SEED PRODUCTION IN BROCCOLI (*Brassica oleracea* var. *italica*) UNDER JAMMU SUB-TROPICS

BY

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Thesis submitted to Faculty of Post Graduate Studies
in partial fulfillment of the requirements
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Division of Vegetable Science and Floriculture
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Main Campus, Chatha, Jammu-180009
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CERTIFICATE-I

This is to certify that the thesis entitled **"Seed production in broccoli (*Brassica oleracea* var. *italica*) under Jammu Sub-tropics"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture Horticulture (Vegetable Science)** to the Faculty of Post-Graduate Studies, Sher-e Kashmir University of Agricultural Sciences and Technology of Jammu, is a record of bonafide research carried out by **Ms. Zahida Parveen (Registration No. J-18-M-588)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that all the help and assistance received during the course of investigation have been duly acknowledged.

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ABSTRACT

Title of the Thesis	:	**Seed Production in Broccoli (*Brassica oleracea* var. *italica*) under Jammu Sub-tropics.**
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The present investigation entitled "Seed production in broccoli (*Brassica oleracea* var. *italica*) under Jammu Sub-tropics" was conducted during the year 2019-20 with the objectives (i) To standardize suitable date of transplanting for maximum seed yield and (ii) To compare *in-situ* and *ex-situ* method of seed production. The experiment was carried out in Randomized Block Design (factorial), with two method of seed production namely *in-situ* (seed to seed) and *ex-situ* (head to seed) and three dates of transplanting viz. 30th September, 15th October and 30th October for getting information on suitable method of seed production and dates of transplanting in broccoli under Sub-tropical conditions of Jammu. Six treatment combinations were taken and replicated four times in 24 plots of size 3 x 3 m with spacing of 60 x 45 cm. The variety taken for study was Jammu Broccoli-07. The studies revealed that *in-situ* method of seed production significantly influenced days to 50% bolting (107.17), days to 50% flowering (130.92), plant height at maturity (85.39 cm), plant spread (51.79 cm), number of primary branches per plant (25.58), days to seed maturity (193.11), number of siliqua per plant (712.32), siliqua length (6.13cm), number of seeds per siliqua (12.71), seed yield per plant (27.59 g), seed yield per hectare (715.33kg), test weight (3.23g) and germination percentage (94.58%).

Amongst dates of transplanting, transplanting on 30th September proved significantly superior to all the characters except for days to 50% bolting, days to 50% flowering, and days to seed maturity which was significantly superior in 30th October transplanting because late sown crop was exposed to low temperature immediately irrespective of its vegetative growth and 15th October transplanting proved superior for number of siliqua per plant. In case of interactions, the treatment combination M_1D_1 (*in-situ* method and 30th September transplanting) significantly influenced plant height at maturity (95.63), plant spread (63.38 cm), number of primary branches per plant (29.35), siliqua length (6.27 cm), number of seeds per siliqua (14.54), seed yield per plant (31.83g), seed yield per hectare (825.0 kg) and germination percentage (97.95%), whereas M_1D_2 (*in-situ*) method and 15th October transplanting) had significant influence on number of siliqua per plant (851.60), whereas the treatment combination M_1D_3 (*in-situ* method and 30th October transplanting) had significant influence on days to 50% bolting (103.0), days to 50% flowering (127.50) and days to seed maturity (184.25). The interaction effect revealed non- significant effect on test weight.

Thus, it can be concluded that *in-situ* method of seed production proved to be significantly superior to the *ex-situ* transplanting method whereas amongst dates of transplanting, 30th September transplanting performed better with respect to most of the characters under study. Among the interaction effects, M_1D_1 i.e. *in-situ* method of seed production and 1st date of transplanting (30th September) performed better for seed production under Jammu Sub-tropics.

Key words: ***In-situ, ex-situ* method, transplanting dates and seed yield broccoli.**

Manoj Kumar

Signature of the Major Advisor

Signature of the Student

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ABBREVIATION

%	=	Percentage
@	=	at the rate of
°C	=	Degree centigrade
ANOVA	=	Analysis of variance
CD	=	Critical differences
cm	=	Centimeter
Cm^2	=	Centimeter square
CV	=	Coefficient of variation
df	=	Degree of freedom
Dr.	=	Doctor
eg.	=	for example
et al.	=	et alii (and others)
etc.	=	et cetera (and so forth)
FOA	=	Faculty of agriculture
Fig.	=	Figure
FYM	=	Farm yard manures
GA_3	=	Gibberellic acid
G	=	Gram
ha	=	Hectare
IAA	=	Indole acetic acid
i.e.	=	*id est* (that is)
IU	=	International unit
K_2O	=	Potassium oxide
kg	=	Kilograms
Km	=	Kilometers
L	=	Linnaeus
m	=	Meter
mg	=	Milligram
mm	=	Millimeter

ml	=	Milliliter
MSE	=	Mean error sum of squares
MSS	=	Mean sum of squares
N	=	Number of observation
No.	=	Number
P_2O_5	=	Phosphorus pentoxide
Ppm	=	Parts per million
q/ha	=	Quintal per hectare
Rpm	=	Rotation per minute
SE	=	Standard error
SE (d)	=	Standard error deviation
SE (m)	=	Standard error means
sec(s)	=	second(s)
SKUAST	=	Sher-e-Kashmir University of Agricultural Sciences & Technology
t/ha	=	Tonnes per hectare
UV	=	Ultra violet
Var.	=	Variety
viz.	=	Videlicet (namely)
w/v	=	Weight/volume
UT	=	Union Territory

Chapter-1

Introduction

CHAPTER-1

INTRODUCTION

Vegetables play a major role in daily human diet for maintaining of good health as they are most important source of macro and micro nutrients. Most of the Indian population is vegetarian and vegetables are the most important component of their diet. India is the second largest producer of vegetables in the world after China and accounts for about 15% of the total world's production. The vegetable production in India is approximately 184.40 million tonnes from 10.26 million hectare of land (Anonymous, 2018).

Of the various vegetable grown in India, broccoli is one of the rare vegetable grown on a small scale. Broccoli (*Brassica oleracea* var. *italica*) is an exotic cole crop grown all over the world belonging to family Brassicaceae. The word broccoli is derived from latin word 'Brachium' which means 'arm of branch'. It was introduced many years after cabbage and cauliflower in India and attained popularity in short span of time. Phenotypically it is closely related to cauliflower except secondary heads formation which develops in the axils of the leaves and contain up to 50% of the total yield. It is widely grown in many countries of the world because of its good organoleptic properties (Dhillon *et al*. 2005). Most commonly grown broccoli in india are "green sprouting broccoli" or "calabrese". It is one of the most nutritious cole crops known as the "Crown of Jewel Nutrition", it contains 2500 I.U. of vitamin A, 113 mg of vitamin C, 3.6 g of protein, 5.9 g of carbohydrates , 103 mg of calcium, 1.1 mg of iron, 78 mg of phosphorous, 382 mg of potassium and 15 mg of sodium per 100 g of edible portion (Rana, 2008). Besides being used as vegetable, the tender fresh leaves are served as salad and are extensively used in the preparation of pickles. Broccoli soup is a delicacy in big hotels and resorts and is being used as a fresh as well as frozen form (Salaria and Salaria, 2011).

Broccoli contains high levels of cancer fighting chemical "sulphoraphanes" which activate the human body to combat cancer naturally and increase resistance to cancer. It

protect the eyes from the damage caused by UV light that can lead to macular degeneration and also prevent high blood pressure, heart disease and stroke.The anti-cancer properties of broccoli are severely decreased if the vegetable is boiled. However, other preparation methods such as steaming, microwaving and frying had no significant effect on the compounds (Jaffery, 2005).

Methods of seed production and transplanting dates play key role to guarantee the desired crop performance and high economic returns to the farmers. The importance of quality seed is the main carrier of genetic potential of an improved variety. Good quality seeds of improved varieties can contribute about 25-40 percent increase in yield (Kanwar *et al.* 2010). *In-situ* (seed to seed method) and *ex-situ* (head to seed method) are two important methods for seed production. The *in-situ* method of seed production is followed for commercial seed production, whereas for nucleus or breeder seed production *ex-situ* method of seed production is followed (Singh *et al.* 1959). For quality seed production in cole crops it requires low temperature (Vernalization) for change of vegetative bud primodial to reproductive bud primodial (Verma and Sharma, 2000).

Proper planting time is the basic requirement for obtaining maximum yield and high returns from any crop. The planting dates have directly affecting yield and quality parameters in broccoli (Kunicki *et al.*1999). Broccoli yield decreases with delay in planting. Early planted crop resulted in longer duration and produced taller plants with more numbers of leaves, higher plant spread and more leaf size index (Gautam *et al.* 1998).

Broccoli is more sensitive when the plants are small and tender. At high temperature the bud cluster grow loose and vice-versa. The process of flowering in sprouting broccoli starts at low temperature but pollination and seed setting does not occur until the average daily temperature goes above 15°C (Ranjan *et al.* 2010). Despite of immense benefits, very little information are available regarding the planting time for commercial production of broccoli. Many experiments revealed that yield of cole crops is markedly influenced by sowing time and spacing (Saikia *et al.* 2010 and Das *et al.* 2000), however, no study was conducted with regard to broccoli seed production under Jammu Sub-tropical conditions.

In India, it is mostly cultivated in the hilly areas of Himachal Pradesh, Uttrakhand, Uttar Pradesh, Jammu and Kashmir, Nilgiri hills (Tamil Nadu) and Northern plains. The Union Territory of Jammu and Kashmir provides ample opportunity for successful cultivation of broccoli due to the mild climatic conditions. The optimal temperature for broccoli, is 16-18°C and is quite suitable for seed production (Lestrange *et al.* 1996). Higher and lower temperature negatively influence the performance of broccoli. The agro-climate of Jammu region is quite suitable for formation of compact heads and also favours floral stock emergence, development of bold and viable broccoli seeds. Seed retention of this high value nutraceutical vegetable by the growers can boost availiblity of good quality seeds at competitive prices. Over the last few years, there has been increased demand of this vegetable among the city dwellers of the UT of Jammu and Kashmir. A few enterprising farmers have already started cultivating broccoli which are fetching premium prices in local markets.

Knowing the fact that broccoli is gaining much popularity now a days in Jammu region but with respect to planting dates and suitable methodology has not been standardized for commercial seed production in broccoli under Sub-tropical zone of Jammu region.

Therefore, the present investigations were conducted with the following defined objectives:

1. To standardize suitable date of transplanting for maximum seed yield.
2. To compare *in-situ* and *ex-situ* method of seed production.

Chapter-2

Review of Literature

CHAPTER-2

REVIEW OF LITERATURE

In this chapter, an attempt has been made to review the important and relevant research work done by various researchers throughout the world, concerning the suitable date of transplanting and methods for maximum seed yield. Literature in the areas of such studies in cole crops has been reviewed and presented below in an objective-wise manner:

1. To standardize suitable date of transplanting for maximum seed yield.

Kumari *et al*. (2019) conducted an experiment to optimize suitable dates of sowing and plant spacing on seed quality of cauliflower. Four different dates of sowing viz. 25th July, 10th August, 26th August and 10th September and four plant spacing viz. 50 x 40 cm, 50x 50 cm, 60 x 50 cm and 60 x 60 cm were used. The results revealed that the significantly maximum germination %, seedling length, seedling dry weight and vigour index were recorded when seed were sown on 10th August and transplanted at spacing 60 x 60cm.

An experiment was performed by Latif *et al.* (2019) in semi-arid conditions of Pakistan to evaluate the effect of different planting dates viz., 15th September, 1st October, 1st November and 15th November on the growth and yield of broccoli. They reported that 1st October proved significantly better than other planting dates on various growth and yield parameters. Similarly, the effect of crop growth under different broccoli sowing dates was studied by Kanase *et al*. (2018). Eight sowing dates, viz. October 11th, October 18th , October 25th , November 1st , November 8th , November 15th , November 22nd and November 29th were taken. Treatment on 1st November were considered most effective in terms of yield, vegetative and reproductive growth among all treatments.

In the two successive winter seasons of 2003-2004 and 2004-2005, Abou El-Magd *et al*. (2017) conducted two field experiments to study the productivity and quality of certain broccoli cultivars in Eastern Egypt under different planting dates. Three

planting dates were used, namely 1st October, 15th October and 1st November. The results showed that by the combined effect of prominent cultivars in the 15th October plantation, the higher head weight and mean weight were obtained.

In an experiment to find out the effect of sowing date on the growth and yield of broccoli. Singh *et al*. (2017) observed that 4th November + Palam Samridhi had the best performance over all other treatments in relation to growth, yield, quality of broccoli under Allahabad's agro-climatic conditions.

An experiment was performed by Getachew *et al.* (2016) in Jimma South Western Ethiopia, to find the effect of various planting dates on growth performance of broccoli and seeds were sown in different dates viz., 23th February, 8th March, and 23th March at intervals of 15 days. Broccoli sowed on 23th February produced more and longer leaves and taller plant. The results showed that by planting broccoli on 23th of February, maximum growth was obtained.

Gogoi *et al.* (2016) conducted a field experiment to optimise suitable sowing time and plant spacing for the production of broccoli seeds. Four different sowing dates viz. 10th October, 30th October, 20th November and 10th December and two spacing viz. 45x 45 cm and 60x 45cm were taken and observed that highest seed yield was obtained with a spacing of 45x45 cm from 10th October sown seedlings. Similarly in cauliflower under the Terai zone of West Bengal, Islam *et al.* (2016) carried out a study to find out the most suitable time of planting of mid-late season varieties and to identify the best performing varieties with three different dates viz., 15th November, 30th November and 15th December and five varieties viz., Girija, White Excell, Remi, Pushpa and White Marvel were taken. The highest net curd weight (620.67 g) was produced by planting on 15th November where White Excel recorded highest net curd weight (820.22 g). The results of their experiment showed that first planting date (15th November) was most suitable for cultivation of the cauliflower varieties viz., Girija, White Excel, Remi, Pushpa and White Marvel except Remi.

A field experiment was carried out to study the effects of the planting date and growth hormone on cauliflower growth and yield by Rahman *et al.* (2016). Three

planting dates, 1st November, 15th November and 1st December, and four growth hormone levels, respectively. 10 ppm IAA, 70 ppm GA_3 and 10 ppm IAA +70 ppm GA_3 were administered without hormones. The result showed that with the other combinations, the combination of planting on 15th November and 10ppm IAA with 70ppm GA_3 was more productive.

In the two consecutive winter seasons of 2009/10 and 2011/12, Abed *et al.* (2015) performed two field trials at Baramon Experimental farm, Dakahlia Governorate to study the effect of planting date and spacing on yield and quality of cabbage. Three planting dates (1st November, 15th November and 1st December) and three planting spacing (50 cm, 60 cm and 70 cm) were used. They concluded that vegetative growth characteristics, i.e. plant weight, number and weight of outer leaves, increased average head weight and marketable yield, were significantly promoted by the earliest planting date (1st November) and wider spacing (70 cm within the rows).

Chaudhari *et al.* (2015) carried out a field experiment to determine the growth of knol khol as affected by different planting date and varieties during the year 2014-15 with three planting dates, viz., 1st November, 15th November and 1st December and observed that on the planting date of 15th November, the best results were recorded, which significantly increased plant height, plant spread and other growth related characteristics. Similarly in order to find out the impact of the planting date on the yield of broccoli genotypes, Hafiz *et al.* (2015) conducted an experiment on five genotypes viz., Early green, Forest green, Green calabrese, Premium crop and Green king and four planting dates viz., 2nd October, 27th October, 21st November and 16th December. Maximum head diameter (16.99 cm), head weight (314.49 g), yield per plant (453.64 g) and total yield (18.15 t/ha) were obtained at planting on 21th November.

Hossain *et al.* (2015) conducted a field experiment at BARI, Bangladesh to determine the optimum sowing date and spacing of plants for cauliflower seed production with four sowing dates viz., 20th September, 1st October, 10th October and 20th October and three plant spacing viz., 60 cm x 50 cm, 60 cm x60 cm and 60 cm x70 cm. The results showed that with 60cm x 50 cm plant spacing sowing on 1st October produced the

highest number of branches per plant, number of pods per plant and seed yield (414.81 kg/ha) due to highest number of seeds/ pod.

An experiment to determine the effect of planting dates on the growth and yield of the 'Palam Samridhi' broccoli variety was laid out by Thakur (2015). Two planting seasons (February-June and July-November) and three planting dates (21-25 March, 25-28 July and 20-25 August) were taken and concluded that July-November season was found better time for getting maximum green head yield of broccoli.

A trial was conducted by Gabhale *et al.* (2014) to study the effect of varieties and planting dates on cauliflower horticultural efficiency with three planting dates i.e. 15th September, 1st October and 15th November. They reported that for all the yield attributing characters, 15th September was the best transplanting date for the variety Early Kunwari. Similarly in cauliflower, an experiment was performed by Hossain *et al.* (2014) to study the effect of sowing date for increasing seed production of cauliflower with four sowing dates viz. 20th September, 1st October, 10th October and 20th October. The results showed that from sowing on 1st October, maximum number of branches per plant, numbers of pods per plant, number of seeds per pod and seed yield was obtained.

Field trial was carried out to determine the effect of transplanting date on yield and quality of broccoli hybrids under rain-fed mid hill condition of Ranichauri, Uttrakhand by Kumar *et al.* (2014). They suggested that 27th July had best affect on head yield characters among different transplanting dates.

At Vegetable Research Farm, SKUAST Jammu, Ranjit *et al.* (2014) conducted a field trial to obtained the appropriate method of seed production and transplanting dates in knol khol under the Jammu Sub-tropical plains. They concluded that early sowing, i.e. 1st October showed better performance for all the characters viz., plant height, plant frame, number of primary branches per plant, days to seed maturity, number of siliqua per plant , siliqua length, number of seeds per siliqua, seed yield per plant, seed yield per hectare and test weight among transplanting dates. Regarding the interaction effects, *in-situ* method and 1st October transplanting combination proved better than all other combinations.

In the period from October 2011 to March 2012, Shapla *et al.* (2014) conducted an experiment at the Horticulture Farm of Sher-e - Bangla Agricultural University, Bangladesh, to study the effect of broccoli growth and yield on different planting times with three planting times viz., 3rd November, 18th November and 3rd December. Maximum weight of primary curd/plant (427.8 g), diameter of primary curd (10.1 cm), weight of secondary curd (66.8 g), dry matter content of leaves (13.6 g), yield/plot (9.9 kg) and yield (10.6 t/ha) was found from 18th November. They concluded that planting was better for the production of broccoli in Bangladesh on November 18th.

Thirupal *et al.* (2014) carried out a field experiment to determine the effect of planting dates and plant spacing during the 2013-14 rabi season on broccoli growth , yield and quality in the Rayalaseema area of Andhra Pradesh. The results of their experiment showed that during planting on 10th December, maximum plant height, plant spread, number of leaves per plant and less number of days for flower bud initiation and high yield / ha were observed than on 20th January.

The influence of transplanting dates on seed yield and quality of broccoli (*Brassica oleracea* var. *italica*) was studied by Chandra and Shukla (2013). Five planting dates viz. 30th September, 10th October, 20th October, 30th October and 9th November were taken. They suggested that plants transplanted on 30th September recorded maximum days of maturity (228.80), plant height (82.30 cm), seed yield (565.33 kg / ha) and siliqua diameter (3.20 mm) compared to the other transplanting dates. Maximum number of primary branches per plant (22.12), siliqua per plant (1651.72) and length of siliqua (6.03 cm) observed on 10th October date of transplanting and on 30th September date of transplanting standard germination (91.00%),seedling length (11.59 cm) and 1000 seed weight (5.86 cm) was reported. Similarly, a field experiment was performed to evaluate broccoli cultivars under various planting dates, viz., 15th September, 1st October and 15th October. El-Magd (2013) observed that 1st October planting date, followed by 15th September, achieved the highest plant height, fresh weight, as well as the highest total head yield, yield and percentage increase.

