang the bag with the plant seed dangling down into it and allow the seeds to mature naturally. Once they are completely mature, the pods are pop

and the seeds drop into the bag. Threshing was done on a clear day. The dried pods were crushed by hand to separate the seeds. After thorough drying of seed, it was placed in partial sun (up to 7% moisture content). Seeds were separated from chaff or broken twigs either by winnowing and cleaned and stored.

3.12 Threshing, cleaning, drying and storage

Harvested radish plants with pods were dried on the cemented floor of under sunlight. Pods were ready for threshing when the pods and small stems were brittle and broke quickly while rubbed between the hands. The seeds were threshed by beating the pods with small stick. Seeds were then cleaned by winnowing manually and dried by spreading in the open sunlight on brown paper until they reached safe moisture content (6-9%). After putting the seeds in airtight polythene bags, these were kept in dry and cool place at room temperature for storing. The seeds thus collected were dried in the sun for reducing the moisture in the seeds to a constant level. The dried seeds and straw were cleaned and weighed.

3.13 Seed quality

Seeds obtained from the field experiment were taken separately. These seeds were used for taking quality determination experiments in the laboratory. For this purpose standard germination test was conducted and other different quality attributes data were taken.

3.14 Collection of data

The data were recorded on the following parameters:

3.14.1 Growth parameters

1. Number of leaves plant^{-1}
2. Leaf length
3. Leaf breadth

3.14.2 Yield contributing parameters

1. Number of pods plant^{-1}
2. Pod length
3. Number of seeds pod^{-1}
4. Dry weight plant^{-1}

3.14.3 Yield parameters

1. Seed yield plant^{-1}
2. Seed yield ha^{-1}

3.14.4 Seed quality parameters

1. Germination percentage
2. Shoot length
3. Root length
4. Seed vigour index

3.15 Data collection procedure

Ten plants per plot were sampled in the middle rows and marked by bamboo stick for collection of per plant data while the crop of whole plot was harvested to record per plot data. The plants in the outer rows and the extreme end of the middle rows were excluded from the random sampling to avoid the border effect.

3.15.1 Number of leaves per plant

Numbers of leaves were counted at 40 days after sowing. Ten plants in each plot were used to count number of leaves per plant and the average number was measured.

3.15.2 Leaf length

Leaf length was measured from ten randomly selected plants with the help of a meter scale at 40 days after sowing and mean was calculated.

3.15.3 Leaf breadth

Leaf breadth was measured from ten randomly selected plants with the help of a meter scale at 40 days after sowing and mean was calculated.

3.15.4 Number of pod plant^{-1}

Number of pods per plant from ten randomly selected plants were counted and their mean values were measured.

3.15.5 Pod length

Ten pods from selected plants were counted at random. Length of pods of the selected plants was measured and their mean value was considered.

3.15.6 Number of seeds pod^{-1}

Numbers of seeds per pod were recorded from ten randomly selected pods and the average value was calculated.

3.15.7 Dry weight plant^{-1}

From each plot, ten plants were collected and sun dried after that collected samples were placed in envelope, were weighted and placed in oven maintained at 70° C for 72 hours. The sample then was transferred into a desiccator and allowed to cool down to the room temperature. The dry weight of the sample was taken and mean value was recorded in gram (g).

3. 15.8 Seed yield plant^{-1}

The 10 plants selected at random from the inner rows of each plot which were harvested to take seed yield per plant. The seed were threshed, cleaned, dried, weighed and then averaged in gram (g).

3.15.9 Grain yield ha^{-1}

The yield of seed in g per plot was adjusted at 12% moisture content of seed and then it was converted to kg per hectare.

3.15.10 Seed viability test

3.15.10.1 Percent seed germination

After collection of harvested seeds, percent seedling emergence was tested in the Laboratory. Sample seeds from each replication collected from the experiment field were tested for percent seed germination. Germination was calculated as the number of seeds which was germinated within 12 days as a proportion of number of seeds set for germination test in each treatment.

$$\text{Germination percentage (\%)} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds set for germination}} \times 100$$

3.15.10.2 Root length

The Root length of five seedlings from each sample was recorded finally at 12 days of germination test. Measurement was done using a meter scale and unit was expressed in centimeter (cm).

3.15.10.3 Shoot length

The shoot length of ten seedlings from each sample was measured finally at 12 days of germination test. Measurement was done using the unit centimeter (cm) by a meter scale.

3.15.10.4 Seed vigor index

The vigor index (VI) of the seedlings can be estimated as suggested by Abdul-Baki and Anderson (1973):

$$VI = RL+SL\times GP,$$

Where

RL = root length (cm),

SL = shoot length (cm) and

GP = germination percentage.

3.16 Statistical analysis

The collected data were compiled and tabulated. Statistical analysis was done on various plant characters to find out the significance of variance resulting from the experimental treatments. Data were analyzed using analysis of variance (ANOVA) technique with the help of computer package programme MSTAT-C (software) and the mean differences were adjudged by least significant difference test (LSD) as laid out by Gomez and Gomez (1984).

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to find out the influence of planting methods and spacing on yield and quality of radish seed. The results have been presented and discussed with the help of Tables and Graphs and possible interpretations have been given under the following headings:

4.1 Growth parameters

4.1.1 Leaf number plant^{-1}

Different planting methods of radish showed significant variation for number of leaves plant^{-1} at harvest (Appendix IV). Results indicated that the highest number of leaves plant^{-1} (12.67) was achieved from the planting method M_1 (Direct sowing of seed) which was varied significantly with other treatments whereas the lowest number of leaves plant^{-1} (10.07) was recorded from the planting method M_3 (2/3 cutting of root) (Table 1). Significant differences among the planting methods for number of leaves plant^{-1} indicated that this factor may have a substantial impact on this particular parameter.

Application of different plant spacing showed significant influence on number of leaves plant^{-1} (Appendix IV). It was observed that the spacing S_3 (30 cm × 40 cm) showed the highest number of leaves plant^{-1} (12.93) which differed significantly to other treatments whereas the lowest number of leaves plant^{-1} (9.80) was found from the plant spacing S_1 (30 cm × 20 cm) (Table 2). Significant variation among the plant spacing treatments indicated that there was a significant contribution of plant spacing on leaf number of radish under the present study.

Treatment combination of planting methods and plant spacing showed significant variation on number of leaves plant^{-1} of radish (Appendix IV). The treatment combination of M_1S_3 showed the highest number of leaves plant^{-1} (13.20) which was significantly different from other treatment combinations followed by M_2S_3 and M_3S_3. The treatment combination of M_3S_1 gave the lowest number of leaves plant^{-1} (9.20) which was significantly different from other treatment combinations (Table 3).

Table 1. Effect of planting methods on different growth parameters of radish

Treatments	Growth parameters		
	Number of leaves plant^{-1}	Leaf length (cm)	Leaf breadth (cm)
M_1	12.67 a	25.23 a	7.88 a
M_2	11.44 b	24.43b	6.56 b
M_3	10.07 c	23.87 c	5.21 c
$LSD_{(0.05)}$	0.532	0.411	0.407
CV(%)	6.10	4.47	6.21

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

M_1 = Direct sowing of seed, M_2 = 1/3 cutting of root, M_3 = 2/3 cutting of root

4.1.3 Leaf length

Different planting methods showed significant variation on leaf length of radish (Appendix IV). The planting methods M_1 (Direct sowing of seed) showed maximum leaf length (25.23 cm) followed by M_2 (1/3 cutting of root) whereas the minimum leaf length (20.88 cm) was found from M_3 (2/3 cutting of root) planting method (Table 1). Under the present study, radish plants might have inherent growth habits that are less influenced by the planting method. For example, if the growth habit of radish primarily involves vertical elongation of the stem to

produce leaves, the planting method may have a limited effect on leaf length. In such cases, the inherent growth habit may overshadow any potential variation caused by planting method differences.

Different plant spacing of radish showed significant variation on leaf length (Appendix IV). The plant spacing S_3 (30 cm × 40 cm) showed best performance in gaining leaf length (27.17 cm) whereas the least performance (23.13 cm) was from the plant spacing S_1 (30 cm × 20 cm) (Table 2). Significant variation of leaf length among the plant spacing treatments might be due to cause of some growth limiting factors such as nutrient availability, water availability and light intensity were not consistent across the different plant spacing treatments, which might be resulted significant differences in leaf length among the treatments.