An experiment was carried out to evaluate the effects of planting dates and broccoli varieties on their growth and yield reactions during the rainy season by

Nooprom and Santipracha (2013) with six planting dates i.e. July, August, September, October, November and December and four broccoli varieties viz., Top Green, Green Queen, Yok Kheo and Special .The experiment revealed that four varieties of broccoli had 70.31-99.22 percent high seedling survival rates when planted in July-December with the exception of 54.68 percent when planted in August.

Ullah *et al.* (2013) worked on cabbage with three planting times (7th November, 21st November and 5th December) and three different spacing (60x40cm, 60x 45cm and 60x50cm) and observed that spacing of 60cm x 50cm and 21st November planting time were found significant for growth and yield.

In Broccoli, the effect of planting time and spacing was studied by Dev (2012) under North India's lower hills. Four planting dates viz., 5th October, 15th October, 25th October and 5th November and three spacing were taken during the 2005-06 and 2006-07 seasons. The result showed that when broccoli transplanted on the first fortnight of October, the maximum gross yields were observed. Similarly, a field trial was done by Khatun *et al.* (2012) to study the effect of various transplanting dates on broccoli growth and yield, viz., 5th October, 25th October, 14th November and 4th December. Different transplanting dates showed significant impact on the yield and yield contributing characteristics of broccoli and suggested that the highest curd yield / ha was obtained from transplantation on 25th October.

An experiment was performed by Hossain *et al.* (2011) at BARI Bangladesh to determine the optimum sowing date on broccoli production with three sowing date viz., 1st October, 15th October and 30th October and observed that 1st October sowing produced the highest yield (21.39 t/ha).

A research was carried out by Sermenli *et al.* (2011) to determine the most effective transplanting dates for broccoli under the conditions of Antakya with four different dates, i.e. September 1st , 10th and 20th during the first year, September 10th , September 20th , October 1st and October 12th during the second year. They observed that the highest total yield was recorded from 10th September transplanting during first and second year and the days to transplanting were longer for 1st October. Their results

also indicated that the first two weeks of September was the most appropriate time for transplanting broccoli.

Solunke *et al.* (2011) studied the effect of planting dates and spacing on broccoli growth and yield. Three planting dates viz., 15th September, 30th September and 15th October and three spacing viz., 60x30 cm, 60x 45cm and 60x 60cm were taken and the result revealed substantial increase in yield over the other treatments. Maximum plant height, number of leaves, stem diameter and leaf area was recorded on the 1st planting date, i.e. 15th September at a spacing of 60x 60 cm.

According to Ara *et al.* (2009) all the vegetative growth parameters like plant height, number of leaves per plant ,whole plant weight, weight of marketable curd per plant and yield t/ha were influenced significantly by the date of planting except days to curd initiation, days to curd harvest and curd length. Curd yield delayed significantly as the planting in summer season. They also observed that the late planting exposed the plants to shorter duration to favourable climate for vegetative growth while the lower temperature helped to set on reproductive phase earlier in summer season. Similarly, an experiment was performed to study the effect of dates of planting and spacing on growth and yield of broccoli by Singhal *et al.* (2009), who observed that maximum curd yield (155.78 q/ ha) from 15th October planting followed by 14th November (139.33 q/ ha).

A field experiment was conducted in Mazandaran province, Iran with respect to three planting dates (5th September, 20th September and 5th October) to determine the best planting date for high yield in cauliflower cv. Snow Crown by Amoli *et al.* (2007). According to their results, highest yield (40t/ ha) was produced in treatment with planting date of 5th September.

An experiment was performed by Din *et al.* (2007) in Northern areas of Pakistan, to study the effect of sowing date on the growth and yield of cauliflower. Five sowing dates viz., 1st June, 16th June, 1st July, 16th July and 31st July were taken and their results showed that 16th June was the suitable sowing period for maximum fresh plant weight, head weight, number of marketable heads and head yield.

El-Yazied *et al.* (2007) investigated an experiment to study the effect of sowing dates and pinching on broccoli seed production with three sowing dates viz., 1st September, 1st October and 1st November and four pinching treatments i.e. pinching apical meristem, pinching mean head, pinching axillary buds and without pinching. They suggested that broccoli on 1st October and pinching on main head combination recorded the tallest plant and highest number of siliques/plant, number of seeds/plant and seed yield. Similarly an experiment was carried out to determine the effects of planting time and curd scooping on the seed development of cauliflower var. BARI Fulkapi-1 by Moniruzzaman *et al.* (2007). Four different dates viz., 15th October, 1st November, 15th November and 1st December and curd scooping at the stage of edible maturity and a control were used. The results indicated that planting on 15th October (earlier planting) in combination with curd scooping gave significantly maximum plant height, pods per plant, 1000 seed weight and seed yield per plant.

Selvakumar *et al.* (2007) evaluated the impact of different sowing dates and planting ratios on hybrid seed production of cauliflower sub var. cauliflora. With respect to fruit set percentage, seeds per siliqua and siliqua length, they found no significant difference between different sowings and planting ratios. Seed yield per plot, seed yield per plant, plant branches and siliqua per plant showed a considerable difference between sowing dates.

In a study to standardize the optimal date of transplantation and spacing to achieve the maximum seed yield and quality of cauliflower cv. Pusa Early Synthetic under the Terai zone of West Bengal. Chatterjee (2006) concluded that highest curd weight (384.17 g), curd diameter (22.38 cm) when transplanted on 15th September and performance was declined gradually in each successive delay of transplanting date among the four transplanting dates (1st September, 15th September, 1st October and 15th October) and four spacing (45x 45cm, 60x 45cm, 60x 60cm and 90 x 60cm). Among the treatment combinations, transplanting on 15th September and 60 x 45cm spacing produced the highest seed yield (5.81 q/ha).

An experiment was conducted by Hossain and Mian (2005) to analyze the effect of planting dates on the severity of cabbage Alternaria blight and seed yield with six

planting dates, viz., 1st and 16th October, 1st and 16th November and 1st and 16th December. The outcome revealed that the numbers of pods, pod length, number of seeds per pod and seed yield per plant were increased by early planting. In October and November, seed yield per hectare was higher and in October it was also less serious.

Ahmed and Siddique (2004) carried out an experiment to find the effect of sowing dates on growth and yield of Green Mountains broccoli variety at Rawalakot, Pakistan. In this experiment seeds were sown on different dates i.e. 20th April, 5th May, 20th May and 4th June. They observed that sowing on 5th May produced more leaves (18.48), more taller plant (30.79 cm), maximum secondary heads (16.0 g) and maximum yield (15.50 kg/ plot).

Jana and Mukhopadhyay (2002) investigated the effect of sowing dates and varieties on cauliflower seed yield and concluded that on 15th August, seed sowing produced maximum seed yield attributing characters and seed yield and sowing delay reduced the seed yield. When seeds were sown early, thousand seed weight and germination percentage of the produced seeds increased. Aghani recorded the highest seed yield among the varieties.

Thapa *et al.* (2002) studied the effect of the planting date and variety on early cauliflower seed production and concluded that transplantation on 20th August recorded the highest number of days for 50 % flowering. The number and height of inflorescence stalks, siliqua per plant, length of siliqua, seeds per siliqua, thousand seed weight, seed yield per plant and per hectare were highest in transplanted plants on 5th September. Delay in transplantation greatly decreased the siliqua length, number of seeds per siliqua and days to seed harvesting.

An experiment was performed by Gautum *et al.* (2001) to determine the effect of various sowing dates and methods of seed production on early cauliflower growth and seed yield. The results revealed that maximum seed yield (4.5q /ha) was observed on 15th July and the yield decreased significantly with delays in seeding regardless of the cultivars. Scooping curds in Pusa Deepali and Strong Silver Plate greatly increased the seed yield.

The head planting period for the development of cabbage seeds in the dry temperate zone of Himachal Pradesh was investigated by Kanwar and Singh (2001). Their studies revealed that different head planting dates have little effect on the number of flowering branches per plant and the length of the stem, but the delay from March to May results in early flowering. When the heads were replanted during March, the highest plant height and germination percentage were observed. When heads were replanted between 30th March to 12th April after meeting the chilling requirement, thousand seed weight and seed yield were maximum.

Singh *et al.* (2000) studied the effect of plant population and transplanting dates on seed yield of cabbage. They identified significant effect of transplanting dates on seed yield and yield contributing characters. Maximum plant height, number of branches, number of pods per plant and maximum seed yield were produced from early planting crop.

Gurusamy (1999) observed that early sowing increased head size and produced the highest seed yield in cauliflower.

An experiment was conducted by Singh *et al.* (1999) to study the impact of different dates of transplantation and steckling size on certain morphological characteristics and radish seed yield (*Raphanus sativus* L.). The results showed that for plants transplanted early i.e. 8th December, plant height, number of primary branches and pods, seed yield per plant, seed germination and total seed yield were the highest.

Shaker (1999) reported that planting dates (first week of November, December and January) and spacing (40cm, 50 cm and 60cm between plants) was effect on the production of seed in cabbage cv. Balday. The plant height, number of branches per plant, number of inflorescence per plant, inflorescence length, number of pods per inflorescence, pod length and seed yield were recorded. The growth of cabbage was greatly improved by early planting and broader spacing. However, early planting and narrow spacing recorded the highest seed yield per hectare.

Gautam *et al.* (1998) performed a study to determine the effect of sowing dates and varieties on the growth and yield of early cauliflower. Three transplanting dates viz.,

15th July, 30th July and 14th August were taken. The result showed that early planting resulted in longer duration and maximum plant height with more number of leaves, higher plant spread, more leaf size index and higher curd yield than the late sown crops.

Kanwar (1996) found that early planted plant received comparatively low temperature during vegetative growth which produced bigger sized head and ultimately produced higher number of branches.

Sharma *et al.* (1996) planted broccoli cv. Green Head on 16th and 31st August and 15th and 30th September and reported that planting on 15th September resulted in the greatest curd and seed yield of 98.72q/ha and17.94 g/ plant respectively.

In order to determine the impact of different planting dates on the seed production potential of five cauliflower varieties, Halim *et al.* (1995) performed a trial experiment. The seed yield was greatly affected by planting time. During planting on 10th October, maximum flower stalks per plant, pods per plant, seeds per pod and seed yield were obtained. The outcome showed that, relative to late sown varieties, early sown varieties produce the highest seed yield.

Patil *et al.* (1995) concluded that the plants grown in early winter produced large sized pod and increased number of seeds per pod because of proper growth and development of cauliflower plants.

Botnes (1990) observed that the influence of planting dates on yield was mainly related to the duration of the growing period when he transplanted 3 cultivars of Brussels sprout on 15th and 21st May and 1st June.

Chatterjee and Som (1990) conducted an experiment with cauliflower cv. KPS-1 from 15th January 1981 to 15th December 1982 and from 15th August 1983 to 15th January 1984. For plants sown in September followed by those sown in August, the average curd gross weight (1.59 kg), height (11.07 cm) and diameter (18.70 cm) were the largest. When seeds were sown in August, seed test weight (3.79 g) and seed yield (22.39 g / plant or 6.21 q/ ha) were highest. Seeds harvested from plants sown in August and January (87.5 percent) was the highest percentage of germination. Seeds harvested from

plants sown in August and January (87.5 percent) had the highest percentage of germination. The results showed that seeds should be sown for curd production from August to January and for seed production from August to October.

An experiment to find the impact of sowing dates and planting distances of stecklings on growth , yield and quality of radish seed cv. Pusa Chetki was laid out by Maurya *et al.* (1990). The maximum number of branches, number of pods and seed yield per plant was produced by early sown radish, i.e. 5th September.

Rashid *et al.* (1990) reported that mean curd weight, yield and number of days to harvest were maximum when cauliflower was transplanted on 1st October, while buttoning occurred in most cultivars when transplanted on 1st November and 1st December at Gazipur.

2. To compare *in-situ* and *ex-situ* method of seed production.

Bhushan *et al.* (2020) performed a field experiment at Regional Agricultural Research Station, Rajouri, SKUAST- Jammu to study the seed production of Knol khol in Jammu region. Two methods of seed production viz., *in-situ* and replanting were taken. Highest seed yield per plant and test weight were observed in *in-situ* method of seed production. The results showed that *in-situ* method of seed production was significantly superior to the replanting method.

A trial was carried out by Mehta *et al.* (2015) to evaluate the impact of head decapitation on plant growth, seed yield and broccoli cv. sprouting. Four methods of head decapitation, viz., D_1 (decapitation of primary head at appearance and harvesting seeds from secondary heads), D_2 (decapitation of primary head at marketable stage and harvesting seeds from secondary heads), D_3 (removal of secondary heads at appearance and harvesting seeds primary head) and D_4 (No decapitation- control) and five planting densities viz., S_1 (60x60cm), S_2 (60x45cm), S_3 (45x45cm), S_4 (60x30cm) and S_5 (45x30cm) were taken. The results showed that for commercial seed production of sprouting broccoli, decapitation of the primary head at appearance and harvesting of seeds from secondary heads (D_1) in combination with plant spacing of 45x45 cm, i.e. D_1S_3, may be recommended.

Ranjit *et al.* (2014) studied a field experiment to obtain the suitable seed production method and transplanting dates in knol khol under the sub-tropical plains of Jammu. They concluded that the *in-situ* seed production method was significantly influenced days to 50% bolting (121.17), days to 50% flowering (151.17), number of primary branches per plant (28.09), days to seed maturity(189.92), number of siliqua per plant (948.33), siliqua length (6.03), number of seeds per siliqua (13.75), test weight (1.77) and seed yield per plant (46.50)and superior to *ex-situ* method.

An experiment was performed by Pant *et al.* (2007) to evaluate the performance of cabbage raised from seeds harvested from various seed production methods: *in-situ* crop plus cut mark, *in-situ* plus (+) cut mark after removing 1/3 top portion of head, re-transplanting on the 30th and 60th days, and re- transplanting the matured head. In the various methods of seed production, significant differences in seed yield were reported. The maximum average seed yield was reported when the seed was produced with treatment in the *in-situ* condition after the plus (+) cut mark. However, when the 1/3 top portion of the head was removed and then given the plus cut mark, equally good seed yield was reported .The maximum average seed yield was recorded when the seed was produced in *in-situ* condition with treatment after giving the plus (+) cut mark. However, equally good seed yield was recorded in treatment when the 1/3 top portion of the head was removed and then given the plus cut mark.

Awan *et al.* (2005) investigated an experiment to compare head to seed method and stump method of cabbage seed production in two ecologically different localities of Azad Kashmir, Pakistan. The outcome showed that plant height and number of branches per plant attained in the method of head to seed were higher than those at both locations attained in the stump method. The average number of pods per plant showed the superiority of the head to seed method over the stump method at location -I, whereas the average number of pods per plant at Location- II showed non-significant differences between the treatments and revealed that the stump method of seed production could generate higher incomes for farmers, both in the vegetative phase selling heads and in the reproductive phase producing seeds.

Mohanty and Srivastava (2002) analyzed the effect on seed development of Pant Shubhra, mid-season cauliflower (*Brassica oleracea* var. *botrytis* sub var. cauliflora) of transplanting time (four transplanting dates) and methods (*in-situ* and *ex-situ*) of crop raising. They observed *ex-situ* transplanted plants took significantly more number of days to flower and the number of main branches per plant, inflorescence stalks per plant and siliqua length were the maximum for planting on 26th September. Although the *in-situ* technique showed a significant improvement in these characters over *ex-situ* production methods.

The effect of various curd-cutting techniques (scooping, curd pruning and half-curd removal) on the yield characters of five cauliflower cultivars was studied by Kumar *et al.* (2000). The result showed that all cutting treatments were effective in increasing seed yield, but the scooping method recorded the highest value of siliqua per primary branches (195.6), siliques per plant (1260), seeds per siliques (13.1) and seed yield (67.4 g / plant).

Malhotra (1996) investigated the effect of suitable planting method of seed production in cabbage. Three seed production methods of planting, viz., Head to seed method, *in-situ* method and stump method. In terms of plant height, number of branches per plant and number of pods per plant, the head to seed method resulted in superior results. Higher seed yields from head to seed method were observed, which were significantly superior to other methods.

The effect of *in-situ* and cabbage replanting with different head sizes on seed productivity and quality was examined by Verma *et al.* (1996). Two methods of seed production, viz. leaving the plants *in-situ* or replanting them, were compared using cabbage cv. Golden acre plants in which the heads designed for seed production were classified as small, medium or large. *In-situ* plants with large heads yielded per plant 54.76g of seeds. Seed quality was also higher for seeds from *in-situ* plants and generally improved with increasing head size.

Chapter-3

Materials and Methods

CHAPTER-3

MATERIALS AND METHODS

The present experiment entitled, "**Seed production in broccoli (*Brassica oleracea var. italica*) under Jammu sub-tropics"** to standardize suitable date of transplanting for maximum seed yield and to compare *in-situ* and *ex-situ* method of seed production. The trial was conducted at experimental farm of Division of Vegetable Science and Floriculture, FOA, Sher-e- Kashmir University of Agriculture Science and Technology, Chatha, Jammu during the rabi (winter) season of 2019-2020. The detailed information of the experimental site and location along with climate and weather recorded along with material used and methodology employed during the course of study are described in this chapter.

3.1 Experimental site and location

The experiment was conducted during winter season 2019-20 at the Experiment Farm, of Division of Vegetable Science, Sher-e- Kashmir University of Agriculture Science and Technology, Chatha, Jammu. The experimental site was located at 32°-40°N latitude and 74°-53°E longitude at a height of 300 meter sea level and at a distance of 15 km from the main city of Jammu. The maximum temperature rises up to 45°C or more during summers and minimum temperature falls at 1°C during winters. Agroclimatically, the location represents zone V of Jammu and Kashmir and is characterized by Sub-tropical climate.

3.2 Climate and weather conditions

The climate of Chatha is Sub-tropical with hot dry summers, hot and humid rainy season and mild to severe cold and frost during the winter. The maximum temperature rises up to 35.20°C during crop growing season (1st week of Septmeber) and minimum temperature occasionally falls to 4.77°C during winter. The mean rainfall during crop growing season is 18.12mm, most of which is received from south-west monsoon during October to 2nd fortnight of January. The data pertaining to weather conditions that

prevailed during the crop season was recorded at the meteorological observatory, located at experimental Farm, Chatha (Fig 3.1). During the crop period from 1st September 2019 to 30th April 2020, the mean maximum and minimum temperature showed a fluctuation throughout the crop growth period. The mean relative humidity varied from 95% (maximum) and 38.4 % (minimum).