Leaf length of radish varied significantly due to combined effect of planting methods and plant spacing (Appendix IV). Results showed that the treatment combination of M_1S_3 showed the maximum leaf length (28.15 cm) which was significantly different from other treatment combinations followed by M_2S_3 and M_3S_3. The treatment combination of M_3S_1 gave the minimum leaf length (20.88 cm) which was statistically identical with the treatment combination of M_2S_1 and M_1S_1 (Table 3). However, when examining the combined effect of planting methods and plant spacing, a significant difference was observed for leaf length. This implies that the interaction between planting methods and plant spacing may influence the elongation of radish leaves.

Table 2. Effect of different plant spacing on different growth parameters of radish

Treatments	Growth parameters		
	Number of leaves plant^{-1}	Leaf length (cm)	Leaf breadth (cm)
S_1	9.80 c	23.13 c	5.48 c
S_2	11.44 b	25.24 b	6.47 b
S_3	12.93 a	27.17 a	7.70 a
$LSD_{(0.05)}$	0.634	1.032	0.637
CV(%)	6.10	4.47	6.21

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

S_1 = 30 cm × 20 cm, S_2 = 30 cm × 30 cm, S_3 = 30 cm × 40 cm

4.1.4 Leaf breadth

Significant variation was found for leaf breadth by different planting methods of radish (Appendix IV). Results indicated that the maximum leaf breadth (7.88 cm) was achieved from the planting method M_1 (Direct sowing of seed) which was significantly different from other treatments whereas the minimum leaf breadth (5.21 cm) was found from the planting method M_3 (2/3 cutting of root) (Table 1). Environmental conditions, such as temperature, humidity, light intensity, and nutrient availability, can significantly impact plant growth and development. In the experimental conditions provided a relatively non-uniform environment for all planting method treatments, this is why the environmental factors might have significant differences in leaf breadth among the treatments.

Different plant spacing of radish showed significant variation on leaf breadth (Appendix IV). Results revealed that the plant spacing S_3 (30 cm × 40 cm) gave the maximum leaf breadth (7.70 cm) which was significantly different from other treatments whereas the minimum leaf breadth (5.48 cm) was recorded from the

plant spacing S_1 (30 cm × 20 cm) (Table 2). Probably, some growth limiting factors like nutrient availability, water availability and light intensity were not consistent across the different plant spacing treatments, which might be the cause of significant differences in leaf breadth of radish among the treatments.

Leaf breadth of radish varied significantly due to combined effect of planting methods and plant spacing (Appendix IV). It was observed that the treatment combination of M_1S_3 showed the maximum leaf breadth (8.04 cm) which differed significantly to other treatment combinations followed by M_2S_3 whereas the treatment combination M_3S_1 gave the minimum leaf breadth (5.12 cm) which was significantly different from other treatment combinations (Table 3).

Table 3. Combined effect of planting methods and plant spacing on different growth parameters of radish

Treatments	Growth parameters		
	Number of leaves plant^{-1}	Leaf length (cm)	Leaf breadth (cm)
M_1S_1	10.27 d	21.40 e	5.80 f
M_1S_2	11.53 c	26.15 bc	6.80 d
M_1S_3	13.20 a	28.15 a	8.04 a
M_2S_1	9.930 e	21.10 e	5.52 g
M_2S_2	11.53 c	25.21 cd	6.40 e
M_2S_3	12.87 b	26.97 b	7.75 b
M_3S_1	9.200 f	20.88 e	5.12 h
M_3S_2	11.27 c	24.35 d	6.20 e
M_3S_3	12.73 b	26.38 b	7.30 c
$LSD_{(0.05)}$	0.328	0.9575	0.251
CV(%)	6.10	4.47	6.21

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

M_1 = Direct sowing of seed, M_2 = 1/3 cutting of root, M_3 = 2/3 cutting of root
S_1 = 30 cm × 20 cm, S_2 = 30 cm × 30 cm, S_3 = 30 cm × 40 cm

4.2 Yield contributing parameters

4.2.1 Number of pods plant^{-1}

The recorded data on number of pods plant^{-1} of radish varied significantly due to the performance of different planting methods (Appendix V). The maximum number of pods plant^{-1} (75.33) was registered from the planting method M_1 (Direct sowing of seed) which differed significantly others followed by M_2 (1/3 cutting of root) whereas the minimum number of pods plant^{-1} (43.00) was recorded from the planting method M_3 (2/3 cutting of root) (Table 4). Planting methods involving root cutting, as mentioned in the study (M_2 and M_3), can impact root development and subsequent nutrient and water uptake. Different root cutting levels may affect the plants' ability to establish a robust root system, which is vital for nutrient acquisition and water absorption. Reduced root development due to cutting can negatively influence pod formation and dry weight accumulation. Kim *et al*. (2020) reported that direct seeding resulted in higher pods number per plant, seeds/pod) and higher seed yield compared to other planting methods which supported the present study. Similar result was also observed by Islam *et al*. (2019).

Different plant spacing of radish showed significant variation on number of pods plant^{-1} (Appendix V). Results indicated that the plant spacing S_3 (30 cm × 40 cm) gave the best performance in gaining number of pods plant^{-1} (61.84) which was significantly different from other spacing treatments. The minimum number of pods plant^{-1} (52.96) was performed by S_1 (30 cm × 20 cm) plant spacing which was statistically identical with the treatment S_2 (30 cm × 30 cm) (Table 5). Plant spacing directly affect plant density, which can impact the availability of resources such as light, water, and nutrients. Higher plant density or lower plant spacing may lead to increased competition among plants for these resources. This competition can influence the number of pods per plant. For example, closer spacing of radish

may result in higher plant density, leading to greater competition and subsequently reducing the number of pods. Similar result was also observed by Bilekudari *et al*. (2005), Warade *et al*. (2004) and Bilgili *et al*. (2003)

Number of pods plant^{-1} of radish varied significantly due to combined effect of planting methods and plant spacing (Appendix V). Results indicated the treatment combination of M_1S_3 gave the maximum number of pods plant^{-1} (82.13) which was significantly different from other treatment combinations followed by M_1S_2. Again, the treatment combination of M_3S_1 gave the minimum number of pods plant^{-1} (38.61) which was significantly different to other treatment combinations (Table 6).

Table 4. Effect of planting methods on different yield contributing parameters of radish

Treatments	Yield contributing parameters			
	No. of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}	Dry weight plant^{-1} (g)
M_1	75.33 a	4.92 a	5.48 a	120.80 a
M_2	53.67 b	4.29 b	4.98 b	114.90 b
M_3	43.00 c	3.89 c	4.01 c	94.22 c
$LSD_{(0.05)}$	1.311	0.312	0.402	1.887
CV(%)	11.35	9.20	12.29	7.43

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

M_1 = Direct sowing of seed, M_2 = 1/3 cutting of root, M_3 = 2/3 cutting of root

Table 5. Effect of different plant spacing on different yield contributing parameters of radish

Treatments	Yield contributing parameters			
	No. of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}	Dry weight plant^{-1} (g)
S_1	52.96 c	3.36 c	4.13 c	102.30 c
S_2	57.20 b	4.19 b	4.69 b	112.10 b
S_3	61.84 a	5.56 a	5.65 a	115.40 a
$LSD_{(0.05)}$	1.311	0.421	0.326	1.887
CV(%)	11.35	9.20	12.29	7.43

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

S_1 = 30 cm × 20 cm, S_2 = 30 cm × 30 cm, S_3 = 30 cm × 40 cm

4.2.2 Pod length

Different planting methods showed significant influence on pod length of radish (Appendix V). The highest pod length (4.92 cm) was achieved from the planting method M_1 (Direct sowing of seed) which was significantly different from other treatments whereas the lowest pod length (3.89 cm) was found from the planting method M_3 (2/3 cutting of root) (Table 4).

Pod length of radish differed significantly due to different treatments of plant spacing (Appendix V). It was observed that the plant spacing S_3 (30 cm × 40 cm) gave the highest pod length (5.56 cm) whereas the plant spacing S_1 (30 cm × 20 cm) gave the lowest pod length (3.36 cm) (Table 5).

Treatment combination of planting methods and plant spacing showed statistically significant variation on pod length of radish (Appendix V). Results indicated that

the treatment combination of M_1S_3 showed the highest pod length (6.24 cm) which was significantly different from other treatment combinations followed by M_2S_3 (Table 6). The treatment combination of M_3S_1 gave the lowest pod length (4.40 cm) which was significantly different from other treatment combinations.

4.2.3 Number of seeds pod^{-1}

Different planting methods showed significant influence on number of seeds pod^{-1} of radish (Appendix V). Results revealed that the highest number of seeds pod^{-1} (5.48) was achieved from the planting methods M_1 (Direct sowing of seed) followed by M_2 (1/3 cutting of root) whereas the lowest number of seeds pod^{-1} (4.01) was found from the planting methods M_3 (2/3 cutting of root) (Table 4).

Number of seeds pod^{-1} of radish differed significantly due to different levels of plant spacing (Appendix V). It was observed that the highest number of seeds pod^{-1} (5.65) was given by the plant spacing S_3 (30 cm × 40 cm) that was significantly different to other treatments whereas the lowest number of seeds pod^{-1} (4.13 cm) was registered by the plant spacing S_1 (30 cm × 20 cm) (Table 5). Higher plant spacing resulting lower competition on the availability of resources such as light, water and nutrients among the plant population which might be the cause of highest number of seed in pods with higher plant spacing or lower plant density. Husnain *et al*. (2020) also found similar result with the present study.

Treatment combination of planting methods and plant spacing showed statistically significant variation on number of seeds pod^{-1} of radish (Appendix V). Results indicated that the treatment combination of M_1S_3 showed the highest number of seeds pod^{-1} (6.31) which was significantly different from other treatment combinations followed by M_2S_3. Again, the treatment combination of M_3S_1 gave the lowest number of seeds pod^{-1} (3.02) which was significantly different from other treatment combinations (Table 6).

Table 6. Combined effect of planting methods with different plant spacing on different yield contributing parameters of radish

Treatments	Yield contributing parameters			
	No. of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}	Dry weight plant^{-1} (g)
M_1S_1	69.20 c	3.80 e	4.96 c	106.00 d
M_1S_2	74.67 b	4.72 c	5.17 bc	121.00 c
M_1S_3	82.13 a	6.24 a	6.31 a	153.70 a
M_2S_1	51.00 e	3.24 f	4.40 d	89.67 g
M_2S_2	53.00 de	4.12 d	5.10 c	101.30 e
M_2S_3	57.00 d	5.52 b	5.44 b	135.30 b
M_3S_1	38.67 g	3.04 f	3.02 f	86.67 g
M_3S_2	43.93 f	3.72 e	3.80 e	96.33 f
M_3S_3	46.40 f	4.92 c	5.20 bc	99.67 e
$LSD_{(0.05)}$	4.348	0.268	0.328	3.268
CV(%)	11.35	9.20	12.29	7.43

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

M_1 = Direct sowing of seed, M_2 = 1/3 cutting of root, M_3 = 2/3 cutting of root

S_1 = 30 cm × 20 cm, S_2 = 30 cm × 30 cm, S_3 = 30 cm × 40 cm

4.2.4 Dry weight plant^{-1}

Effect of planting methods

The recorded data on dry weight plant^{-1} varied significantly due to different planting methods of radish (Appendix VI). The maximum 1000 dry weight plant^{-1} (120.80 g) was registered from the planting methods M_1 (Direct sowing of seed) that was significantly different to other treatments followed by M_2 (1/3 cutting of root) whereas the minimum dry weight plant^{-1} (94.22 g) was recorded from the planting method M_3 (2/3 cutting of root) (Table 7). Different planting methods involving root cutting, as mentioned in the study (M_2 and M_3), might be due to cause of reduced root development due to cutting can negatively influence dry weight accumulation. Supported result was also observed by Liu and Wang (2020).

Application of different plant spacings of radish showed significant variation on dry weight plant^{-1} (Appendix VI). Result revealed that the maximum dry weight plant^{-1} (115.40 g) was given by the plant spacing S_3 (30 cm × 40 cm) followed by S_2 (30 cm × 30 cm) whereas the minimum dry weight plant^{-1} (102.30 g) was performed by S_3 (30 cm × 40 cm) that was significantly different to other plant spacings (Table 8). Higher plant density resulting increased competition for the availability of resources such as light, water, and nutrients which might influenced the dry weight per plant that might be resulted lower dry weight with higher plant density or lower plant spacing. Supported results were also observed by Detroja and Davara (2016) and Albayral *et al*. (2004).

Treatment combination of planting methods and plant spacing showed significant variation on dry weight plant^{-1} of radish (Appendix VI). Results indicated the treatment combination of M_1S_3 gave the maximum dry weight plant^{-1} (153.70 g) that was significantly different to other treatment combinations followed by the treatment combinations of M_2S_3 (Table 9). Again the treatment combination of

M_3S_1 gave the minimum dry weight plant^{-1} (86.67 g) which was significantly different to other treatment combinations.

4.3 Yield parameters

4.3.1 Seed yield plant^{-1}

The recorded data on seed yield plant^{-1} of radish varied significantly due to the performance of different planting methods (Appendix VI). The maximum seed yield plant^{-1} (10.87 g) was registered from the planting method M_1 (Direct sowing of seed) which was significantly different from other planting methods followed by M_2 (1/3 cutting of root) whereas the minimum seed yield plant^{-1} (8.46 g) was recorded from the planting method M_3 (2/3 cutting of root) (Table 7). Similar result was also observed by Kim *et al*. (2020).

Different spacing treatments showed significant variation on seed yield plant^{-1} of radish (Appendix VI). Results revealed that the plant spacing S_3 (30 cm × 40 cm) gave the highest seed yield plant^{-1} (12.02 g) followed by the plant spacing S_2 (30 cm × 30 cm) whereas the minimum seed yield plant^{-1} (7.70 g) was registered by S_1 (30 cm × 20 cm) treatment that was significantly different to other treatments (Table 8). When radish plants are spaced further apart (30 cm × 30 cm and 30 cm × 40 cm), each plant has more space, receives more light, and has access to more nutrients and water without intense competition from neighboring plants. This allows individual plants to grow larger, develop more extensive root systems, and produce a higher number of seeds per plant. Similar result was observed by Bilekudari *et al*. (2005).

Seed yield plant^{-1} of radish varied significantly due to combined effect of planting methods and plant spacing (Appendix VI). Results indicated the treatment combination of M_1S_3 gave the maximum seed yield plant^{-1} (13.81 g) which was significantly different from other treatment combinations followed by the

treatment combination of M_2S_3 whereas M_3S_1 gave the minimum seed yield plant^{-1} (7.01 g) which was statistically similar with the treatment combination of M_2S_1 (Table 9).

Table 7. Effect of planting methods on different yield parameters of radish

Treatments	Yield parameters	
	Seed yield plant^{-1} (g)	Seed yield ha^{-1} (kg)
M_1	10.87 a	1234.00 a
M_2	9.76 b	1180.00 b
M_3	8.46 c	976.13 c
$LSD_{(0.05)}$	0.664	6.961
CV(%)	6.70	7.48

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

M_1 = Direct sowing of seed, M_2 = 1/3 cutting of root, M_3 = 2/3 cutting of root

Table 8. Effect of different plant spacing on different yield parameters of radish

Treatments	Yield parameters	
	Seed yield plant^{-1} (g)	Seed yield ha^{-1} (kg)
S_1	7.70 c	1283.33 a
S_2	9.36 b	1072.17 b
S_3	12.02 a	1034.63 c
$LSD_{0.05}$	0.746	5.839
$LSD_{(0.05)}$	6.70	7.48
CV(%)	6.70	7.48

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

S_1 = 30 cm × 20 cm, S_2 = 30 cm × 30 cm, S_3 = 30 cm × 40 cm

4.3.2 Seed yield ha^{-1}

Effect of planting methods

Different radish planting methods showed significant influence on seed yield of radish (Appendix VI). Results revealed that the highest seed yield (1234.00 kg ha^{-1}) was achieved from the planting method M_1 (Direct sowing of seed) which was followed by the planting method M_2 (1/3 cutting of root) whereas the lowest seed yield (976.13 kg ha^{-1}) was found from the planting method M_3 (2/3 cutting of root) (Table 7). Direct sowing allows the radish plants to develop their root systems without any interference or disturbance. This promotes the growth of a healthy and robust root system, which is essential for nutrient uptake and water absorption. A well-developed root system can support optimal plant growth, including seed development and yield. When seeds are directly sown, the young radish plants establish their roots directly in the soil, providing them with immediate access to nutrients. The root cutting methods, on the other hand, involve removing a portion of the root system, which can temporarily disrupt nutrient uptake. This disturbance may affect the plants' ability to obtain essential nutrients, potentially impacting seed yield. The results obtained from the present study was similar with the findings of Kim *et al*. (2020) and Liu *et al*. (2020).