3.3 Experimental material

The experimental materials for the present investigation are given below

1. **Crop** : Sprouting Broccoli (*Brassica oleracea* var. *italica*)
2. **Variety** : Jammu broccoli-07

3.3.1 Experimental layout

The experimental material i.e. Broccoli variety, Jammu broccoli-07 was grown in Factorial Randomized Block Design with 4 replications during winter season of 2019 at the experimental farm of the Division of Vegetable Science and Floriculture, SKUAST-Jammu. The details information of experiment are presented below :-

1. **Experimental Design** : Factorial Randomized Block Design
2. **Plot size** : 3m x 3m
3. **Spacing** : 60cm x45cm
4. **No of replication** : 4
5. **No. of treatments** : 6
6. **Total no. of plots** : 24
7. **No. of plants per treatment** : 30

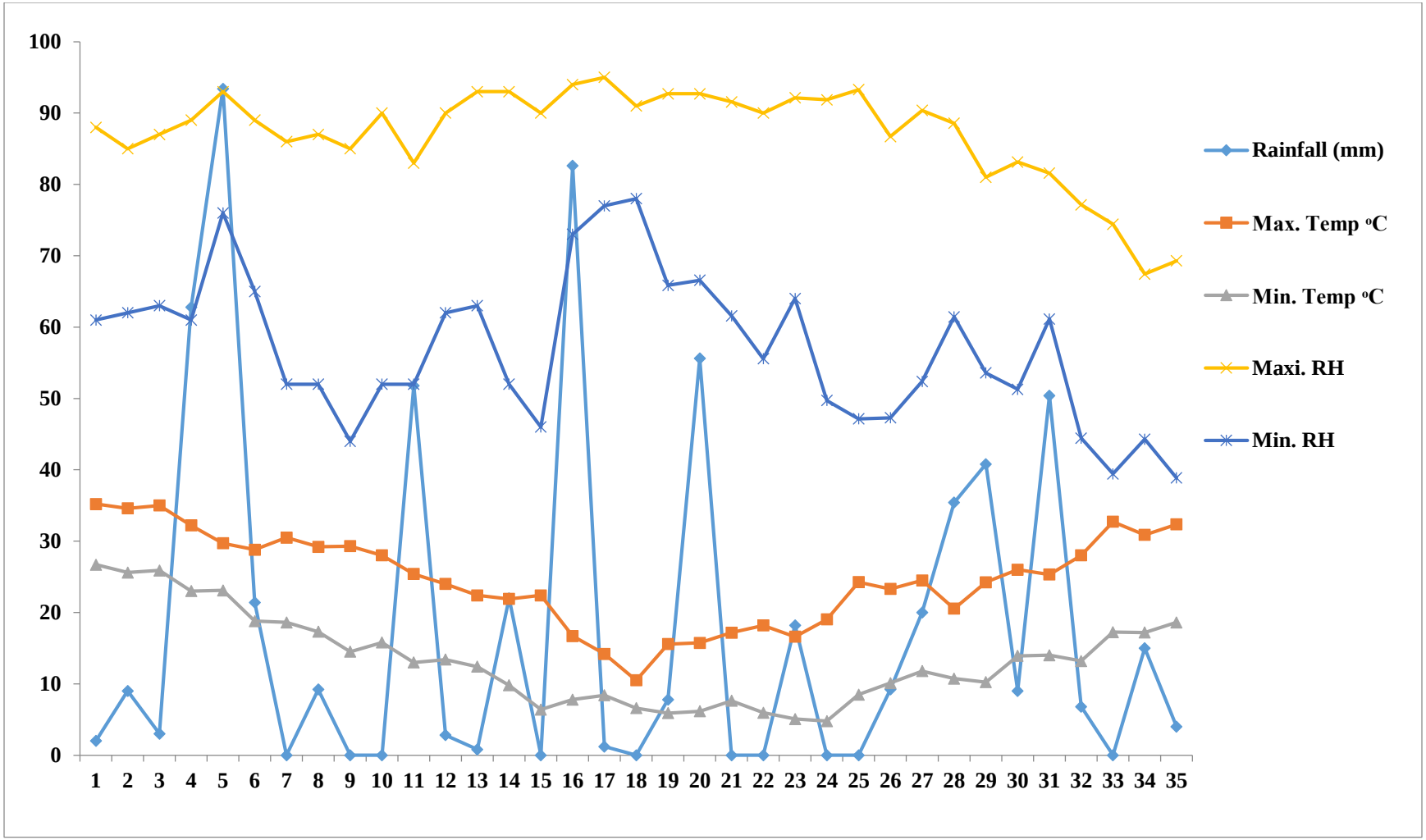


Fig. 3.1. Weekly metrological data during the period (1st September 2019 to 30th April 2020) of experiment

The various treatments used and their layout is as under:-

3.3.2 Methods of Seed Production

M_1 : *In-situ* method of seed production

M_2 : *Ex-situ* method of seed production

3.3.3 Dates of transplanting

D_1 : 30th September

D_2 : 15th October

D_3 : 30th October

3.3.4 Treatment combinations

M_1D_1 : *In-situ* method of seed production x 30th September transplanting

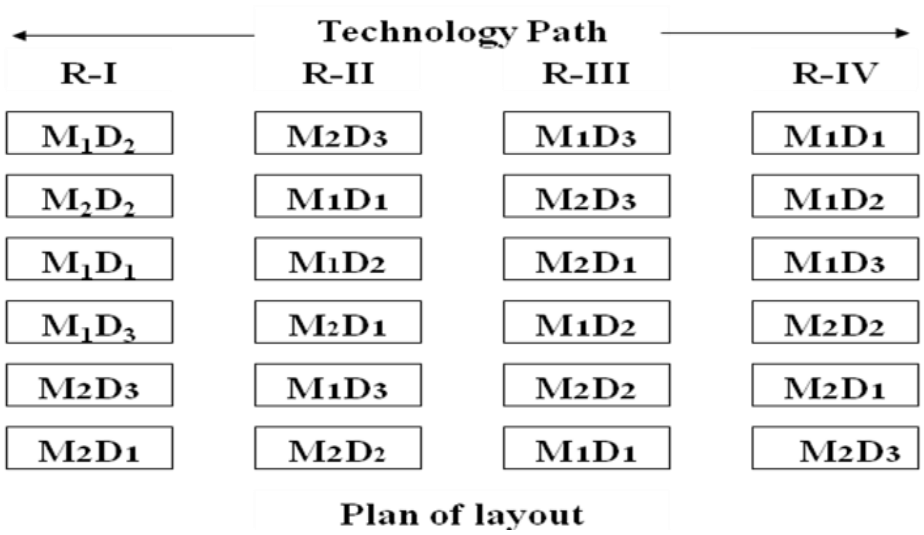
M_2D_1 : *Ex-situ* method of seed production x 30th September transplanting

M_1D_2 : *In-situ* method of seed production x I5th October transplanting

M_2D_2 : *Ex-situ* method of seed production x 15th October transplanting

M_1D_3 : *In-situ* method of seed production x 30th October transplanting

M_2D_3 : *Ex-situ* method of seed production x 30th October transplanting



3.4 Cultural practices

The necessary tillage operations were performed as per the requirements considering the recommendations for growing good crop.

3.4.1 Nursery sowing and transplanting

Seeds were sown on different dates at 15 days interval (1st September, 15th September and 30th September) in September 2019 and nursery beds was raised at the experimental farm of Division of Vegetable Science and Floriculture, SKUAST-Jammu. Healthy seedlings were transplanted in well prepared plot of 3 x 3m size and 60 x 45cm spacing on 30th September, 15th October and 30th October, 2019 (Fig.3.2).

3.4.2 Fertilizer application

Besides the application of farm yard manures (FYM) @ 25t/ ha, the chemical fertilizers (120kg N, 60kg P_2O_5, 60kg K_2O) were applied as per the recommendations in Packages and Practices of Vegetables, SKUAST-Jammu. FYM was mixed at the time of transplanting along with 1/3rd dose of N and full doses of P_2O_5 and K_2O. Remaining 2/3rd of N was top dressed in two equal amounts after 30 and 45 days of transplanting. Other intercultural operations were carried out in accordance with the recommended package of practices from time to time.

For seed crop additional dose of 50kg N, 50 kg P_2O_5 and 50Kg K_2O was given to the *in-situ* crop, whereas for *ex-situ* seed production, separate field was selected and after proper ploughing, pits of 1 feet diameter and 1feet depth were dug. Half the pit was filled with well rotten FYM and the N P K were applied in these pits. The plants were lifted with mud ball without disturbing the roots and were replanted in these pits (Fig.3.3).

3.5 Intercultural operations

3.5.1 Gap filling

The mortality of seedling in the field was observed (visible after third day of transplanting) and gap filling was done by the seedlings from the same nursery to maintain desired plant density.

Fig. 3.2. A view of experiment field (A), Nursery crop (B) and Layout planning (C) of Broccoli

Fig. 3.3. A view of transplanting techniques i.e. Digging of pit (A), plant with mud ball (B), and Replanting (C) of Broccoli plants

3.5.2 Irrigation

Irrigation was given by flooding the field as per requirement of the crop in order to maintain the soil moisture because broccoli requires continuous supply of moisture. At the time of irrigating the crop, care was taken to avoid the heavy irrigation.

3.5.3 Weeding and hoeing

The crop was kept weed free throughout its growth period to avoid weed competition. Weeding was done at time. Broccoli roots are surface feeders; hence care was taken at the time of weeding.

3.6 Pest control

Two sprays of Chlorophyriphos @ 0.04% viz., one on the day following transplanting and the other a week later were given to control cutworms, 3 sprays of imidacloprid @ 0.3 ml per litre water were given at an interval of 10 days during November to December and 3 sprays during February- March to check the attack of cabbage caterpillar and aphids. Two sprays of bavistin to the *ex-situ* seed crop were given, one immediately after transplanting and one after 15 days to control fungal infection.

3.7 Experimental observations

Data were recorded for both the crops (*in-situ* and *ex-situ*) for various parameters viz., days to 50% bolting, days to 50% flowering, plant height (cm), plant spread (cm), days to seed maturity, number of siliqua per plant, siliqua length (cm), number of seeds per siliqua, seed yield per plant (g), seed yield per ha (kg), test weight (g) and germination % age from ten plants per treatment and per replication. Data were recorded as below:

3.7.1 Days taken to 50% bolting

The number of days from the date of transplanting to the day when 50 % of plants showed bolting in each plot was worked out.

3.7.2 Days to 50% flowering

The number of days to 50% flowering was counted from the date of transplanting to when 50% plants in individual plot produced flowers (Fig. 3.4).

3.7.3 Plant height (cm) at maturity stage

The plant height was recorded at the time of maturity and was measured from the ground level to the axil of the last leaf on the main shoot.

3.7.4 Plant spread (cm)

Plant spread was measured in cm at the full bloom stage of the plant. The total spread of plant was measured by taking measurements in two directions with meter rod, and its average was taken.

3.7.5 Number of primary branches per plant

The total number of primary branches i.e. branches arising from the main shoot was counted from the selected plants of each and every replication at the time of maturity.

3.7.6 Days to seed maturity

The days to seed maturity were counted from the date of transplanting to the date of picking of mature siliqua.

3.7.7 Number of siliqua per plant

The total number of siliqua per plant was counted when they were ready for harvested (Fig. 3.4).

3.7.8 Siliqua length (cm)

The length of siliqua in centimeter was measured with the scale for 25 randomly selected siliqua per plant and then there average was taken.

Fig. 3.4. Broccoli at flowering (A) and siliqua (B) stage

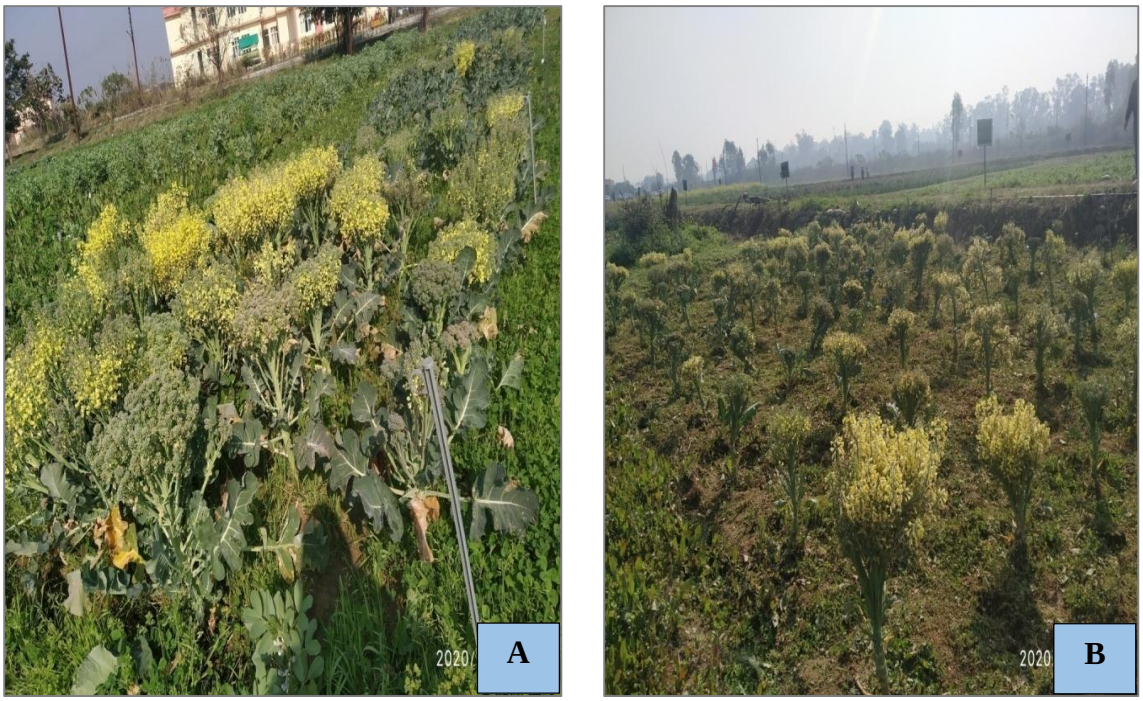


Fig. 3.5. Plants morphology at *in-situ* (A) and *ex-situ* (B) methods of seed production

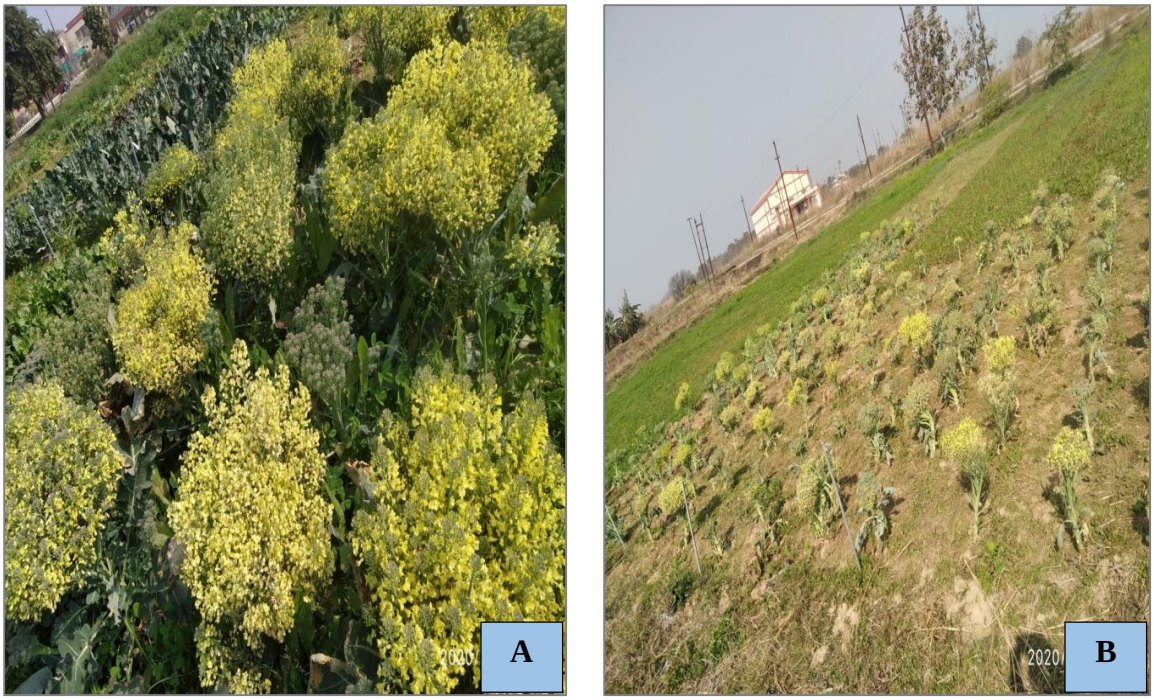


Fig. 3.6. Flowering stage at *in-situ* (A) and *ex-situ* (B) methods of seed production

Fig. 3.7. Siliua stage at *in-situ* (A) and *ex-situ* (B) methods of seed production

3.7.9 Number of seeds per siliqua

The number of seeds per siliqua was worked out by counting the seeds extracted from 25 randomly selected siliqua per plant and their average was calculated.

3.7.10 Seed yield per plant (g)

The seed yield per plant in grams (g) was recorded by weighing the seeds obtained from individual ten plants and then their average was calculated.

3.7.11 Seed yield per hectare (kg)

The seed yield per hectare in kilograms was calculated by recording the seed yield per plant and then converting it in to seed yield per hectare.

3.7.12 Test weight (g)

The test weight was calculated by weighing 1000 seeds of each sample with the help of electronic weighing machine.

3.7.13 Germination %

100 seeds from each sample per replication were kept in petridishes, kept in seed germinator at 24°C and germination count was taken after 7 days. The number of normal seedling for each seedling for each treatment in each replication were counted and later converted into seed germination percentage.

$$\textbf{Standard Germination percentage} = \frac{\text{Number of seeds germinated}}{\text{Total number of seed sown}} \times 100$$

3.8 Statistical analysis

The data recorded on various parameters of the present study after proper tabulation was put to statistical analysis as per the Factorial Randomized Block Design to draw the inferances of the study. The significance of treatment effects was tested through variance ratio and the significance of difference between any two means was judged with the critical difference (C.D) at 5% level of significance. Data for the parametes was put to statistical analysis by using OPSTAT software developed by Sheoran *et al.* (1998) of Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), Hissar.

Chapter-4

Experimental Results

CHAPTER-4

EXPERIMENTAL RESULTS

The results of the present investigation entitled "**Seed production in broccoli (*Brassica oleracea* var. *italica*) under Jammu sub-tropics**" conducted during 2019-2020 have been described in this chapter. The data on various characters was recorded and put to statistical analysis for proper interpretation of the results. The results of the study are presented as under following headings under following headings:

4. Analysis of variance for experimental design

The analysis of variance (Appendix II) showed significant differences for all the traits under study except for test weight in the interaction effects.

4.1 Days to 50% bolting

The influence of methods of seed production towards 50% bolting in broccoli grown at three different transplanting dates has been depicted in Table 4.1 and Fig 4.1(a).

4.1.1 Methods of Seed Production

In-situ method of seed production (M_1) took significantly less number of days (107.17) to 50% bolting and was statistically superior to the *ex-situ* method (115.75).

4.1.2 Dates of transplanting

Days to 50% bolting showed significant response towards the dates of transplanting. 30th October transplanting (D_3) took minimum number of days (104.62) to 50% bolting and was significantly earlier to 15th October and30th September date of transplanting, which took (110.87) and (118.87) days , respectively for the said trait.

4.1.3 Methods of seed production × Transplanting dates

The treatment combination M_1D_3 (*in-situ* method of seed production and 30th October transplanting) took minimum days (103) for 50% bolting which was statistically

at par with M_1D_2 (*in-situ* method of seed production and 15th October transplanting) and M_2D_3 (*ex-situ* method of seed production x 30th October transplanting) treatment combination. Treatment combination M_2D_1 (*ex-situ* method of seed production and 30th September transplanting) took the maximum number of days (124.75) to 50% bolting [Table 4.1 and Fig. 4.1(b)].

4.2 Days to 50% flowering

The results are presented in Table 4.2 and Fig 4.2(a) revealed that, the significant influences of methods of seed production, dates of transplanting and their interaction effect on days to 50 % flowering.

4.2.1 Methods of Seed Production

Minimum number of days (130.92) was recorded in *in-situ* method (M_1) of seed production which was earlier to flower then the *ex-situ* method (M_2) of seed production (142.17).

4.2.2 Dates of transplanting

The effect of dates of transplanting showed significant results on days to 50% flowering. Among three dates, 30th October (D_3) took lesser number of days (130.38) and was statistically superior to 30th September and 15th October transplanting dates, respectively.

4.2.3 Method of seed production × Transplanting dates

In-situ method of seed production and 30th October transplanting (M_1D_3) took least number of days (127.50) for 50% flowering which was found to be statistically at par with *in-situ* method of seed production and 15th October transplanting (M_1D_2). Maximum number of days (151.75) for 50% flowering observed in *ex-situ* method of seed production and 30th September (M_2D_2) transplanting [Table 4.2 and Fig 4.2(b)].

Table 4.1: Effect of methods of seed production and dates of transplanting on days to 50% bolting

	Days to 50% bolting			
	D_1	**D_2**	**D_3**	**Mean**
M_1	113.00	105.50	103.00	107.17
M_2	124.75	116.25	106.25	115.75
Mean	118.87	110.87	104.62	
	CD (5%)	**SE (d)**	**S.Em(±)**	**CV**
Methods (M)	2.92	1.36	0.96	2.98
Dates of transplanting (D)	3.58	1.66	1.17	
Interaction effect (M×D)	5.06	2.35	1.66	

Note:-

M_1: *In-situ* Method

M_2: *Ex-situ* Method

D_1: 30th September date of transplanting

D_2: 15th October date of transplanting

D_3: 30th October date of transplanting

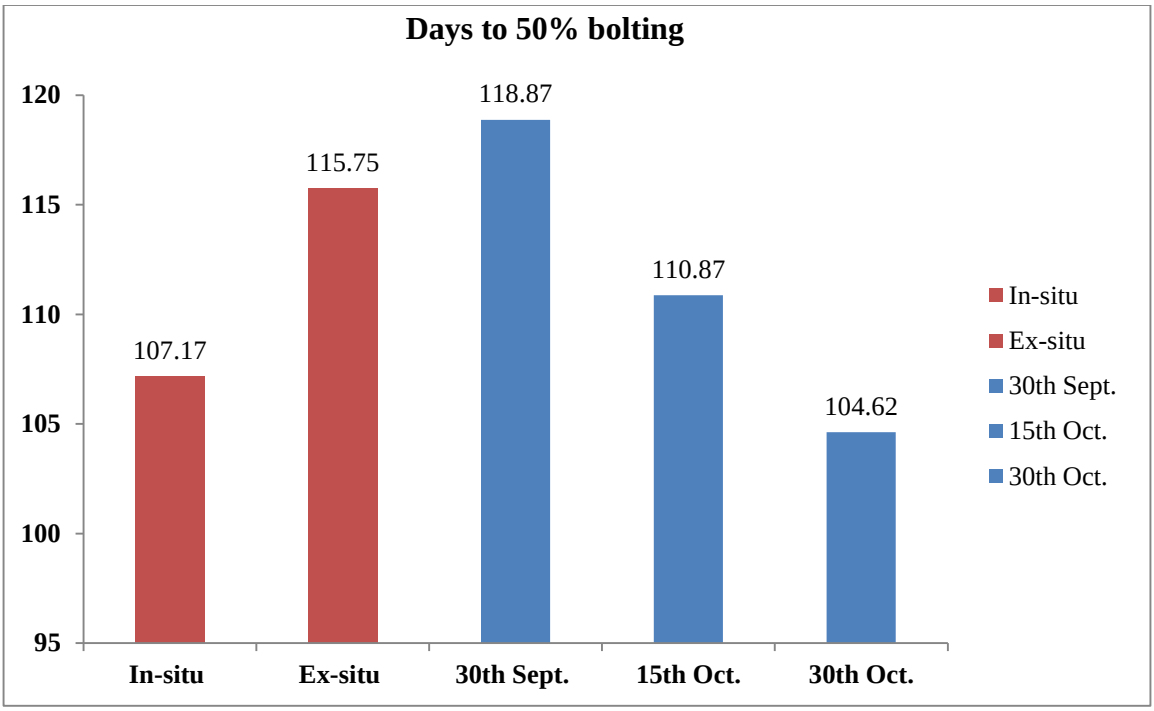


Fig. 4.1(a). Effect of seed production method and dates of transplanting on days to 50% bolting

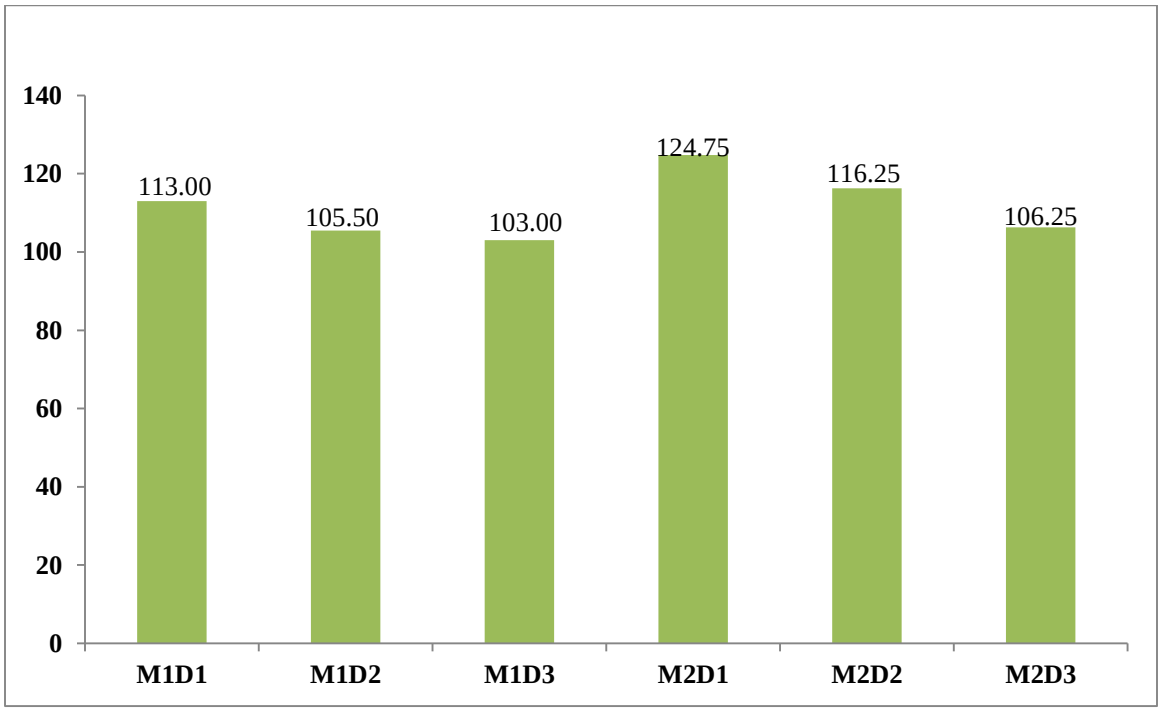


Fig. 4.1(b). Interaction effect of seed production method × dates of transplanting (M×D) on days to 50% bolting

Table 4.2: Effect of methods of seed production and dates of transplanting on days to 50 % flowering

	Days to 50% flowering			
	D_1	**D_2**	**D_3**	**Mean**
M_1	134.50	130.75	127.50	130.92
M_2	151.75	141.50	133.25	142.17
Mean	143.13	136.13	130.38	
	CD (5%)	**SE (d)**	**S.Em(±)**	**CV**
Methods (M)	2.54	1.18	0.84	2.12
Dates of transplanting (D)	3.11	1.45	1.02	
Interaction effects (M×D)	4.40	2.05	1.45	

Note:-

M_1: *In-situ* Method

M_2: *Ex-situ* Method

D_1: 30th September date of transplanting

D_2: 15th October date of transplanting

D_3: 30th October date of transplanting

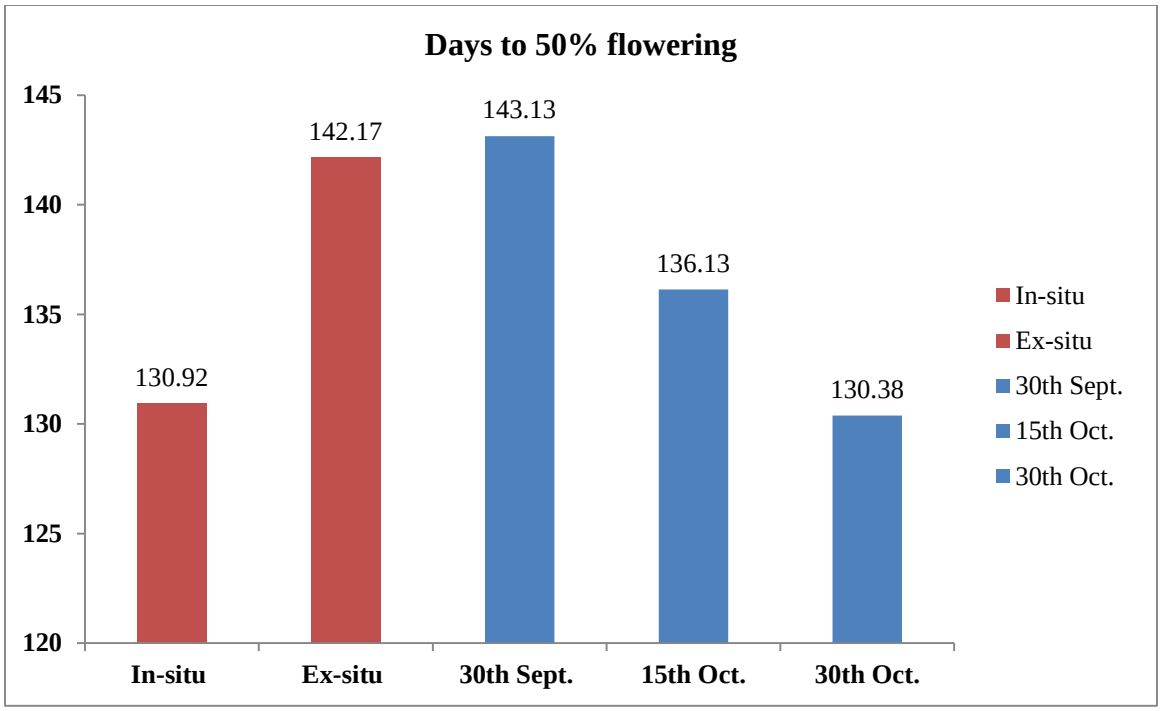


Fig. 4.2(a). Effect of methods of seed production and dates of transplanting on days to 50 % flowering

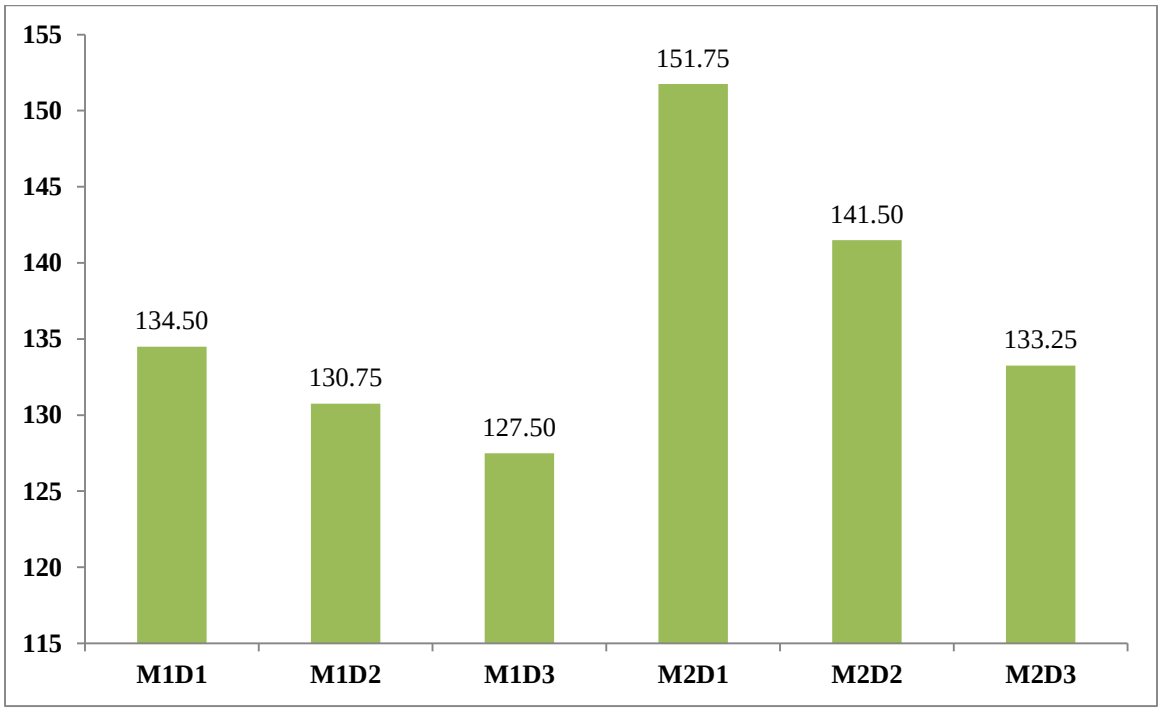


Fig. 4.2(b). Interaction effect of seed production method × dates of transplanting (M×D) on days to 50% flowering

4.3 Plant height (cm) at maturity stage

The results depicted significant differences for methods of seed production, dates of transplanting and their interaction effect on plant height at maturity stage is present in Table 4.3 and Fig 4.3(a).

4.3.1 Methods of Seed Production

Data with respect to plant height at maturity stage was influenced by seed production methods. Maximum plant height (85.39 cm) at maturity stage was recorded under *in-situ* method of seed production (M_1) which was significantly higher than the plant height at maturity observed in *ex-situ* method (M_2) of seed production (63.83).

4.3.2 Dates of transplanting

Significant effect of plant height at maturity stage towards the dates of transplanting was evident from Table 4.3. 30th September (D_1) transplanting recorded the maximum (82.23 cm) plant height at maturity which was statistically superior than the D_2 and D_3 treatments.

4.3.3 Method of seed production × Transplanting dates

Combined effect of methods of seed production and dates of transplanting also observed significant differences on the plant height. Highest plant height (95.63 cm) at maturity stage was obtained in *in-situ* method of seed production and 30th September transplanting dates (M_1D_1) which were statistically superior to all other treatment combinations [Table 4.3 and Fig 4.3(b)]. The lowest (59.93 cm) plant height at maturity stage was recorded with treatment combination of M_2D_3 (*ex-situ* method of seed production and 30th October transplanting) and found statistically at par with (M_2D_2) *ex-situ* method of seed production and 15th October transplanting dates.

4.4 Plant Spread (cm)

Significant differences were observed for the plant spread in methods of seed production, dates of transplanting and their interaction effects are presented in Table 4.4 and Fig 4.4(a).

4.4.1 Methods of Seed Production

Data depicted that *in-situ* method of seed production (D_1) gave larger plant spread (51.79 cm), which was significantly superior to the one obtained in *ex-situ* method of seed production (35.29 cm).

4.4.2 Dates of transplanting

Maximum plant spread (55.97cm) was observed in 30th September (M_1) transplanting which was statistically superior to the 15th October and 30th October transplanted crop respectively.

4.4.3 Method of seed production × Transplanting dates

Method of seed production and dates of transplanting interaction revealed that larger plant spread (63.38cm) was observed with *in-situ* method of seed production and 30th September transplanting (M_1D_1), which was statistically superior to rest of the treatment combinations as presented in Table 4.4 and Fig 4.4(b). Minimum plant spread (23.67 cm) was obtained with treatment combination *ex-situ* method of seed production and 15th October transplanting (M_2D_2)

4.5 Number of primary branches per plant

For number of primary branches per plant shown in Table 4.5 and Fig 4.5(a), the data influenced significant differences for methods of seed production, dates of transplanting and method of seed production x dates of transplanting interaction effect.

4.5.1 Methods of Seed Production

Highest number of primary branches per plant (25.58) was recorded in *in-situ* (D_1) method of seed production as compared to *ex-situ* (D_2) method of seed production (21.44).

4.5.2 Dates of transplanting

Among dates of transplanting, 30th September transplanting observed the highest number of primary branches per plant (27.07) than the 15th October (23.44) and 30th October (20.03) transplanting dates.

Table 4.3: Effect of methods of seed production and dates of transplanting on plant height at maturity stage

	Plant height (cm)			
	D_1	**D_2**	**D_3**	**Mean**
M_1	95.63	84.10	76.45	85.39
M_2	68.83	62.73	59.93	63.83
Mean	82.23	73.41	68.19	
	CD (5%)	**SE (d)**	**S.Em (±)**	**CV**
Methods (M)	3.09	1.44	1.02	4.71
Dates of transplanting (D)	3.78	1.76	1.24	
Interaction effects (M×D)	5.35	2.49	1.76	

Note:-

M_1: *In-situ* Method

M_2: *Ex-situ* Method

D_1: 30th September date of transplanting

D_2: 15th October date of transplanting

D_3: 30th October date of transplanting

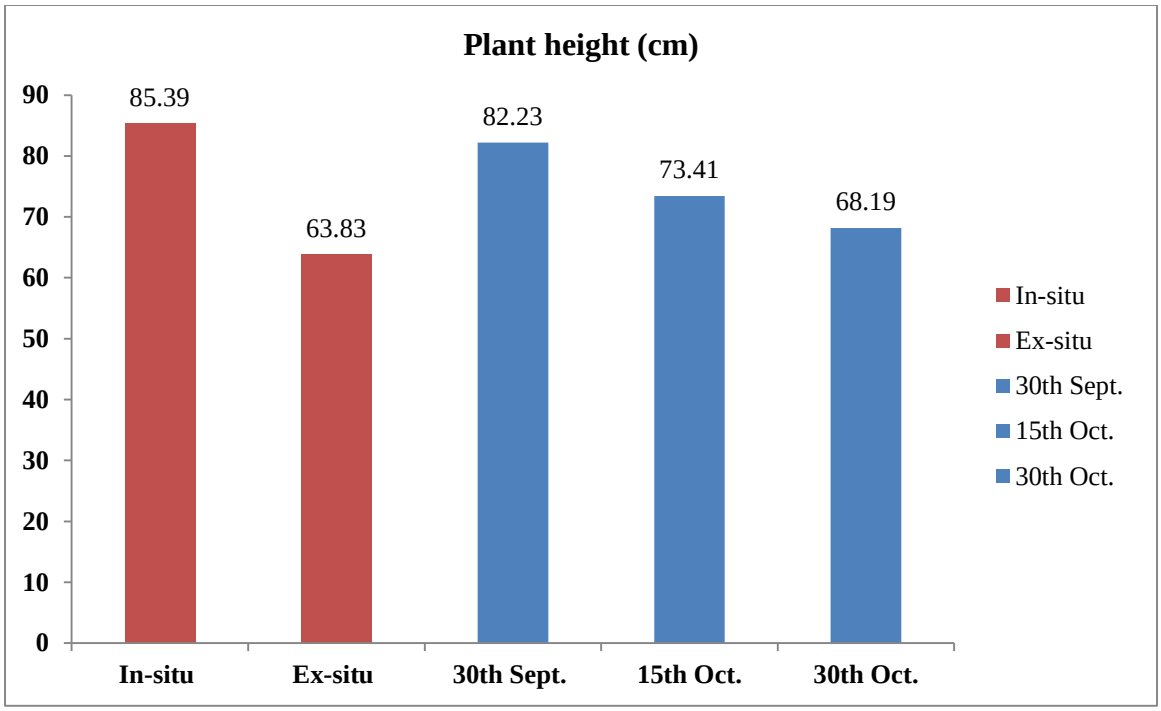


Fig 4.3(a). Effect of methods of seed production and dates of transplanting on plant height (cm) at maturity stage

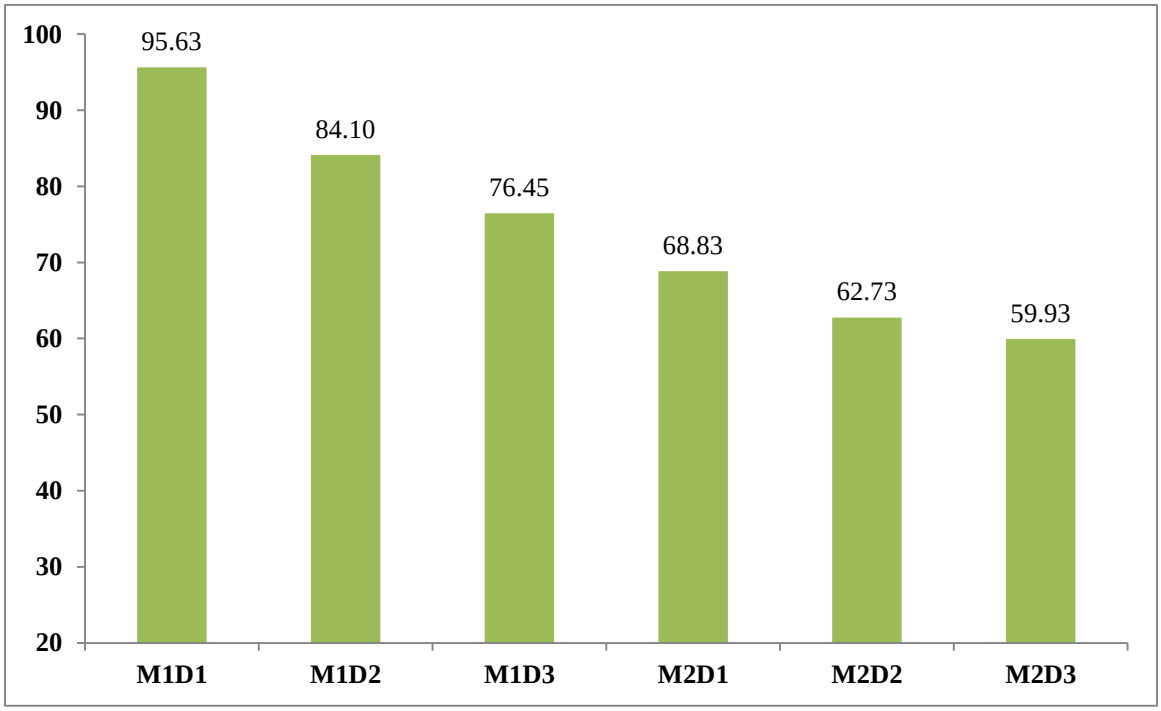


Fig. 4.3(b). Interaction effect of seed production method × dates of transplanting (M×D) on plant height (cm) at maturity stage