Seed yield of radish differed significantly due to different plant spacing of radish (Appendix VI). It was observed that the plant spacing treatment S_1 (30 cm × 20 cm) gave the highest seed yield (1283.33 kg ha^{-1}) that was significantly different to other treatments followed by S_2 (30 cm × 30 cm) whereas the lowest seed yield (1034.63 kg ha^{-1}) was given by the plant spacing treatment S_3 (30 cm × 40 cm) (Table 8). This result indicated that lower plant spacing gave higher plant population. With lower plant spacing i.e. higher plant population, individual plants have access to a smaller amount of resources. This limitation stimulates more efficient resource utilization, as plants allocate more energy towards seed

production rather than vegetative growth. The limited space and competition for resources can trigger early flowering and seed development, resulting in higher seed yield per plant. Closer spacing (30 cm × 20 cm) means more plants are grown per unit area. While individual plants might produce fewer seeds due to competition for resources, the overall yield per hectare increases because there are more plants in the field. This higher plant population compensates for the reduced seed yield per plant, resulting in a higher yield at the field level. Similar result was observed by the findings of Husnain *et al*. (2020) and Bilekudari *et al*. (2005).

Table 9. Combined effect of planting methods with different plant spacing on different yield parameters of radish

Treatments	Yield parameters	
	Seed yield plant^{-1} (g)	Seed yield ha^{-1} (kg)
M_1S_1	8.32 d	1386.00 a
M_1S_2	10.49 c	1151.00 d
M_1S_3	13.81 a	1165.00 c
M_2S_1	7.78 de	1296.00 b
M_2S_2	10.33 c	1147.00 d
M_2S_3	12.16 b	1097.00 e
M_3S_1	7.01 e	1168.00 c
M_3S_2	8.27 d	918.50 f
M_3S_3	10.10 c	841.90 g
$LSD_{(0.05)}$	1.149	6.649
CV(%)	6.70	7.48

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

M_1 = Direct sowing of seed, M_2 = 1/3 cutting of root, M_3 = 2/3 cutting of root
S_1 = 30 cm × 20 cm, S_2 = 30 cm × 30 cm, S_3 = 30 cm × 40 cm

Treatment combination of planting methods and plant spacing showed statistically significant variation on seed yield of radish (Appendix VI). Results indicated that the treatment combination of M_1S_1showed the highest seed yield (1386.00 kg ha^{-1}) which was significantly different to other treatment combinations followed by M_2S_1whereas the lowest seed yield (841.90 kg ha^{-1}) was given by the treatment combination of M_3S_3 (Table 9).

4.4 Seed quality parameters

After completion of field experiment, produced seeds were tested for quality. Regarding quality test, seed germination, shoot and root length of seedlings and seed vigour index were tested.

4.4.1 Germination percentage

Significant variation was observed on seed germination as influenced by different planting method (Appendix VII). Results indicated that the highest seed germination (88.43%) was given from the seeds obtained from M_1 (Direct sowing of seed) planting method which was statistically identical to seeds obtained from M_2 (1/3 cutting of root) treatment (Table 10). On the other hand, the lowest seed germination (85.87%) was found from seeds which was obtained from M_3 (2/3 cutting of root) planting method. Kim *et al*. (2020) and Liu and Wang (2020) found that direct seeding resulted in better seed quality in terms of germination percentage which supported the present findings.

Seeds of radish obtained from different plant spacing levels showed significant variation on seed germination (Appendix VII). The highest seed germination (89.00%) was recorded from the seeds obtained from the plant spacing treatment S_3 (30 cm × 40 cm) followed by S_2 (30 cm × 30 cm) treatment whereas seeds obtained from S_1 (30 cm × 20 cm) plant spacing gave the lowest seed germination (85.33%) (Table 11).

Radish seeds obtained from the treatment combination of different planting method and plant spacing showed significant variation on seed germination (Appendix VII). Seeds obtained from M_1S_3 treatment combination showed highest seed germination (90.40%) which was statistically similar with the treatment combination of M_2S_3 (Table 12). Reversely, seeds obtained from the treatment combination of M_3S_1 showed the lowest seed germination (84.30%) which was statistically identical with the treatment combination of M_2S_1.

Table 10. Effect of planting methods on different seed quality parameters of radish

Treatments	Seed quality parameters			
	Germination percentage	Shoot length (cm)	Root length (cm)	Vigor index
M_1	88.43 a	8.86 a	7.21 a	1434.57 a
M_2	87.70 a	8.66 a	7.17 a	1381.81 b
M_3	85.87 b	8.02 b	6.55 b	1252.22 c
$LSD_{(0.05)}$	1.005	0.483	0.324	7.269
CV(%)	6.66	7.82	11.24	7.22

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

M_1 = Direct sowing of seed, M_2 = 1/3 cutting of root, M_3 = 2/3 cutting of root

4.4.2 Shoot length

Shoot length obtained from seeds of different planting method showed significant variation (Appendix VII). The highest shoot length (8.86 cm) was recorded from the planting method M_1 (Direct sowing of seed) that was statistically identical to the treatment M_2 (1/3 cutting of root) whereas the seeds of M_3 (2/3 cutting of root) treatment showed the lowest shoot length (8.02 cm) (Table 10).

Shoot length obtained from seeds of different treatments of plant spacing showed significant variation (Appendix VII). Seeds obtained from S_3 (30 cm × 40 cm) plant spacing gave the highest shoot length (10.15 cm) followed by S_2 (30 cm × 30 cm) treatment whereas seeds of S_1 (30 cm × 20 cm) plant spacing gave the lowest shoot length (7.30 cm) (Table 11).

Shoot length achieved from seeds of different treatment combinations of planting method and plant spacing showed significant variation (Appendix VII). Seeds obtained from the M_1S_3 treatment combination gave the highest shoot length (10.75 cm) that was statistically similar to the treatment combinations of M_2S_3 and M_3S_3 (Table 12). On the other hand, seeds obtained from the treatment combination of M_3S_1 gave the lowest shoot length (7.10 cm) which was statistically similar with the treatment combinations of M_1S_1, M_1S_2, M_2S_1, M_2S_2 and M_3S_2.

Table 11. Effect of different plant spacing on different seed quality parameters of radish

Treatments	Seed quality parameters			
	Germination percentage	Shoot length (cm)	Root length (cm)	Vigor index
S_1	85.33 c	7.30 c	6.29 b	1160.28 c
S_2	87.67 b	8.09 b	6.69 b	1296.57 b
S_3	89.00 a	10.15 a	7.95 a	1611.74 a
$LSD_{(0.05)}$	1.104	0.643	0.674	7.598
CV(%)	6.66	7.82	11.24	7.22

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

S_1 = 30 cm × 20 cm, S_2 = 30 cm × 30 cm, S_3 = 30 cm × 40 cm

4.4.2 Root length

Significant variation on root length was obtained from seeds of different planting method treatments (Appendix VII). The highest root length (8.86 cm) was recorded from the planting method M_1 (Direct sowing of seed) that was statistically identical to the treatment M_2 (1/3 cutting of root) whereas the seeds of M_3 (2/3 cutting of root) treatment showed the lowest root length (8.02 cm) (Table 10).

Different treatments of plant spacing showed significant variation on root length germinated seeds (Appendix VII). Seeds obtained from S_3 (30 cm × 40 cm) plant spacing gave the highest root length (7.95 cm) whereas seeds of S_1 (30 cm × 20 cm) plant spacing gave the lowest shoot length (6.29 cm) that was statistically identical to S_2 (30 cm × 30 cm) (Table 11).

Root length achieved from seeds of different treatment combinations of planting method and plant spacing showed significant variation (Appendix VII). Seeds obtained from the M_1S_3 treatment combination gave the highest root length (10.75 cm) that was statistically similar to the treatment combinations of M_2S_3 (Table 12). On the other hand, seeds obtained from the treatment combination of M_3S_1 gave the lowest root length (5.92 cm) which was statistically similar with the treatment combinations of M_3S_2.

4.4.4 Seed vigour index

The recorded data on seed vigour index was affected significantly by different planting method (Appendix VII). Results indicated that the highest seed vigour index (1434.57) was given by M_2 (1/3 cutting of root) planting method followed by M_2 (1/3 cutting of root) whereas the M_3 (2/3 cutting of root) planting method resulted the lowest seed vigour index (1252.22) (Table 10). Kim *et al*. (2020) found that direct seeding also showed better seed quality in terms of vigor index which was also supported by the findings of Liu *et al*. (2020).

Different plant spacing showed significant variation on seed vigour index (Appendix VII). The highest seed vigour index (1611.74) was recorded from the treatment S_3 (30 cm × 40 cm) followed by S_2 (30 cm × 30 cm) whereas S_1 (30 cm × 20 cm) plant spacing gave the lowest seed vigour index (1097.59) (Table 11).

Significant influence was observed on seed vigour index as influenced by combined effect of different planting method and plant spacing (Appendix VII). The M_1S_3 treatment combination registered the highest seed vigour index (1722.12) followed by M_2S_3 (Table 12). Reversely, the treatment combination of M_3S_1 showed the lowest seed vigour index (1097.59).

Table 12. Combined effect of planting methods with different plant spacing on different seed quality parameters of radish

Treatments	Seed quality parameters			
	Germination percentage	Shoot length (cm)	Root length (cm)	Vigor index
M_1S_1	86.30 d	7.44 c	6.52 de	1204.75 f
M_1S_2	88.60 bc	8.40 bc	7.14 c	1376.84 d
M_1S_3	90.40 a	10.75 a	8.30 a	1722.12 a
M_2S_1	85.40 e	7.36 c	6.44 de	1178.52 g
M_2S_2	88.20 bc	8.36 bc	6.80 cd	1337.11 e
M_2S_3	89.50 ab	10.27 a	7.94 ab	1629.80 b
M_3S_1	84.30 e	7.10 c	5.92 f	1097.59 h
M_3S_2	86.20 d	7.52 c	6.12 ef	1175.77 g
M_3S_3	87.10 cd	9.43 ab	7.60 b	1483.31 c
$LSD_{(0.05)}$	1.739	1.807	0.406	8.792
CV(%)	6.66	7.82	11.24	7.22

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

M_1 = Direct sowing of seed, M_2 = 1/3 cutting of root, M_3 = 2/3 cutting of root
S_1 = 30 cm × 20 cm, S_2 = 30 cm × 30 cm, S_3 = 30 cm × 40 cm

CHAPTER V

SUMMARY AND CONCLUSION

This experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from November 2021 to March 2022 to study the influence of planting methods and spacing on yield and quality of radish seed. The whole experiment was conducted in two different phases *viz.* growth and seed yield performance at field level and after that collected seeds from the experiment field was tested in Laboratory for seed quality. Two factor experiment was conducted; Factor A: 3 planting methods *viz.* M_1 = Direct sowing of seed, M_2 = 1/3 cutting of root and M_3 = 2/3 cutting of root and Factor B: 3 plant spacings *viz.*, S_1 = 30 cm × 20 cm, S_2 = 30 cm × 30 cm, S_3 = 30 cm × 40 cm. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The data on different crop characters, yield and seed quality attributes were recorded. Collected data were analyzed using a computer software MSTAT-C. The significance of difference among the treatments means was estimated by the least significant difference (LSD) at 5% level of probability.

Different planting methods showed significant variation for growth parameters; however, the highest number of leaves plant^{-1} (12.67), leaf length (25.23 cm) and leaf breadth (7.88 cm) were recorded from the planting method M_1 (Direct sowing of seed) whereas the lowest number of leaves plant^{-1} (10.07), leaf length (23.87 cm) and leaf breadth (5.21 cm) were recorded from the planting method M_3 (2/3 cutting of root).

Considering yield contributing parameters and yield parameters, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, dry weight plant^{-1}, seed yield plant^{-1} and seed yield ha^{-1} varied significantly among the planting methods. The highest number of pods plant^{-1} (75.33), pod length (4.92 cm), number of seeds pod^{-1}

(5.48), dry weight plant^{-1} (120.80 g), seed yield plant^{-1} (10.87 g) and seed yield ha^{-1} (1234.00 kg) were recorded from the planting method M_1 (Direct sowing of seed) were recorded from M_1 (Direct sowing of seed) whereas the treatment M_3 (2/3 cutting of root) showed the lowest number of pods plant^{-1} (43.00), pod length (3.89 cm), number of seeds pod^{-1} (4.01), dry weight plant^{-1} (94.22 g), seed yield plant^{-1} (8.46 g) and seed yield ha^{-1} (976.13 kg). In case of seed quality parameters, significant variation was found for the parameters among the planting methods; and the M_1 (Direct sowing of seed) treatment gave the maximum germination percentage (88.43%), shoot length (8.86 cm), root length (7.21 cm) and vigor index (1434.57) whereas M_3 (2/3 cutting of root) treatment gave the minimum germination percentage (85.87%), shoot length (8.02 cm), root length (6.55 cm) and vigor index (1252.22).

Different plant spacing of radish showed significant variation for growth parameters, the highest number of leaves plant^{-1} (12.93), leaf length (27.17 cm) and leaf breadth (7.70 cm) were recorded from the higher plant spacing S_3 (30 cm × 40 cm) whereas the lowest number of leaves plant^{-1} (9.80), leaf length (23.13 cm) and leaf breadth (5.48 cm) were recorded from the lower plant spacing S_1 (30 cm × 20 cm).

Considering yield contributing parameters and yield parameters, the number of pods plant^{-1}, pod length, number of seeds pod^{-1}, dry weight plant^{-1}, seed yield plant^{-1} and seed yield ha^{-1} influenced significantly among the plant spacings. The highest number of

pods plant^{-1} (61.84), pod length (5.56 cm), number of seeds pod^{-1} (5.65), dry weight plant^{-1} (115.40 g) and seed yield plant^{-1} (12.02 g) were recorded from the plant spacing S_3 (30 cm × 40 cm) but the highest seed yield ha^{-1} (1283.33 kg) was recorded from the plant spacing S_1 (30 cm × 20 cm) whereas the lowest number of pods plant^{-1} (52.96), pod length (3.36 cm), number of seeds pod^{-1} (4.13), dry weight plant^{-1} (102.30 g) and seed yield plant^{-1} (7.70 g) were recorded from the

plant spacing S_1 (30 cm × 20 cm) but the lowest seed yield ha^{-1} (976.13 kg) was recorded from S_3 (30 cm × 40 cm) spacing. In case of seed quality parameters, different plant spacing showed significant variation for the parameters; and the S_3 (30 cm × 40 cm) spacing gave the maximum germination percentage (89.00%), shoot length (10.15 cm), root length (7.95 cm) and vigor index (1611.74) whereas S_1 (30 cm × 20 cm) spacing gave the minimum germination percentage (85.33%), shoot length (7.30 cm), root length (6.29 cm) and vigor index (1160.28).