Table 4.4: Effect of methods of seed production and dates of transplanting on plant spread

	Plant spread (cm)			
	D_1	**D_2**	**D_3**	**Mean**
M_1	63.38	53.66	38.33	51.79
M_2	48.56	33.65	23.67	35.29
Mean	55.97	43.65	31.00	
	CD (5%)	**SE (d)**	**S.Em (±)**	**CV**
Methods (M)	0.22	0.10	0.07	0.57
Dates of transplanting (D)	0.27	0.12	0.08	
Interaction effects (M×D)	0.38	0.17	0.12	

Note:-

M_1: *In-situ* Method

M_2: *Ex-situ* Method

D_1: 30th September date of transplanting

D_2: 15th October date of transplanting

D_3: 30th October date of transplanting

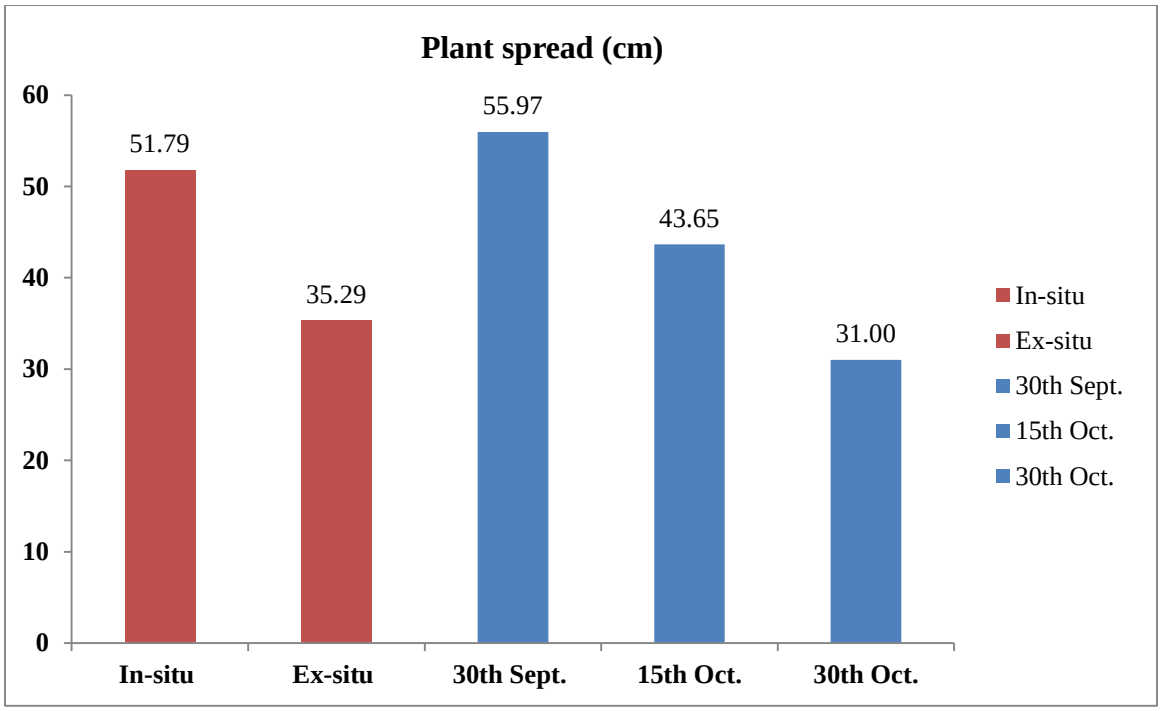


Fig. 4.4. Effect of methods of seed production and dates of transplanting on plant spread (cm)

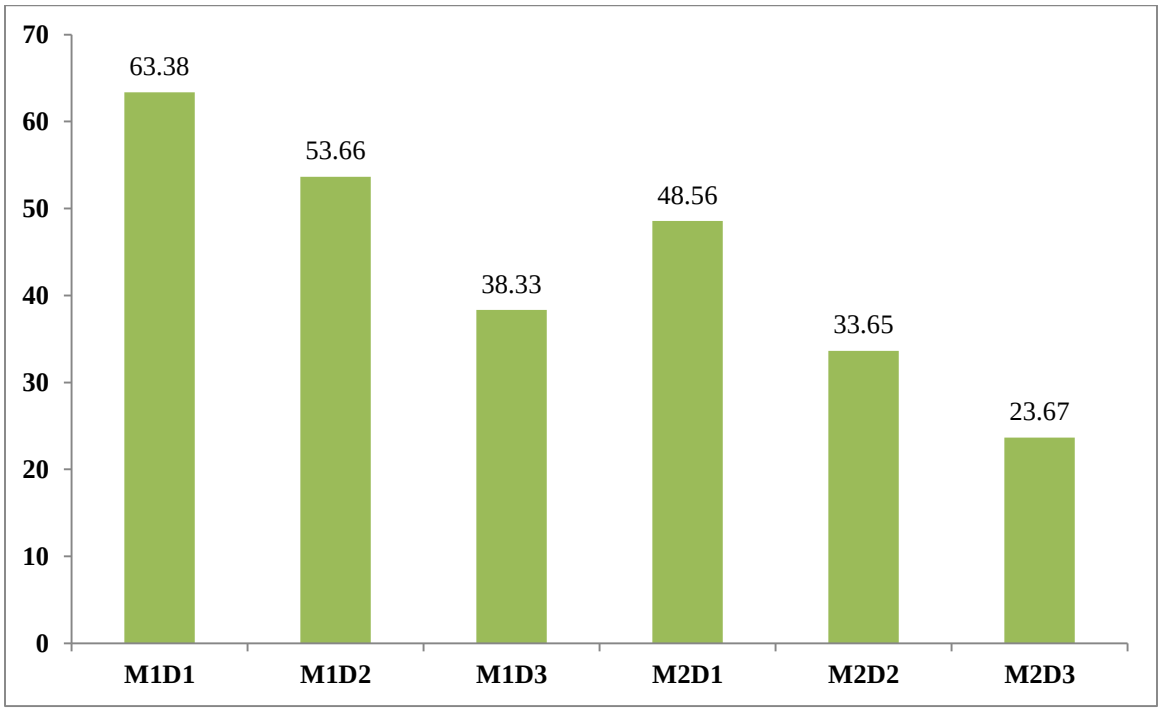


Fig. 4.4(b). Interaction effect of seed production method × dates of transplanting (M×D) on plant spread (cm)

Table 4.5: Effect of methods of seed production and dates of transplanting on number of primary branches per plant

	Number of primary branches per plant			
	D_1	**D_2**	**D_3**	**Mean**
M_1	29.35	26.17	21.22	25.58
M_2	24.80	20.70	18.83	21.44
Mean	27.07	23.44	20.03	
	CD (5%)	**SE (d)**	**S.Em (±)**	**CV**
Methods (M)	0.93	0.43	0.31	4.51
Dates of transplanting (D)	1.14	0.53	0.37	
Interaction effects (M×D)	1.61	0.75	0.53	

Note:-

M_1: *In-situ* Method

M_2: *Ex-situ* Method

D_1: 30th September date of transplanting

D_2: 15th October date of transplanting

D_3: 30th October date of transplanting

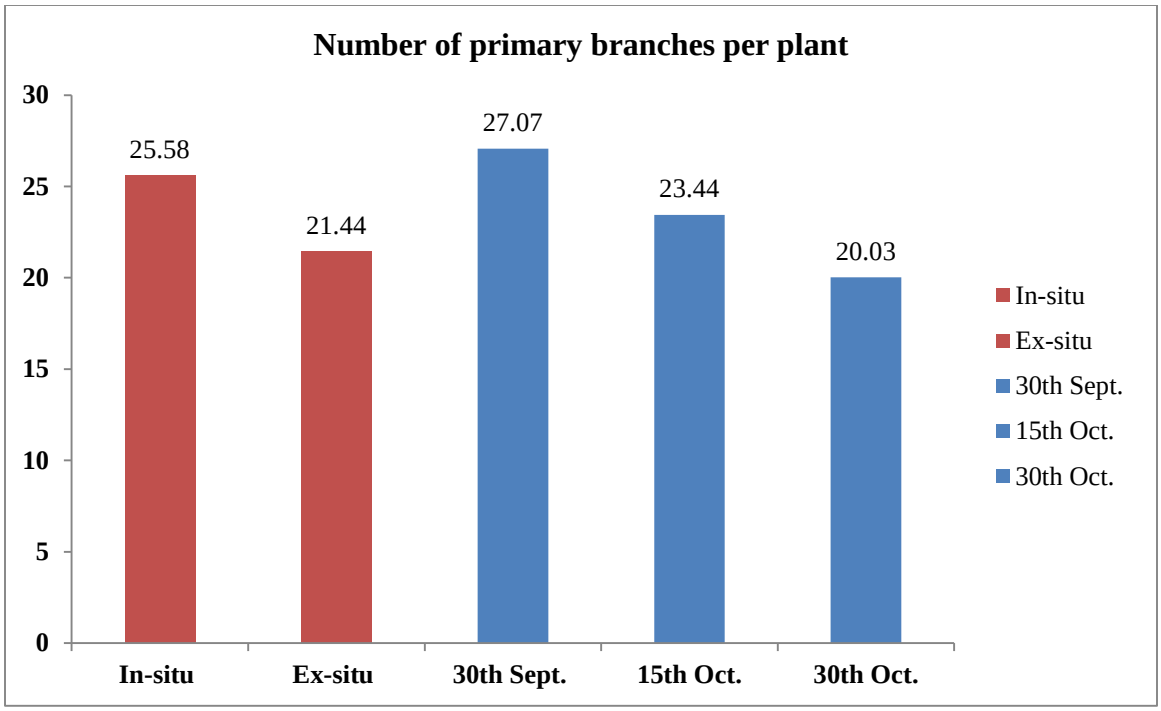


Fig. 4.5(a). Effect of methods of seed production and dates of transplanting on number of primary branches per plant

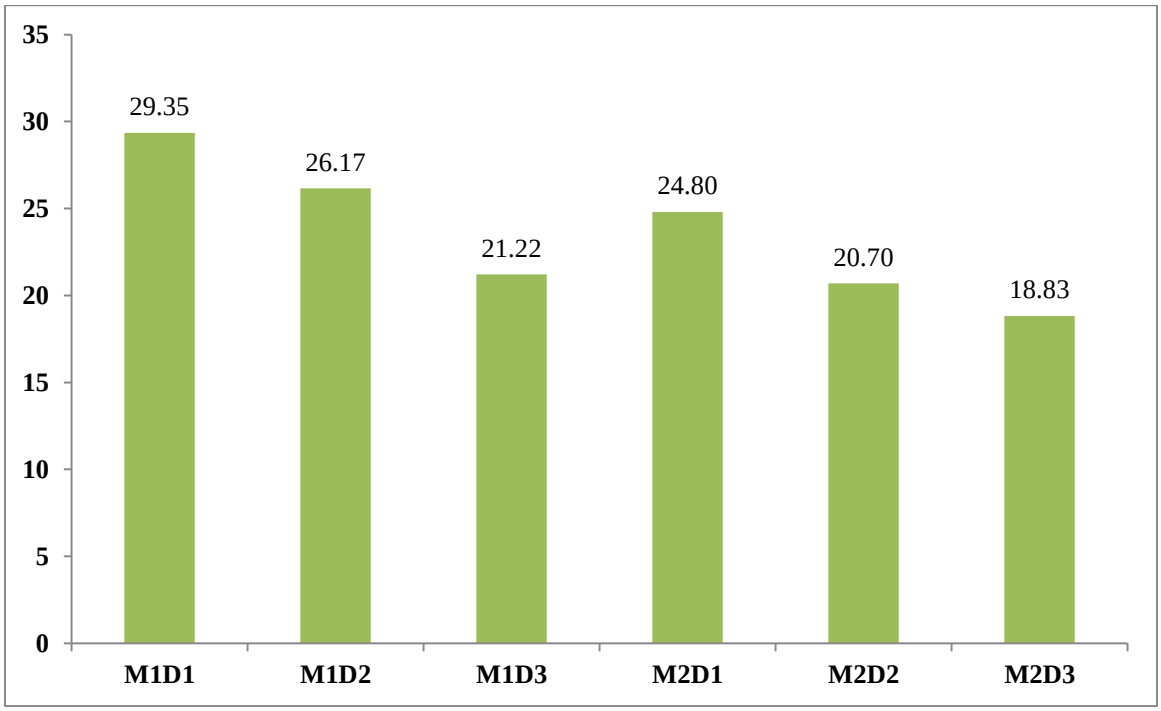


Fig. 4.5(b). Interaction effect of seed production method × dates of transplanting (M×D) on number of primary branches per plant

4.5.3 Method of seed production × Transplanting dates

The interaction effects [Table 4.5 and Fig 4.5(b)] between methods of seed production and dates of transplanting (M x D) showed that maximum number of primary branches per plant (29.35) was obtained in *in-situ* method of seed production and 30th September transplanting (M_1D_1), whereas minimum number of primary branches per plant (18.83) was obtained with treatment combination *ex-situ* method of seed production and 30th October transplanting (M_2D_3).

4.6 Days to seed maturity

The character days to seed maturity showed significant differences for methods of seed production, dates of transplanting and method of seed production x dates of transplanting interactions in Table 4.6 and Fig 4.6(a).

4.6.1 Methods of Seed Production

In-situ method of seed production (M_1) took significantly lesser number of days (193.11) to seed maturity than the *ex-situ* method of seed production.

4.6.2 Dates of transplanting

30th October transplanting (D_3) took minimum days (187.74) for seed maturity, which was statistically superior to the 15th October (D_2) and 30th September (D_1) transplanting.

4.6.3 Method of seed production × Transplanting dates

Interaction effects of methods of seed production and dates of transplanting (M x D) showed that the treatment combination M_1D_3 (*in-situ* method of seed production and 30th October transplanting) took minimum number of days (184.25) for seed maturity, which was statistically superior to all other treatment combinations. Treatment combination M_2D_1 (*ex-situ* method of seed production and 30th September transplanting) took maximum number of days (212.73) for seed maturity [Table 4.6 and Fig 4.6(b)].

4.7 Number of siliqua per plant

The number of siliqua per plant in Table 4.7 and Fig 4.7(a) depicted significant differences for the methods of seed production, dates of transplanting and their interaction effects.

4.7.1 Methods of Seed Production

Maximum number of siliqua per plant (712.32) was observed in *in-situ* method of seed production (M_1) and minimum number of siliqua in *ex-situ* method (M_2) of seed production (552.66).

4.7.2 Dates of transplanting

The data clearly indicated that the crop transplanted on 15th October (D_2) gave the highest number of siliqua per plant (754.47), which was statistically superior to the 30th September (D_1) and 30th October (D_3) transplanting, respectively.

4.7.3 Method of seed production × Transplanting dates

Data revealed that the interaction between methods of seed production and dates of transplanting (M x D) was significant [Table 4.7 and Fig 4.7(b)]. M_1D_2 (*in-situ* method of seed production and 15th October transplanting) recorded the highest number of siliqua per plant (851.60) followed by M_1D_1 treatment combination *(in-situ* method of seed production and 30th September transplanting). Lowest number of siliqua per plant (455.12) was observed with treatment combination M_2D_3 (*ex-situ* method of seed production and 30th October transplanting).

4.8 Siliqua length (cm)

The perusal of data for siliqua length in Table 4.8 and Fig 4.8(a) depicted significant differences for methods of seed production, dates of transplanting and their interaction effects.

4.8.1 Methods of Seed Production

Siliqua length for methods of seed production was obtained maximum (6.13cm) with *in-situ* method of seed production and statistically superior than the *ex-situ* (D_2) method.

Table 4.6: Effect of methods of seed production and dates of transplanting on days to seed maturity

	Days to seed maturity			
	D_1	**D_2**	**D_3**	**Mean**
M_1	203.20	191.88	184.25	193.11
M_2	212.73	207.55	191.22	203.83
Mean	207.96	199.71	187.74	
	CD (5%)	**SE (d)**	**S.Em (±)**	**CV**
Methods (M)	1.70	0.79	0.56	0.97
Dates of transplanting (D)	2.08	0.97	0.69	
Interaction effects (M×D)	2.95	1.37	0.97	

Note:-

M_1: *In-situ* Method

M_2: *Ex-situ* Method

D_1: 30th September date of transplanting

D_2: 15th October date of transplanting

D_3: 30th October date of transplanting

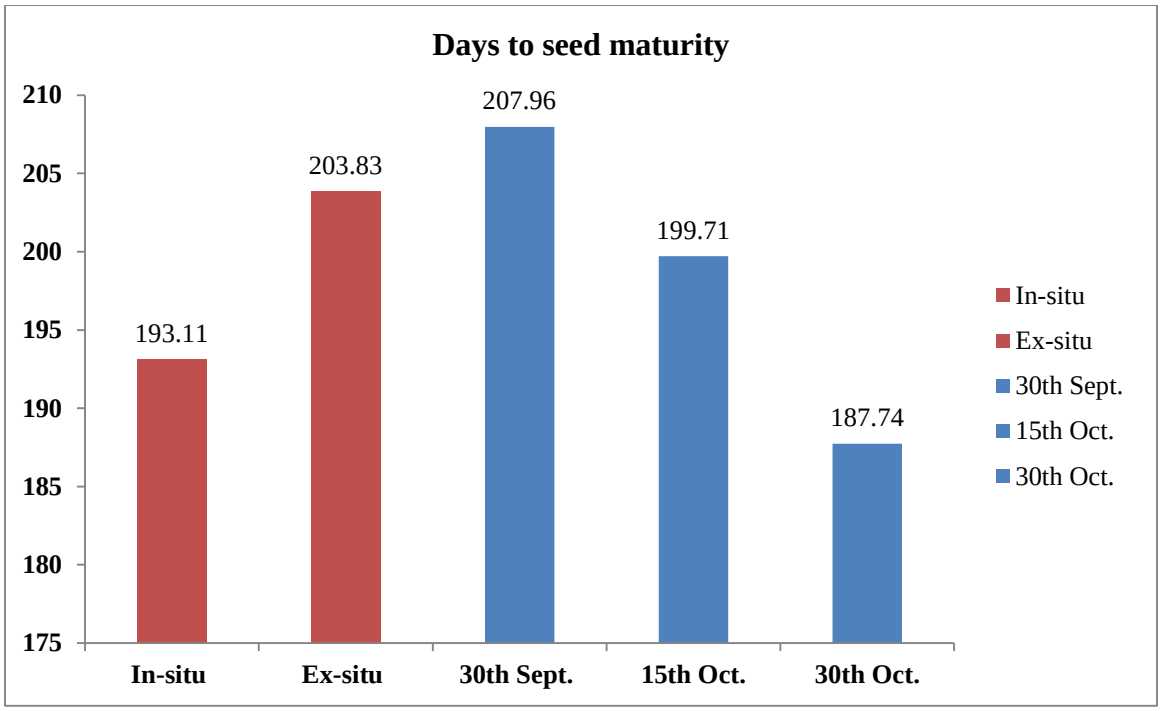


Fig. 4.6(a). Effect of methods of seed production and dates of transplanting on days to seed maturity

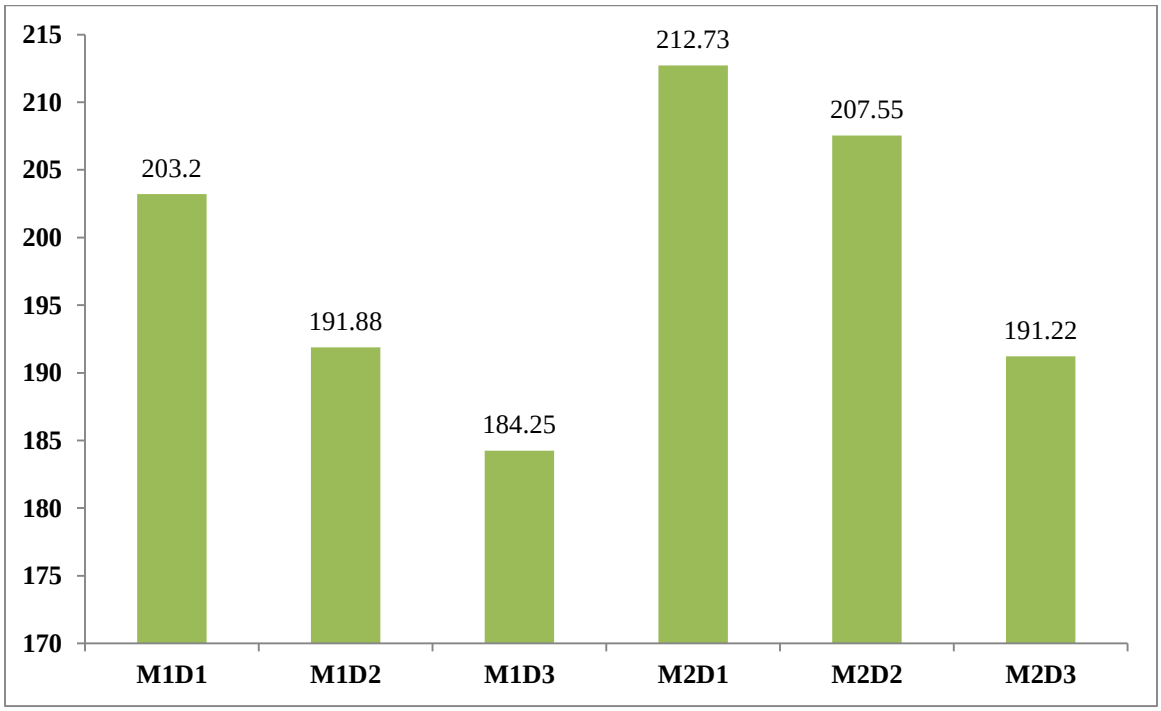


Fig. 4.6(b). Interaction effect of seed production method × dates of transplanting (M×D) on days to seed maturity

Table 4.7: Effect of methods of seed production and dates of transplanting on number of siliqua per plant

	Number of siliqua per plant			
	D_1	**D_2**	**D_3**	**Mean**
M_1	751.40	851.60	533.95	712.32
M_2	545.50	657.35	455.12	552.66
Mean	648.45	754.47	494.54	
	CD (5%)	**SE (d)**	**S.Em (±)**	**CV**
Methods (M)	26.27	12.22	8.64	4.73
Dates of transplanting (D)	32.18	14.96	10.58	
Interaction effects (M×D)	45.51	21.16	14.97	

Note:-

M_1: *In-situ* Method

M_2: *Ex-situ* Method

D_1: 30th September date of transplanting

D_2: 15th October date of transplanting

D_3: 30th October date of transplanting

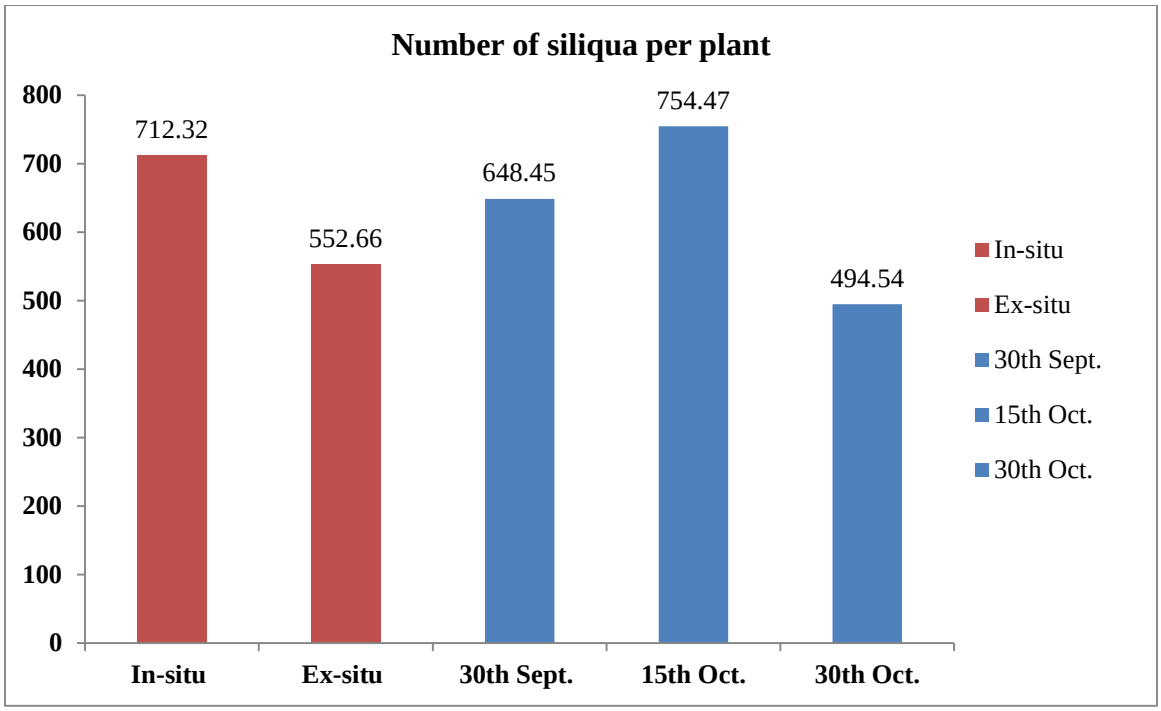


Fig. 4.7(a). Effect of methods of seed production and dates of transplanting on number of siliqua per plant

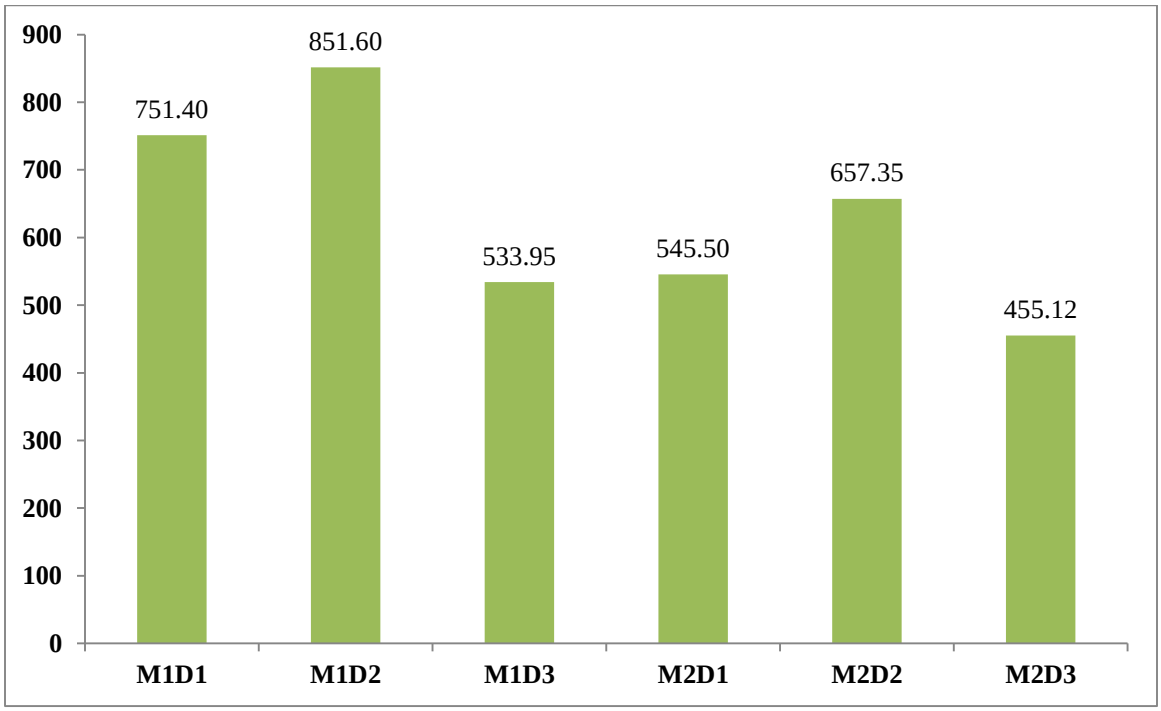


Fig. 4.7(b). Interaction effect of seed production method × dates of transplanting (M×D) on number of siliqua per plant

Table 4.8: Effect of methods of seed production and dates of transplanting on siliqua length

	Siliqua length (cm)			
	D_1	**D_2**	**D_3**	**Mean**
M_1	6.27	6.18	5.95	6.13
M_2	6.08	5.94	5.18	5.73
Mean	6.18	6.06	5.56	
	CD (5%)	**SE (d)**	**S.Em (±)**	**CV**
Methods (M)	0.11	0.05	0.03	1.92
Dates of transplanting (D)	0.12	0.06	0.04	
Interaction effects (M×D)	0.17	0.08	0.06	

Note:-

M_1: *In-situ* Method

M_2: *Ex-situ* Method

D_1: 30th September date of transplanting

D_2: 15th October date of transplanting

D_3: 30th October date of transplanting

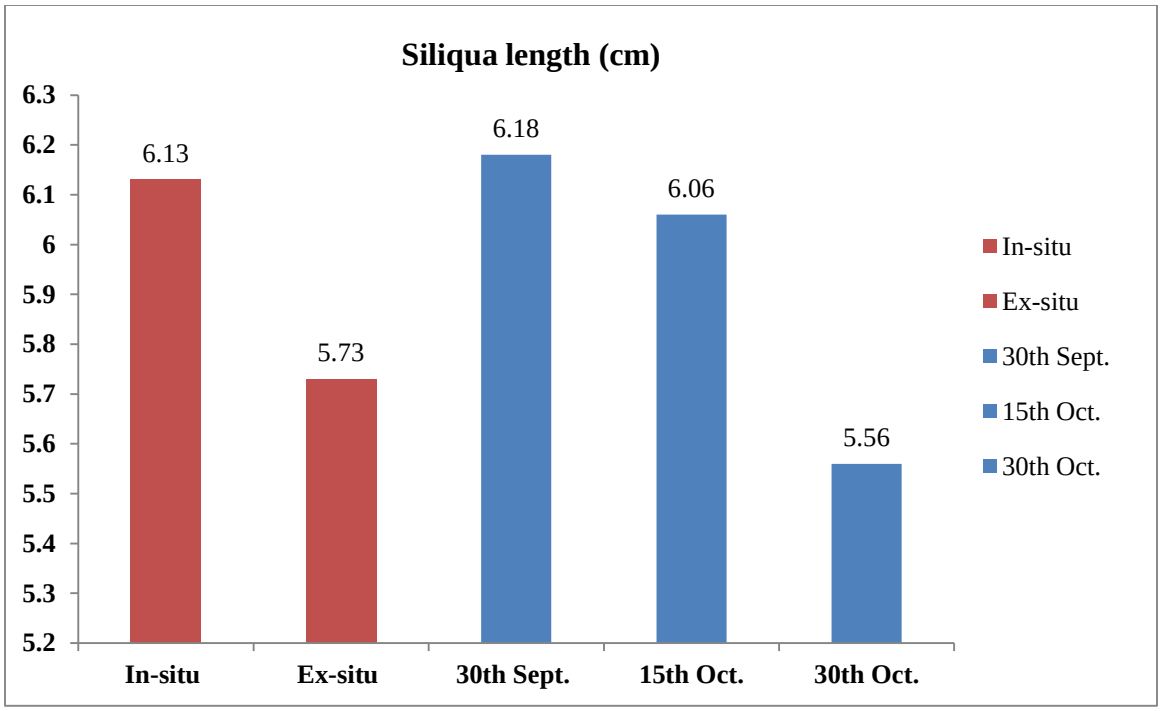


Fig. 4.8(a). Effect of methods of seed production and dates of transplanting on siliqua length (cm)

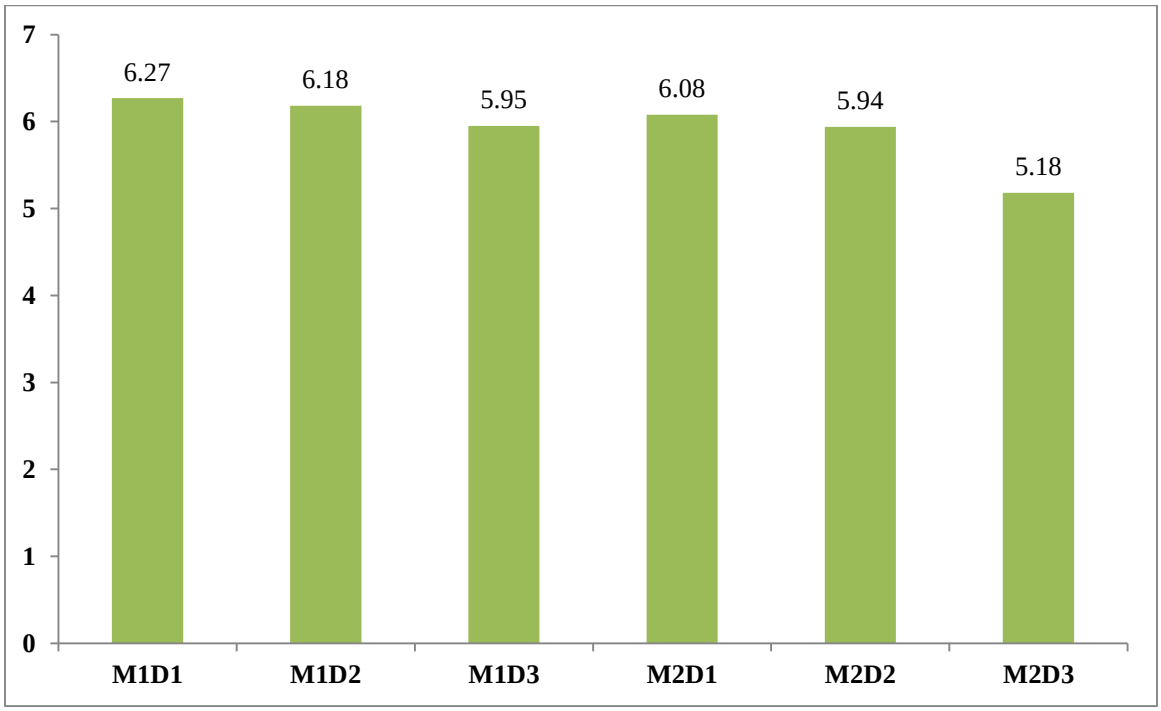


Fig. 4.8(b). Interaction effect of seed production method × dates of transplanting (M×D) on siliqua length (cm)

4.8.2 Dates of transplanting

30th September transplanting (D_1) depicted the maximum number of siliqua length (6.18cm) which was statistically at par with siliqua length obtained in 15th October transplanting.

4.8.3 Method of seed production × Transplanting dates

It was evident from the data that interaction between methods of seed production and different dates of transplanting had significant influence on siliqua length. Maximum siliqua length (6.27cm) was recorded in *in-situ* method and 30th September transplanting dates (M_1D_1) which was statistically more than other interaction. However minimum siliqua length (5.18cm) was recorded in treatment combination (M_2D_3) ex-situ method and 30th October transplanting dates [Table 4.8 and Fig 4.8(b)].

4.9 Number of seeds per siliqua

Significant differences for number of seeds per siliqua were obtained for methods of seed production, dates of transplanting and methods of seed production x dates of transplanting interaction effects [Table 4.9 and Fig 4.9(a)].

4.9.1 Methods of Seed Production

Highest numbers of seeds per siliqua (12.71) were recorded in *in-situ* (M_1) method of seed production, which was statistically superior to the number of seeds per siliqua (11.15) in *ex-situ* method of seed production.

4.9.2 Dates of transplanting

For dates of transplanting maximum number of seeds per siliqua (13.49) were obtained in 30th September (D_1) transplanting which was statistically superior to 15th October (D_2) and 30th October (D_3) transplanting.

4.9.3 Method of seed production × Transplanting dates

Interaction effect of methods of seed production and dates of transplanting showed significant differences for number of seeds per siliqua [Table 4.9 and Fig 4.9(b)].

Treatment combination *in-situ* method and 30th September transplanting (M_1D_1) recorded the maximum number of seeds per siliqua (14.54), which was statistically superior to all other treatment combinations. The treatment combination M_2D_3 obtained the minimum number of seeds per siliqua (9.85).

4.10 Seed yield per plant (g)

Seed yield per plant in Table 4.10 and Fig 4.10(a) showed significant differences for methods of seed production, dates of transplanting and their interaction effects.

4.10.1 Methods of Seed Production

Seed yield per plant with respect to methods of seed production was observed maximum in *in-situ* method of seed production (27.59 g), which was statistically superior to the seed yield per plant in *ex-situ* method of seed production (23.02 g).

4.10.2 Dates of transplanting

Highest seed yield (28.51 g) per plant were obtained from 30th September transplanting (D_1) which was statistically and significantly superior to the seed yield obtained in 15th October and 30th October transplanting.

4.10.3 Method of seed production×Transplanting dates

Combined effects of methods of seed production and date of transplanting varied significantly for seed yield per plant. Data indicated that highest seed yield per plant (31.83 g) was obtained with *in-situ* method and 30th September transplanting (M_1D_1), which was statistically superior to all other interactions. Lowest seed yield (20.44 g) was observed with treatment combination (M_2D_3) i.e. *ex-situ* method and 30th October transplanting [Table 4.10 and Fig 4.10(b)].

4.11 Seed yield per hectare (kg)

The data on seed yield per hectare in Table 4.11 and Fig 4.11(a) depicted significant differences for methods of seed production, dates of transplanting and methods of seed production and dates of transplanting interactions.