In terms of combined effect of planting methods and plant spacings, significant variation on number of leaves plant^{-1}, leaf length and leaf breadth was found. The highest number of leaves plant^{-1} (13.20), leaf length (28.15 cm) and leaf breadth (8.04 cm) were recorded from the treatment combination of M_1S_3 whereas the lowest number of leaves plant^{-1} (9.20), leaf length (20.88 cm) and leaf breadth (5.12 cm) were recorded from the treatment combination of M_3S_1. Considering yield contributing parameters and yield parameters, the pod length, number of pods plant^{-1}, number of seeds pod^{-1}, dry weight plant^{-1}, seed yield plant^{-1} and seed yield ha^{-1} influenced significantly among the treatment combinations. The highest number of pods plant^{-1} (82.13), pod length (6.24 cm), number of seeds pod^{-1} (6.31) dry weight plant^{-1} (153.70 g) and seed yield plant^{-1} (13.81 g) were recorded from the treatment combination of M_1S_3 but the highest seed yield ha^{-1} (1386.00 kg) was recorded from the treatment combination of M_3S_1 followed by M_2S_1. The lowest number of pods plant^{-1} (38.67), pod length (3.04 cm), number of seeds pod^{-1} (3.80), dry weight plant^{-1} (86.67 g) and seed yield plant^{-1} (7.01 g) were recorded from the treatment combination of M_3S_1 but the lowest seed yield ha^{-1} (841.90 kg) was recorded from M_3S_3. In case of seed quality parameters, different treatment combinations of planting method and plant spacing showed significant variation for the parameters; and the treatment combination of M_3S_1 gave the maximum germination percentage (90.40%), shoot length (10.75 cm), root length (8.30 cm) and vigor index (1722.12) whereas the treatment combination of M_3S_1 gave the

minimum germination percentage (84.30%), shoot length (7.10 cm), root length (5.92 cm) and vigor index (1097.59).

Conclusion

From the above results, it can be concluded that among the planting methods, M_1 (Direct sowing of seed) performed the best regarding growth, seed yield and seed quality compared to M_2 (1/3 cutting of root) and M_3 (2/3 cutting of root).

Considering plant spacing, S_1 (30 cm × 20 cm) performed the highest seed yield whereas the lowest seed was recorded from the plant spacing S_3 (30 cm × 40 cm) but the best quality seeds were performed by S_3 (30 cm × 40 cm) plant spacing and S_1 (30 cm × 20 cm) showed lower quality seeds.

The combination of M_1S_1 (Direct sowing of seed with 30 cm × 20 cm plant spacing) is very much promising for higher seed yield but the treatment combination of M_1S_3 (Direct sowing of seed with 30 cm × 40 cm plant spacing) gave better quality seeds of radish compared to other treatment combinations whereas M_3S_3 (2/3 cutting of root with 30 cm × 20 cm plant spacing) treatment combination showed lowest seed yield while the minimum quality seed was recorded from M_3S_1 (2/3 cutting of root with 30 cm × 20 cm plant spacing). So, M_1S_1 (Direct sowing of seed with 30 cm × 20 cm plant spacing) treatment combination was the best for higher seed production of radish while M_1S_3 (Direct sowing of seed with 30 cm × 40 cm plant spacing) treatment combination can be considered for higher quality seed production under the present study.

REFERENCES

Abdul-Baki, A.A. and Anderson, J.D. (1973). Vigour determination in soybean seed by multiple criteria. *Crop Sci*., **13**:630–633.

Albayrak, S., Camas, N. and Sevimay, C.S. (2004). The influence of row spacing in root and leaf yields components of forage Turnip. *Turkish J. Field Crops*., **9**(2): 72-77.

Ashraf, U., Abbas, R.N., Hussain, S., Mo, Z.W., Anjum, S.A., Khan, I. and Tang, X.R. (2016). Consequences of varied planting geometry and early post emergence herbicides for crop-weed interventions in rice under semi-arid climate. *Planta Daninha ViCosa-MG*., **34**:737-746.

Asil, M. H., Ardakani, M. D. and Rabiee, M. (2013). The effect of seed density and plant distance on the yield and growth components of radish (*Rhaphanus sativus* cv. Longipinatus) as second culture in paddy field. *J. Hort. Sci*., **27**(2):12.

BARI (Bangladesh Agricultural Research Institute). (2019). Production technology of radish, Krishi Projukti Hat Boi. p. 140.

Baumhardt, R.L., Schwartz, R.C., Marek, G.W. and Bell, J.M. (2018). Planting geometry effects on the growth and yield of dryland cotton. *Agric. Sci*., **9**: 99-116.

BBS (Bangladesh Bureau of Statistics). (2018). The Year Book of Agricultural Statistics of Bangladesh. Statistics and Informatics Division (SID) Ministry of Planning Government of the People's Republic of Bangladesh, Dhaka, pp. 123-124.

Bilekudari, M. K., Deshpande, V. K. and Shekhargouda, M. (2005). Effect of spacing and fertilizer levels on growth, seed yield and quality of radish. *Karnataka J. Agric. Sci*., **18**(2): 338-342.

Bilgili, U., Sincik, M., Uzun, A. and Acikgoz, E. (2003). The influence of row spacing and seeding rate on seed yield and yield components of forage Turnip. *J. Agron. Crop Sci*., **189** (4): 250-254.

Bose, T.K., Kabir, J., Das, P. and Joy, P. P. (2000). Naya Prokash, Calcuta. *Trop. Hort*., **1**: 145.

Champion, G.T., Froud-Williams, R.J. and Holland, J.M. (1998). Interactions between wheat (*Triticum aestivum* L.) cultivar, row spacing and density and the effect on weed suppression and crop yield. *Ann. Appl. Biol*., **133**: 443-453.

Chaudhary, R.S., Singh, R.K., Hati, K.M. and Biswas, A.K. (2015). Strategies for promoting water and nutrients use efficiencies. *JNKVV Res. J*., **49**:347-365.

Chen, X., Wang, Y. and Zhang, L. (2019). Comparative study of planting methods on radish (*Raphanus sativus* L.) seed production. *J. Crop Sci*., **12**(4): 137-142.

Desuki, M., Ara, N., Uddin, M. R., Islam, M. R. and Azam, M. G. (2005). Effect of sowing date and plant spacing on seed production of cauliflower. *Bangladesh J. Agril. Res*., **40**(3): 491-500.

Dev, H. (2010). Effect of root size on yield and quality of radish cv. White Icicle seed crop. *Asian J. Hort*., **5**(2): 281-283.

Detroja, A.M. and Davara, D.K. (2016). Effect of spacing and potassium fertilizer growth and yield of the radish (*Raphanus sativus* L.). *Adv. Lif. Sci*., **5**(12): 5162-5166.

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

FAO. (1988). Production Year Book. Food and Agricultural Organizations of the United Nations Rome, Italy. **42**: 190-193.

Gonge, V.S., Giri, J., Jogdande, N.D., Dalal, S.R. and Bharad, S.G. (2004). Performance of varieties and plant spacings on seed yield and quality of radish. *Agric. Sci. Digest*., **24**(3): 215-217.

Gomez, K.H. and Gomez, A.A. (1984). "Statistical Procedures for Agricultural Research". Inter Science Publication, Jhon wiley and Sono, New York. pp. 680.

Gonzalez, M.C., Espinosa, J.M., Sanchez-Guerrero, M.C. and Del, R.C.E. (2017). Evaluation of direct seeding and transplanting methods on yield and quality of radish. *Scientia Hort*., **218**:153-159.

Gupta, S., Sharma, P. and Singh, R. (2016). Impact of planting techniques on seed yield and quality of radish (*Raphanus sativus* L.). *J. Crop Improv*., **8**(6): 128-137.

Hong, S.T., Lim, J.M., Kim, S.B., Park, H.W., and Jung, J.S. (2016). Effects of planting density and method on seed yield and quality of radish (*Raphanus sativus* L.). *J. Korean Soc. Int. Agric*., **28**(4): 369-375.

Horbe, T.A., Amado, T.J. Reimche, G.B. Schwalbert, R.A. Santi, A.L. and Nienow, C. (2016). Optimization of withinrow plant spacing increases nutritional status and corn yield: a comparative study. *Agron. J*., **108**: 1962-1971.

Husnain, R.T., Amjad. M. and Ziaf, K. (2020). Planting geometry effects on seed yield and quality of two radish cultivars. *Pak. J. Agri. Sci*., **57**(3): 637-643.

Hussain, M., Mehmood, Z., Khan, M.B., Farooq, S., Lee, D.J. and Farooq, M. (2012). Narrow row spacing ensures higher productivity of low tillering wheat cultivars. *Int. J. Agric. Biol*., **14**: 413-418.