Table 4.9: Effect of methods of seed production and dates of transplanting on number of seeds per siliqua

	Number of seeds per siliqua			
	D_1	**D_2**	**D_3**	**Mean**
M_1	14.54	12.43	11.16	12.71
M_2	12.45	11.15	9.85	11.15
Mean	13.49	11.79	10.50	
	CD (5%)	**SE (d)**	**S.Em (±)**	**CV**
Methods (M)	0.28	0.13	0.10	2.69
Dates of transplanting (D)	0.34	0.16	0.11	
Interaction effects (M×D)	0.49	0.23	0.16	

Note:-

M_1: *In-situ* Method

M_2: *Ex-situ* Method

D_1: 30th September date of transplanting

D_2: 15th October date of transplanting

D_3: 30th October date of transplanting

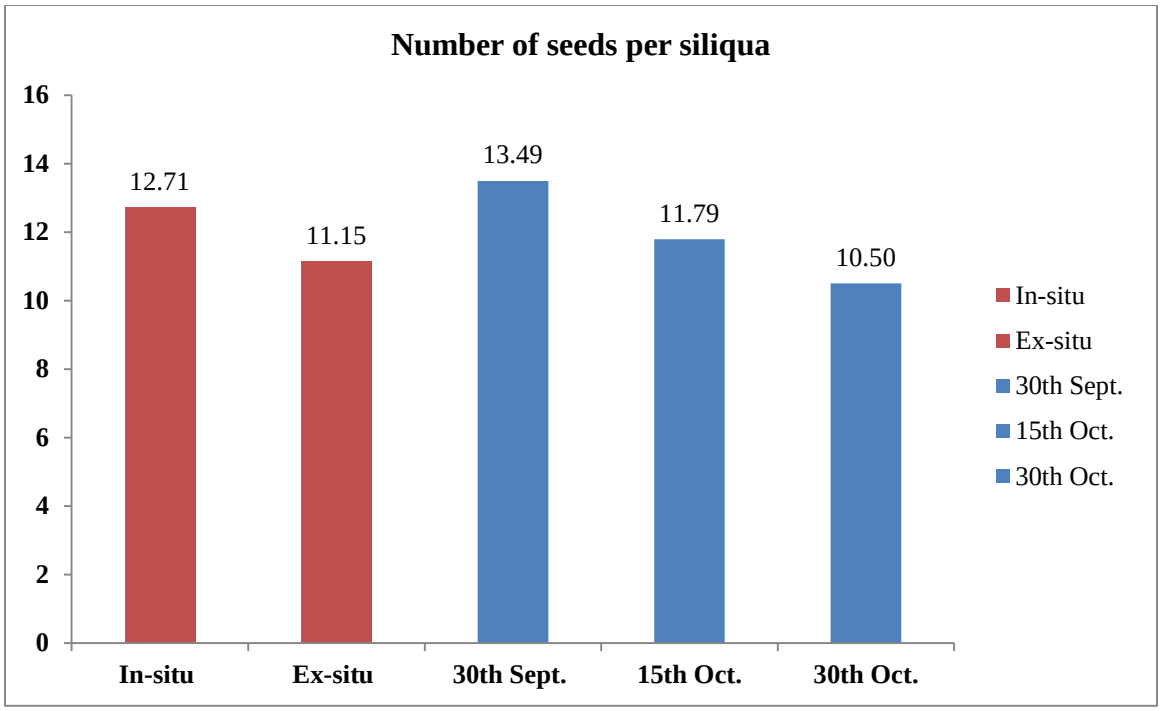


Fig. 4.9(a). Effect of methods of seed production and dates of transplanting on number of seeds per siliqua

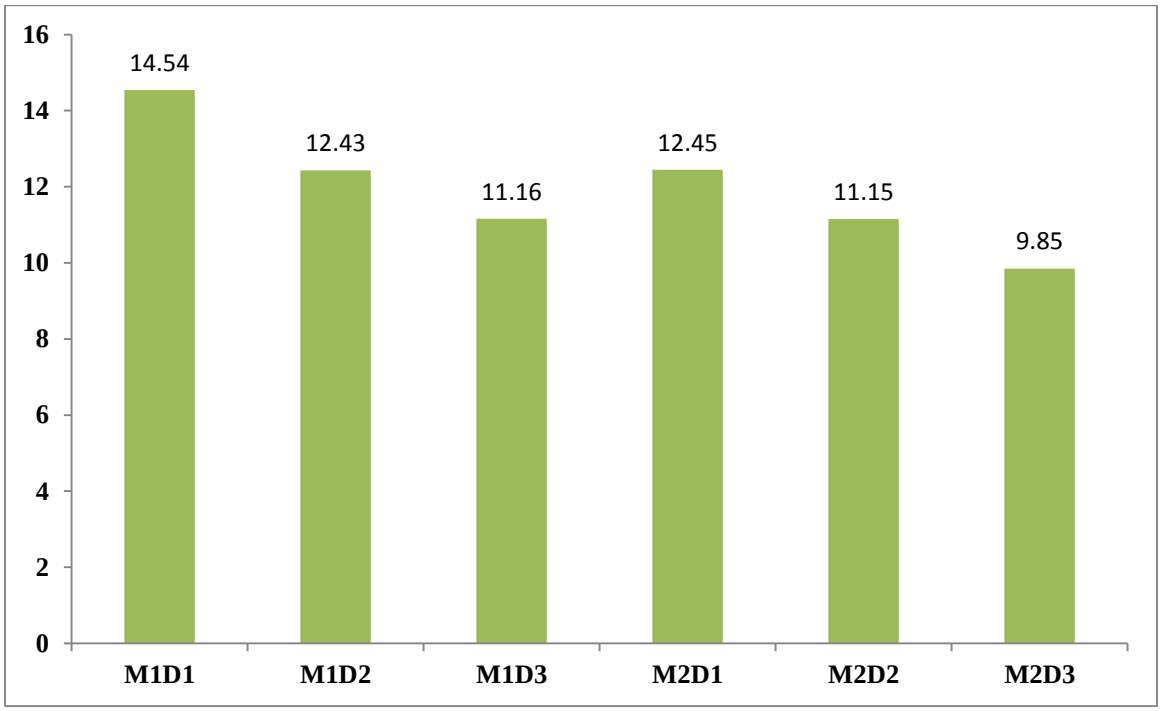


Fig. 4.9(b). Interaction effect of seed production method × dates of transplanting (M×D) on number of seeds per siliqua

Table 4.10: Effect of methods of seed production and dates of transplanting on seed yield per plant

	Seed yield per plant (g)			
	D_1	**D_2**	**D_3**	**Mean**
M_1	31.83	27.10	23.84	27.59
M_2	25.19	23.42	20.44	23.02
Mean	28.51	25.26	22.14	
	CD (5%)	**SE (d)**	**S.Em(±)**	**CV**
Methods (M)	0.80	0.37	0.26	3.60
Dates of transplanting (D)	0.98	0.46	0.32	
Interaction effects (M×D)	1.39	0.65	0.46	

Note:-

M_1: *In-situ* Method

M_2: *Ex-situ* Method

D_1: 30th September date of transplanting

D_2: 15th October date of transplanting

D_3: 30th October date of transplanting

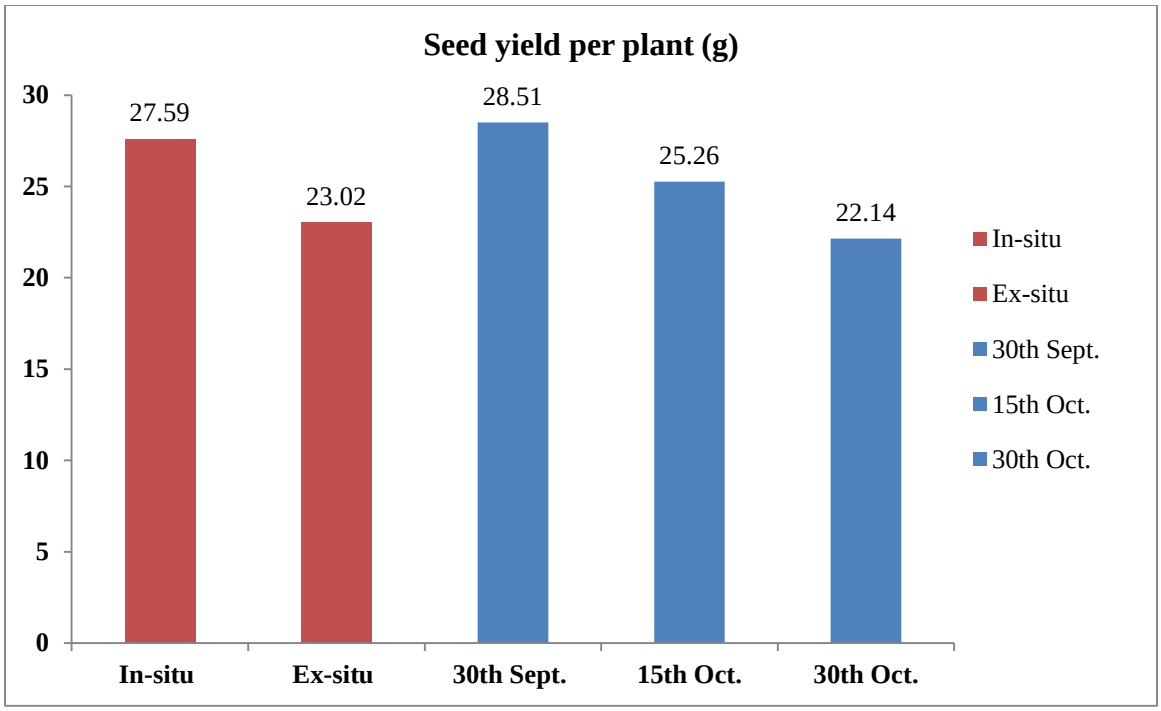


Fig. 4.10(a). Effect of methods of seed production and dates of transplanting on seed yield per plant (g)

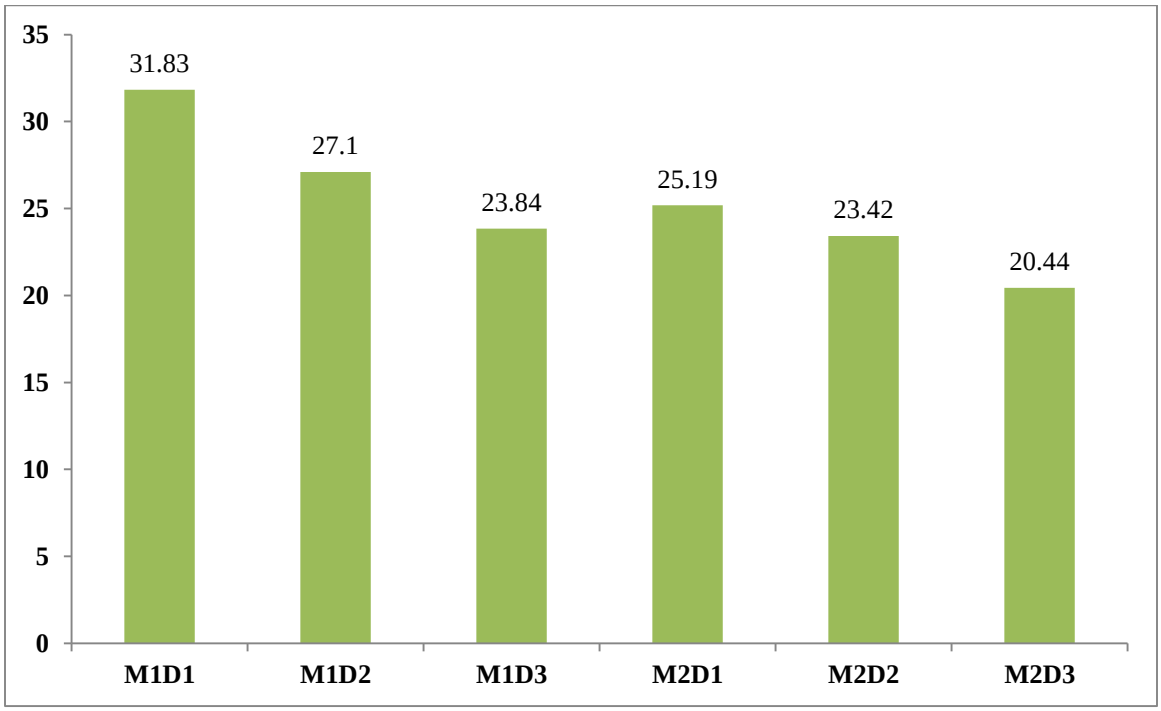


Fig. 4.10(b). Interaction effect of seed production method × dates of transplanting (M×D) on seed yield per plant (g)

Table 4.11: Effect of methods of seed production and dates of transplanting on seed yield per hectare

	Seed yield per hectare (kg)			
	D_1	**D_2**	**D_3**	**Mean**
M_1	825.00	702.50	618.50	715.33
M_2	653.25	607.00	529.75	596.66
Mean	739.12	654.75	574.12	
	CD (5%)	**SE (d)**	**S.Em (±)**	**CV**
Methods (M)	20.71	9.63	6.80	3.59
Dates of transplanting (D)	25.36	11.79	8.34	
Interaction effects (M×D)	35.87	16.67	11.79	

Note:-

M_1: *In-situ* Method

M_2: *Ex-situ* Method

D_1: 30th September date of transplanting

D_2: 15th October date of transplanting

D_3: 30th October date of transplanting

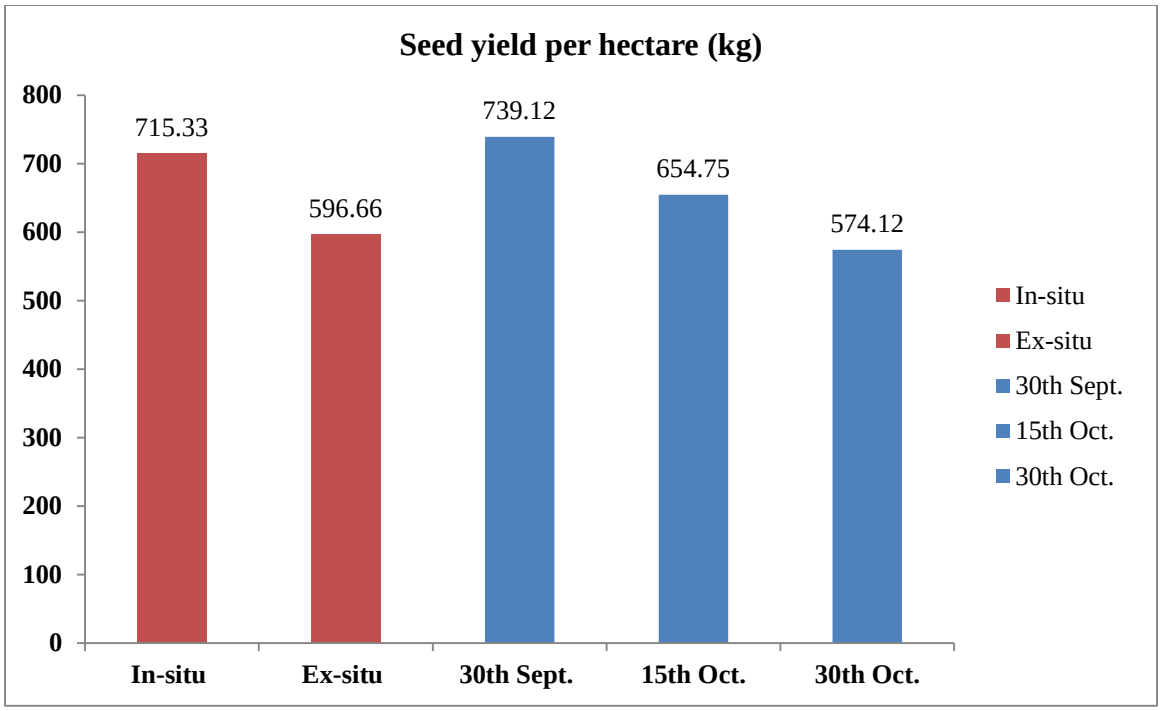


Fig. 4.11(a). Effect of methods of seed production and dates of transplanting on seed yield per hectare (kg)

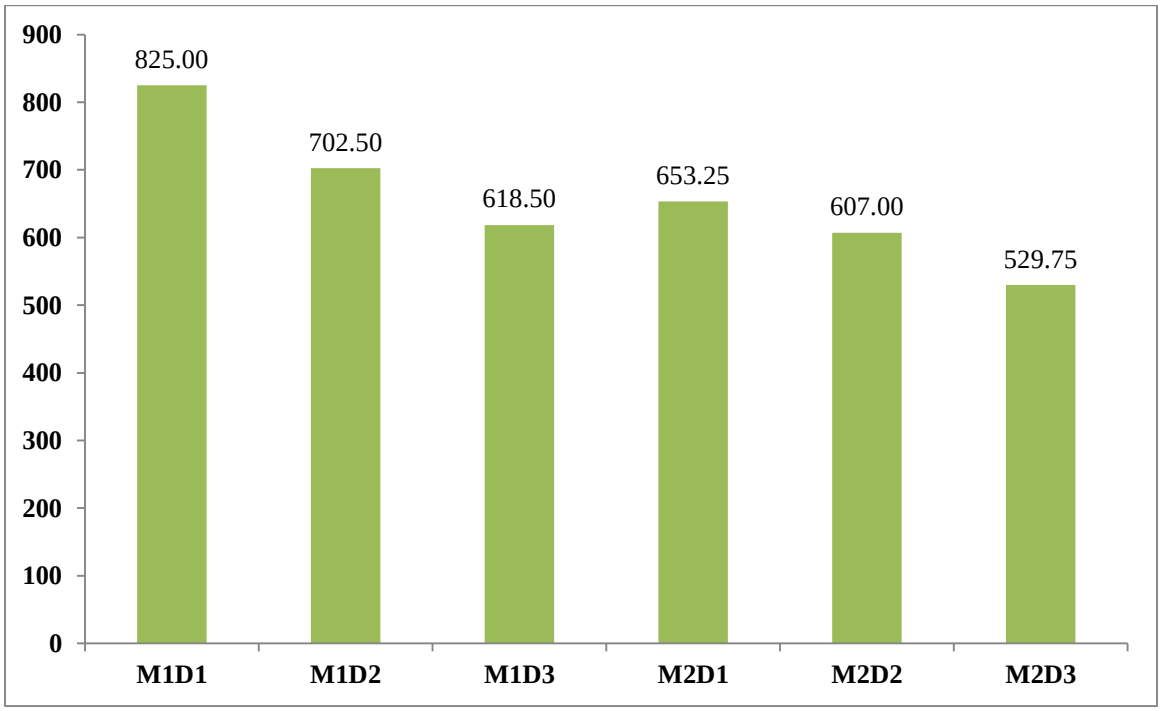


Fig. 4.11(b). Interaction effect of seed production method × dates of transplanting (M×D) on seed yield per hectare (kg)

4.11.1 Methods of Seed Production

It followed the same trend as for seed yield per plant i.e. maximum seed yield per hectare (715.33 kg) was obtained in *in-situ* method of seed production which was significantly superior to the seed yield observed in *ex-situ* method of seed production.

4.11.2 Dates of transplanting

30th September transplanting (D_1) recorded the highest seed yield (739.12 kg) per plant were obtained from which was statistically and significantly superior to the seed yield obtained in D_2 and D_3 treatments.

4.11.3 Method of seed production × Transplanting dates

The interaction effects of methods of seed production and dates of transplanting showed significant differences for seed yield per hectare. The treatment combination M_1D_1 observed the highest seed yield of 825.0 kg, which was significantly superior to all the treatment combinations. The lowest yield 529.75 kg was observed with treatment combination M_2D_3 [Table 4.11 and Fig 4.11(b)].

4.12 Test weight

The data in Table 4.12 and Fig 4.12(a) revealed significant effects for methods of seed production and dates of transplanting on test weight. While non-significant response was recorded by the interaction between methods and transplanting dates.

4.12.1 Methods of Seed Production

Test weight showed significant response towards the methods. *In-situ* method (M_1) recorded higher test weight (3.23) as compared to *ex-situ* method.

4.12.2 Dates of transplanting

Significantly more test weight (3.29) was recorded in 30th September transplanting over the remaining treatments.

4.12.3 Method of seed production × Transplanting dates

Interaction effect of methods of seed production and transplanting dates revealed non-significant effects on test weight [Table 4.12 and Fig 4.12(b)].

4.13 Germination Percentage

The results revealed significant differences for methods of seed production, dates of transplanting and their interaction effects in Table 4.13 and Fig 4.13(a).

4.13.1 Methods of Seed Production

For germination percentage the data showed significant differences for method of seed production. Maximum germination percentage (94.58%) was recorded from *in-situ* method (M_1) than the *ex-situ* method of seed production.

4.13.2 Dates of transplanting

Among transplanting dates**,** 30th September transplanting gave the highest germination percentage of (97.02%), which was statistically superior than the 15th October transplanting (93.98%).

4.13.3 Method of seed production × Transplanting dates

The perusal of the data indicated that there was significant variation between the treatments combinations. The interaction of *in-situ* method and 30th September showed higher germination percentage (97.95%) which was statistically more than rest of interactions. Minimum germination percentage (91.32%) was recorded from treatment *ex-situ* method and 30th October transplanting dates [Table 4.13 and Fig 4.13(b)].