Islam, M.M., Rahman, M.H., and Hossain, M.M. (2019). Effects of planting methods on growth, yield, and quality of radish (*Raphanus sativus* L.). *Int. J. Plant Soil Sci*., **28**(5): 1-7.

Johnson, A., Smith, B. and Anderson, C. (2018). Effect of planting methods on seed production of radish (*Raphanus sativus* L.). *J. Plant Sci.*, **6**(3): 56-61.

Kang, E.S., Ha, S.M., Cheong, S.R. Seo, M.W. Kwack, Y.B. Choi, K.J. and Chae, W.B. (2015). Optimum double-row spacing in the autumn cultivation of radish (*Raphanus sativus* L.). *Korean J. Environ. Agric*., **34**:204-209.

Khaliq, G., Ali, A., and Hussain, M. (2017). Influence of sowing methods on yield and quality of radish (*Raphanus sativus* L.) roots under temperate conditions of Pakistan. *Sarhad J. Agric*., **33**(1): 12-18.

Khan, A., Jan, I. U., Ali, M., Jahangir, M. M., Karim, W.,Khan, A. A., Ullah, M. and Rafique, M. Z. (2016). Effect of different plant spacing on the performance of radish in the agroclimatic conditions of Swabi. *Pure Appl. Biol*., **5**(4): 1120-1125.

Kim, D.G., Son, K.C., Jeong, S.T., and Jeong, B.R. (2016). Effects of planting density and depth on growth, yield, and quality of radish in greenhouse conditions. *J. Korean Soc. Hort. Sci*., **34**(5): 584-590.

Kim, D.H., Oh, S.H., Kim, J.H., Shin, C.K., and Kim, H.S. (2020). Influence of planting methods on yield and quality of radish (*Raphanus sativus* L.) seeds in organic farming. *Korean J. Organic Agric*., **28**(3): 441-450.

Kim, J.W., Lee, K.S., Shin, H.S., Kim, H.T. and Park, S.H. (2021). Effects of sowing methods and harvest time on seed yield and quality of radish (*Raphanus sativus* L.) for mechanical harvesting. *Korean J. Hort. Sci. Technol*., **39**(1): 1-11.

Kim, S., Lee, J., Kim, H., and Park, S. (2015). Effect of planting methods on growth, yield, and seed quality of radish (*Raphanus sativus* L.) seeds. *Korean J. Hort. Sci. Technol*., **33**(3): 350-355.

Kumar, M.; Kumar, S.; Kumar, P.; Rathore, S.V.S; Singh, R.N. and Singh, S. K. (2012). Effect of steckling size and spacing on growth, yield and quality of radish seed C.V. Pusa Rashmi. *Prog. Agric*., **12**(1): 194 -198.

Kwon, Y.S. (2014). Effects of direct sowing and transplanting on the growth and seed yield of radish (*Raphanus sativus* L.). *Korean J. Hort. Sci. Technol*., **32**(4): 496-503.

Lavanya, A.V.N., Vani, V.S., Reddy, P. S. S. and Chaitanya, K. (2014). Root yield of radish as affected by sowing dates and spacing. *Plant Arch*., **14**(1): 615-618.

Lee, S.J. (2018). Comparison of root characteristics and seed yield in radish (*Raphanus sativus* L.) using different sowing methods. *J. Korean Soc. Hort. Sci*., **36**(1): 10-17.

Lee, S.W., Lee, J.H., Park, S.J., and Kim, H.J. (2017). Effects of planting methods on the yield and quality of radish (*Raphanus sativus* L.) seeds in a greenhouse. *J. Bio-Env. Control*., **26**(3): 279-284.

Lim, Y.P., Kang, J.H., Lee, H.S., Jung, K.M., Lee, J.S. and Kim, S.Y. (2018). Effect of planting depth and method on growth, yield, and seed quality of radish (*Raphanus sativus* L.). *Korean J. Crop Sci*., **63**(4): 319-326.

Liu, H., Wang, J. and Li, M. (2020). Effect of different planting methods on seed yield and quality of radish (*Raphanus sativus* L.) under field conditions. *J. Soil Plant Sci*., **12**(5): 78-84.

Maurya, A. N., Pathak, M. P. and Singh, K. P. (1990). A note on the effect of seed sowing dates and planting distances of stecklings on growth, yield and quality of radish seed cv. *Pusa Chetki. Acta Hort.*, **267**: 169-173.

Mwai, G.N., Ayele, S., and Ibrahim, A. (2018). Comparative effects of transplanting and direct seeding on growth, yield, and seed quality of radish (*Raphanus sativus* L.). *J. Agric. Rural Dev. Trop. Subtrop*., **119**(2): 139-147.

Naik, P.R., and Saha, R. (2017). Effect of different planting methods on the growth, yield, and quality of radish (*Raphanus sativus* L.). *Indian J. Hort*., **74**(1): 104-108.

Ogata, S. (2020). Effect of cutting ratios on growth and yield components of spring radish (*Raphanus sativus* L.). *Plant Prod. Sci*., **23**(2): 238-243.

Pandey, B.P., Basnet, K.B., Bhatta, M.R., Sah, S.K., Thapa, R.B. and Kandel, T.P. (2013). Effects of row spacing a direction of sowing on yield and yield attributing characters of wheat cultivated in Western Chitwan, *Nepal. Agric. Sci*., **4**:309-316.

Park, J.Y. (2016). Growth, yield, and quality of radish (*Raphanus sativus* L.) affected by different sowing methods and nitrogen fertilization. *Korean J. Agric. Sci*., **43**(4): 612-620.

Perez, J., Fernandez, M. and Gomez, F. (2017). Influence of planting methods on seed production of radish (*Raphanus sativus* L.) in a Mediterranean environment. *Scientia Hort*., **14**(3): 304-311.

Pervez, M. A., Ayub, C. M., Saleem, B. A., Virk, N. A. and Nasir, M. (2004). Effect of nitrogen levels and spacing on growth and yield of radish (Raphanus sativus L.). *Int. J. Agric. Biol*., **6**(3): 504-506.

Rahman , M. T., Hossain, A. K. M. A. and Rashid, M.A. (1990). Yield and quality of radish seed as affected by time of sowing and spacing. *Tropical Agric. Res*., **2**: 55-67.

Salehi, M., Jafari, M., and Rahmani, M.S. (2015). Effect of planting methods and planting date on yield and yield components of radish (*Raphanus sativus* L.) in a cold semi-arid region. *J. Agril. Sci. Technol*., **17**(4): 945-954.

Sanjari, G., Kafi, M. and Khazaei, H.R. (2014). Evaluation of sowing methods on the growth, yield, and quality of radish (*Raphanus sativus* L.). *Notulae Sci. Biol*., **6**(3): 330-334.

Singh, A.K., Bhatt, B.P., Sundaram, P.K., Gupta, A.K. and Singh, D. (2013). Planting geometry to optimize growth and productivity in faba bean (*Vicia faba* L.) and soil fertility. *J. Environ. Biol*., **34**:117-22.

Srivastava, B.K., Singh, M.P. and Jain, S.K. (1994). Effect of spacing and nitrogen levels on growth, yield and quality of seed crop of radish cv. Pusa Chetki. *Seed Res*., **20**(2): 85-87.

Sudhavani, V., Viji, C.P., Lavanya, A. and Syamsundar, R.P. (2015). Isothiocyanate levels in relation to population of Lipaphis erysimi (Kaltenbach) in radish as affected by sowing dates and spacing. *J. Crop Weed*., **11**(Special Issue):171-174.

Suh, J.K., Lee, C.H., Kim, H.J., Kim, J.K., Kim, J.S., and Park, K.W. (2014). Effect of planting density and method on yield and seed quality of radish (*Raphanus sativus* L.). *J. Agric. Life Sci*., **48**(2): 79-87.

Suthar, G.R., Saran, S., and Sharma, D.K. (2016). Influence of planting methods on growth, yield, and quality of radish (*Raphanus sativus* L.). *Int. J. Pure Appl. Bio-Sci*., **4**(5): 208-213.

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

Warade, A.D., Gonge, V.S., Kulwal, L.V. and Girl, J. (2004). Effect of time of planting and spacing on seed yield and quality of radish var. pusa chetki. *Agric. Sci. Digest*., **24** (1): 21 – 23.

APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

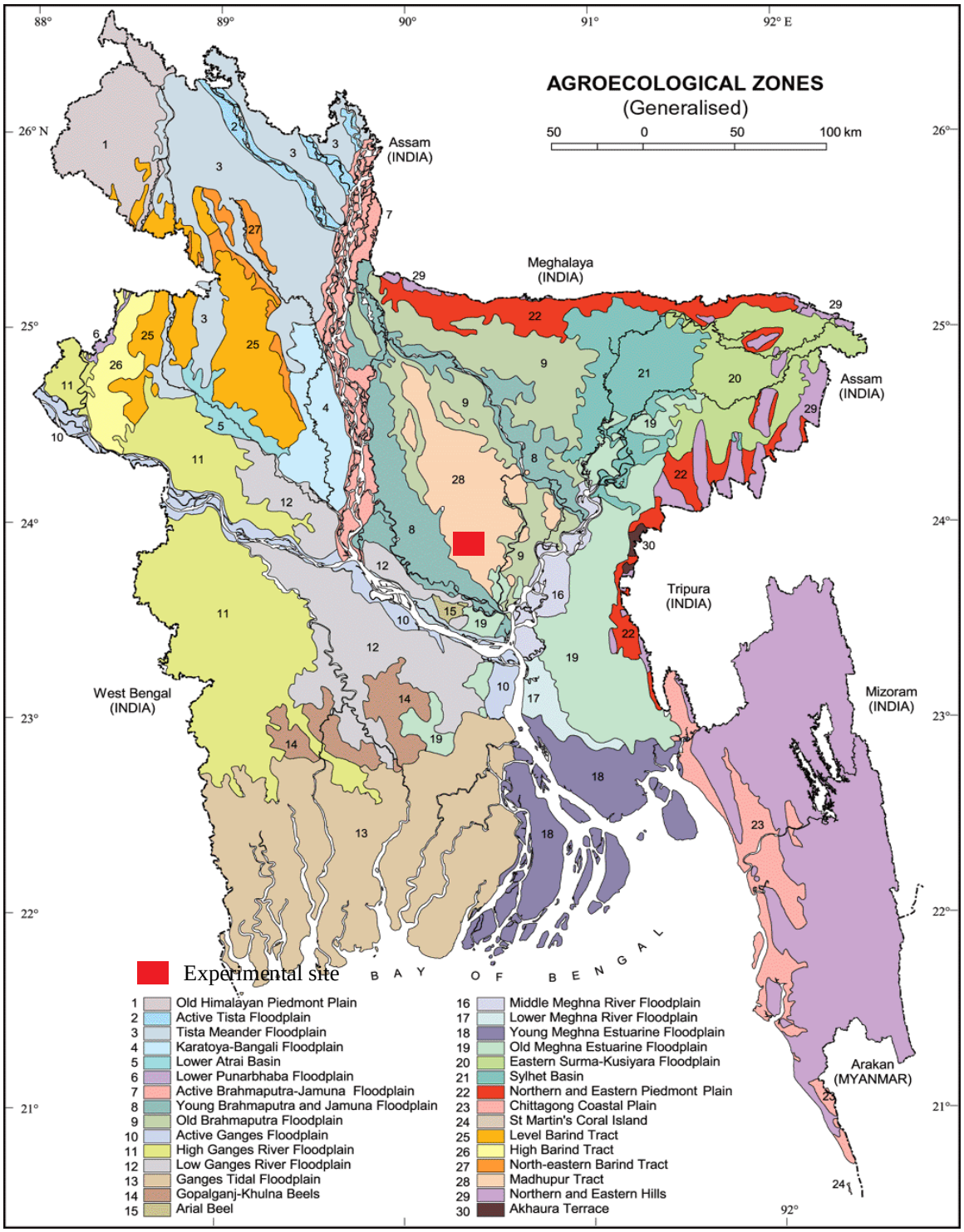


Fig. 2. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2021 to March 2022

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2021	November	28.60	8.52	18.56	56.75	14.40
2021	December	25.50	6.70	16.10	54.80	0.0
2018	January	23.80	11.70	17.75	46.20	0.0
2018	February	22.75	14.26	18.51	37.90	0.0
2018	March	35.20	21.00	28.10	52.44	20.4

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Analysis of variance for the effect of planting methods with different plant spacing on different growth parameters of radish

Sources of variation	Degrees of freedom	Mean square of growth parameters		
		Number of leaves plant^{-1}	Leaf length (cm)	Leaf breadth (cm)
Replication	2	3.111	2.773	0.180
Factor A	2	0.111**	0.460**	0.820**
Factor B	2	0.338**	0.104**	1.251**
AB	4	0.509**	3.273*	0.207**
Error	16	0.489	0.360	0.211

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

Appendix V. Analysis of variance for the effect of planting methods with different plant spacing on different yield contributing parameters of radish

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters			
		No. of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}	Dry weight plant^{-1} (g)
Replication	2	401.464	0.462	0.014	103.815
Factor A	2	317.335*	0.229**	0.471**	1750.48*
Factor B	2	100.593*	0.144**	2.937*	417.926*
AB	4	58.639*	0.087**	3.824*	1924.87*
Error	16	1.720	0.180	0.372	3.565

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

Appendix VI. Analysis of variance for the effect of planting methods with different plant spacing on different yield parameters of radish

Sources of variation	Degrees of freedom	Mean square of yield parameters	
		Seed yield plant^{-1} (g)	Seed yield ha^{-1} (kg)
Replication	2	0.609	16035.949
Factor A	2	10.863*	104468.865*
Factor B	2	49.129*	163843.577*
AB	4	3.388**	34902.769*
Error	16	0.441	14.758

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

Appendix VII. Analysis of variance for the effect of planting methods with different plant spacing on different seed quality parameters of radish

Sources of variation	Degrees of freedom	Mean square of seed quality parameters			
		Germination percentage	Shoot length (cm)	Root length (cm)	Vigor index
Replication	2	4.030	0.111	1.255	175.949
Factor A	2	15.73*	4.835*	0.863**	900.985*
Factor B	2	31.00*	14.02*	7.194*	4150.03*
AB	4	0.485**	1.399**	0.076**	140.281*
Error	16	1.009	1.090	0.055	57.803

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

Pictorial view of the experiment field

Plate 1. Sowing of seeds of radish in the experiment field

Plate 2. Overall field view of radish at vegetative stage

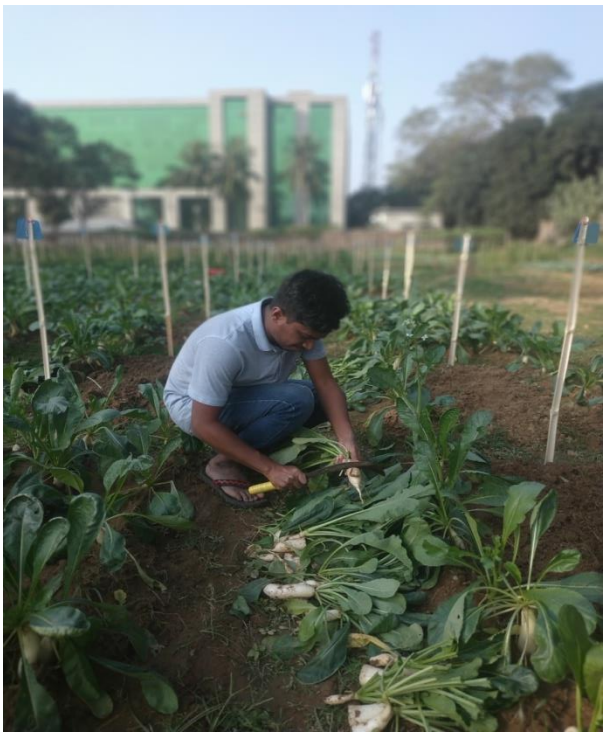


Plate 3. Root cutting of radish for experimental treatments

Plate 4. Preparation of roots after cutting before plantation

Plate 5. Flowering of radish

Plate 6. Data collection after harvest

Plate 7. Threshing of radish stover after harvest