Table 4.12: Effect of methods of seed production and dates of transplanting on test weight

	Test weight (g)			
	D_1	**D_2**	**D_3**	**Mean**
M_1	3.44	3.24	3.02	3.23
M_2	3.14	3.01	2.90	3.02
Mean	3.29	3.12	2.96	
	CD (5%)	**SE (d)**	**S.Em (±)**	**CV**
Methods (M)	0.09	0.04	0.03	3.03
Dates of transplanting (D)	0.10	0.05	0.03	
Interaction effects (M×D)	N/S	0.07	0.05	

Note:-

M_1: *In-situ* Method

M_2: *Ex-situ* Method

D_1: 30th September date of transplanting

D_2: 15th October date of transplanting

D_3: 30th October date of transplanting

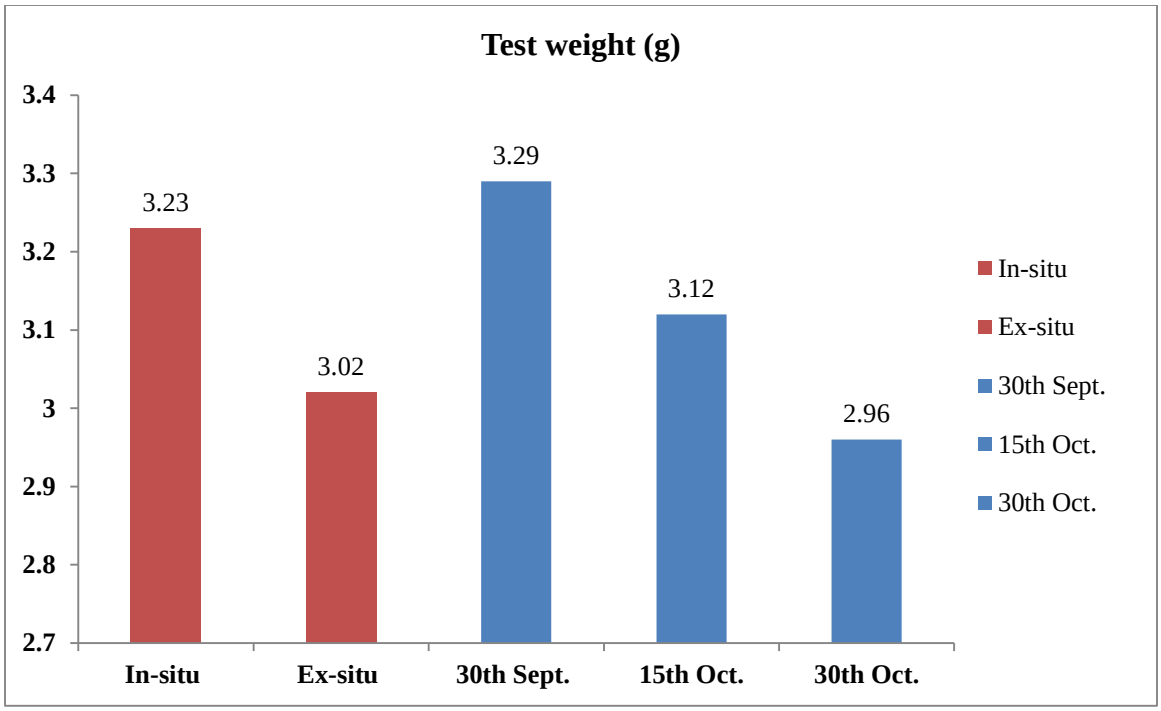


Fig. 4.12(a). Effect of methods of seed production and dates of transplanting on test weight (g)

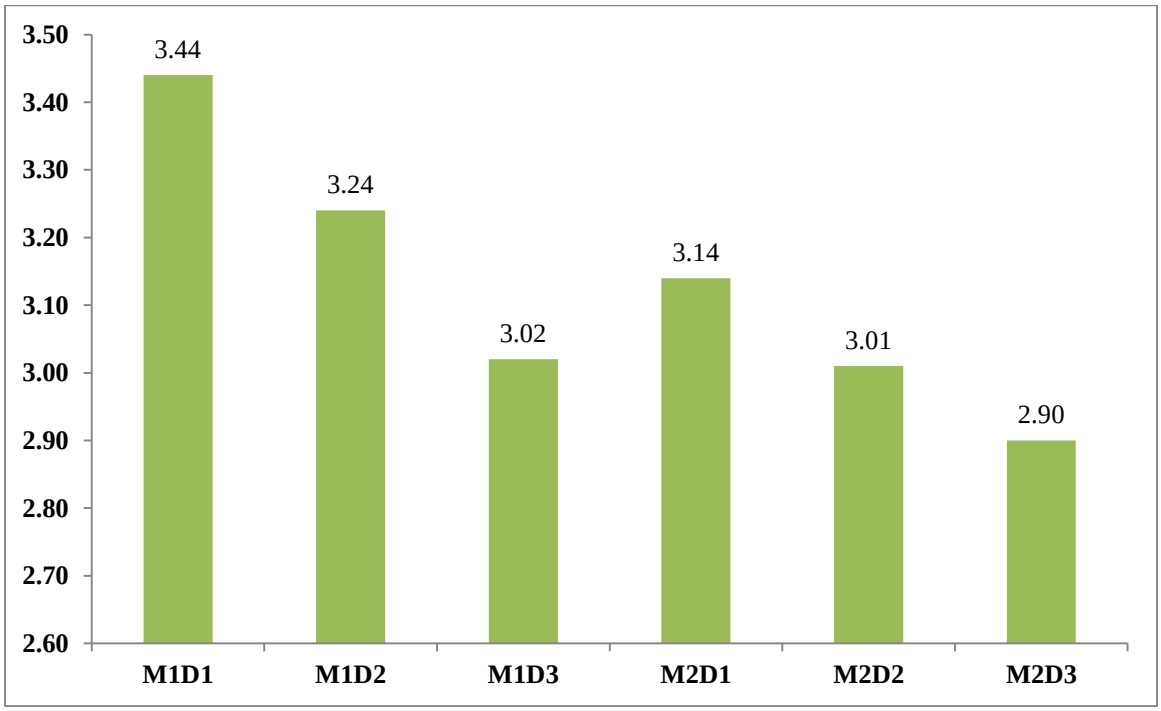


Fig. 4.12(b). Interaction effect of seed production method × dates of transplanting (M×D) on test weight (g)

Table 4.13: Effect of methods of seed production and dates of transplanting on seed germination

	Seed germination (%)			
	D_1	**D_2**	**D_3**	**Mean**
M_1	97.95	94.87	90.92	94.58
M_2	96.10	93.10	91.32	93.50
Mean	97.02	93.98	91.12	
	CD (5%)	**SE (d)**	**S.Em (±)**	**CV**
Methods (M)	0.61	0.28	0.20	0.74
Dates of transplanting (D)	0.74	0.34	0.24	
Interaction effects (M×D)	1.05	0.49	0.34	

Note:-

M_1: *In-situ* Method

M_2: *Ex-situ* Method

D_1: 30th September date of transplanting

D_2: 15th October date of transplanting

D_3: 30th October date of transplanting

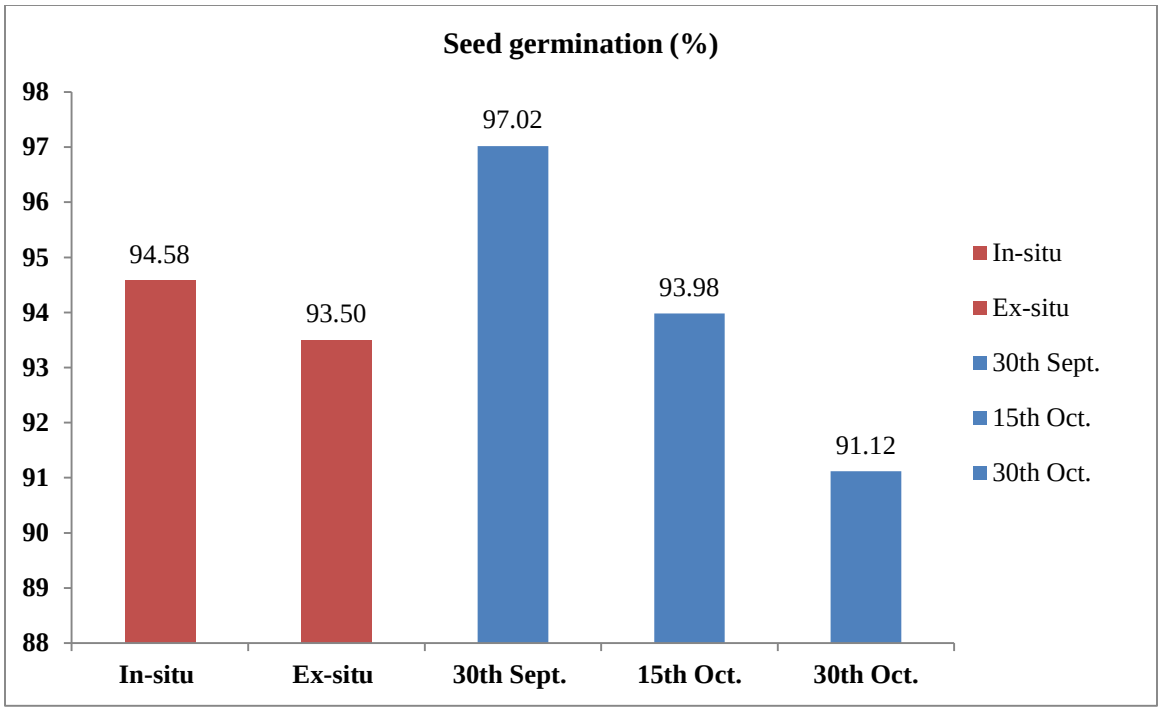


Fig. 4.13(a). Effect of methods of seed production and dates of transplanting on seed germination (%)

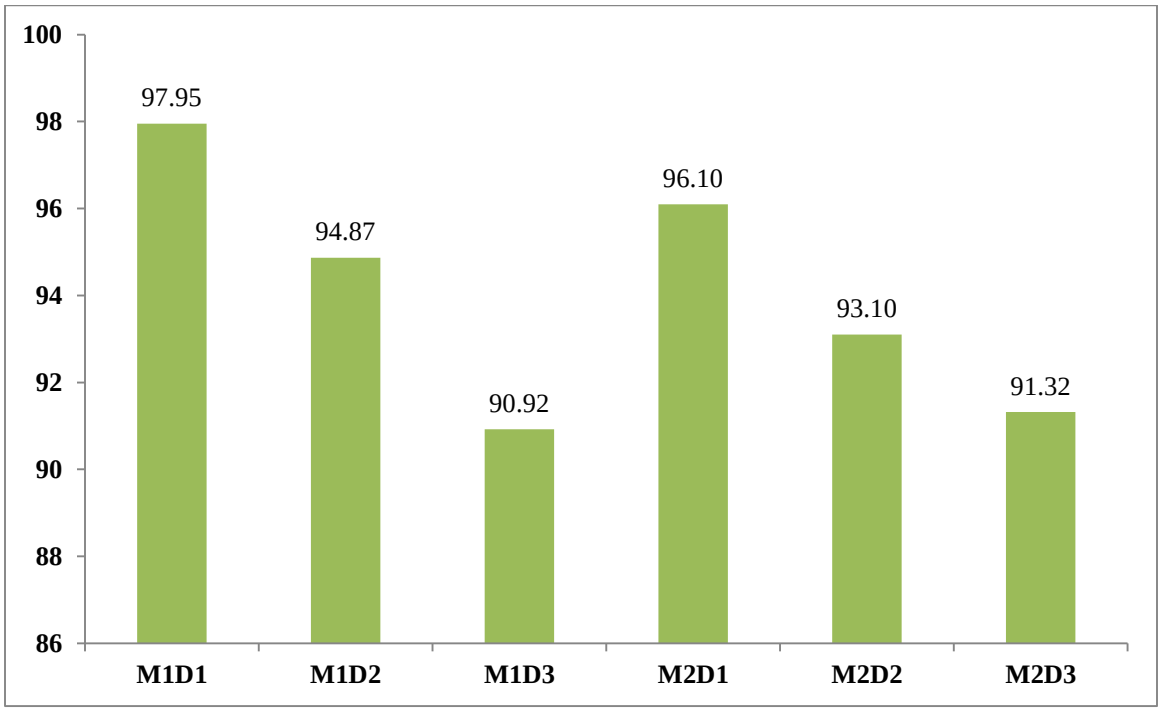


Fig. 4.13(b). Interaction effect of seed production method × dates of transplanting (M×D) on seed germination (%)

Chapter-5

Discussion

CHAPTER-5

DISCUSSIONS

In this chapter an attempt has been made to study the possible reasons of the effects of methods of seed production and dates of transplanting on various parameters related to seed yield in broccoli. In order to make the findings more illustrative, reasons for effects been discussed separately. The results have been duly supported by references available in the literature as and where necessary. The findings of the experiment entitled "**Seed production in broccoli (*Brassica oleracea* var. *italica*) under Jammu sub-tropics**" has been described and explained with ample support as well as the reported postulation from various works within the country and abroad.

5.1 Days to 50% bolting

The perusal of data revealed significant differences for method of seed production, dates of transplanting and their interaction. *In-situ* method of seed production took less number of days to 50% bolting as compared to *ex-situ* method. The decrease in number of days to 50% bolting may be because the plant was not disturbed in *in-situ* method. 30th October transplanting took the minimum number of days to 50% bolting, whereas 30th September transplanting took the maximum number of days to 50% bolting. This is because late sown crop was exposed to low temperature immediately irrespective of its vegetative growth. These results are in accordance with the findings of Ranjit *et al.* (2014) and Selvakumar *et al.* (2007).

With respect to method of seed production and dates of transplanting interactions the treatment combination M_1D_3 (*in-situ* method of seed production and 30th October transplanting) took the minimum days to 50% bolting, which is again a close conformity to the findings of Ranjit *et al.* (2014).

5.2 Days to 50% flowering

Data for days to 50% flowering depicted significant differences for methods of seed production, dates of transplanting and method of seed production x dates of

transplanting interaction effects. It is evident from the data that M_1 treatment (*in-situ* method of seed production) was significantly earlier to flower than M_2 treatment (*ex-situ* method of seed production). These findings are in agreement with the earlier work of Mohanty and Srivastava, (2002). For dates of transplanting, earliness was observed in 30th October transplanting, which was statistically superior to 30th September and 15th October transplanting because sowing on 30th October got shorter cool period for vegetative growth and its turns quickly for reproductive phase. The delay in transplanting triggered floral initiation. The environmental conditions prevailing during early crop period might have proved more effective in stimulating the plant growth. These results are in accordance with the findings of Ranjit *et al.* (2014) and Mohanty and Srivastava (2002).

The interaction effect of methods of seed production and dates of transplanting (M x D) showed that treatment combination M_1D_3 (*in-situ* method of seed production x 30th October transplanting) took minimum days to 50% flowering, which was statistically at par with treatment combination M_1D_2.

5.3 Plant height (cm) at maturity stage

The data for plant height at maturity indicated significant differences for methods of seed production, dates of transplanting and their interactions. Maximum plant height was observed in *in-situ* method, which was significantly superior to *ex-situ* method of seed production. For dates of transplanting, maximum plant height at maturity was recorded in 30th September transplanting. This increase in plant height at maturity in the earliest sown crop may be because of better environmental conditions resulting in better vegetative growth. Similar results were reported by El-Magd (2013), EI-Yazied *et al.* (2007) and Moniruzzaman *et al.* (2007). The experimental findings of Ahmed and Siddique (2004) showed that height is related with the vegetative growth of the plant.

The method of seed production and dates of transplanting (M x D) interaction effects were significant for plant height at maturity. Maximum plant height at maturity was recorded with treatment combination M_1D_1 (*in-situ* method of seed production and

30th September transplanting). The results corroborate the finding of Ranjit *et al.* (2014) and Mohanty and Srivastava, (2002).

5.4 Plant spread (cm)

Plant spread showed significant differences for method of seed production, dates of transplanting and their interaction. *In-situ* method observed maximum plant spread because the replanted crop required some time to recover from the transplanting shock caused due to their displacement and *in-situ* technique exhibited a significant improvement for plant spread. These results are in conformity with findings of Mohanty and Srivastava (2002). For dates of transplanting 30th September transplanting gave the maximum plant spread, which was statistically superior to 15th October and 30th October transplanting. These results are in accordance with Mohanty and Srivastava (2002).

The interaction effect of method of seed production x dates of transplanting showed that maximum plant spread was obtained with treatment combination M_1D_1 i.e. *in-situ* method of seed production and 30th September transplanting. These results are in agreement with the findings of Mohanty and Srivastava (2002).

5.5 Number of primary branches per plant

Data for number of primary branches per plant revealed significant differences for method of seed production, dates of transplanting and their interaction effects (MxD). Maximum number of primary branches per plant was recorded in *in-situ* method of seed production, which was statistically superior to the *ex-situ* method. The finding of Ranjit *et al.* (2014) are in conformity to the present results. For dates of transplanting 30th September transplanting gave the maximum number of primary branches per plant, which was superior then the 15th October transplanting, where as 30th October planting indicated the minimum number of primary branches per plant. The experimental findings of Hossain *et al.* (2015) reported that being a thermo sensitive plant the early planted plant received comparatively low temperature during vegetative growth which produced bigger size head which ultimately produced more number of branches per plant. Likewise, Ranjit *et al.* (2014) observed that the difference was due to the fact that late sown crop

attained lesser vegetative growth and head diameter, which lead to less number of primary branches.

The interaction effects (MxD) showed that maximum number of primary branches per plant was obtained with treatment combination of M_1D_1 i.e. *in-situ* method of seed production and 30th September transplanting. These results are in agreement with the findings of Mohanty and Srivastava (2002).

5.6 Days to seed maturity

The perusal of data for days to seed maturity depicted significant differences for method of seed production, dates of transplanting and their interaction effects. *In-situ* method of seed production took significantly lesser number of days (193.11) to seed maturity than *ex-situ* method. This may be because the replanted crop for *ex-situ* seed production required some time to recover from transplanting shock. The findings confirm to those of Ranjit *et al.* (2014) and Mohanty and Srivastava (2002). For dates of transplanting the D_3 treatment i.e. 30th October transplanting took significantly lesser number of days to seed maturity than other two. This may be attributed to the fact that early planting dates have improved growth and yield attributes and plants were exposed to higher temperatures at the time of maturity. Similar results were reported by Chandra and Shukla (2013).

The interaction effects of method of seed production x dates of transplanting revealed that minimum days taken for seed maturity were obtained with treatment combination M_1D_3 i.e. *in-situ* method of seed production and 30th October transplanting. These findings are in accordance with earlier work of Chandra and Shukla (2013), Ranjit *et al.* (2014) and Mohanty and Srivastava (2002).

5.7 Number of siliqua per plant

Number of siliqua per plant is an important key factor for determining the yield parameters for broccoli seed production. Data regarding number of siliqua per plant indicated significant differences for main effects and their interaction effects. Highest number of siliqua was recorded in *in-situ* method of seed production, which was

significantly superior to the *ex-situ* method. Similar results were reported by Mohanty and Srivastava (2002). For dates of transplanting, maximum number of siliqua per plant were recorded in 15th October transplanting. Hossain *et al.* (2015) obtained highest number of pods per plant from 1st October sowing, which was significantly influenced by the prevailing growing conditions of a crop. Similarly Chandra and Shukla (2013) reported maximum number of siliqua per plant in 10th October planting dates due to fact that temperature during late transplanting may caused reduced growth and development of seed yield contributing characters of broccoli plants. The findings of El-Yazied *et al.* (2007) are in accordance with the present study.

The interaction effect of method of seed production x dates of transplanting showed that maximum number of siliqua per plant was obtained with treatment combination M_1D_2 i.e. *in-situ* method of seed production and 15th October transplanting (Ranjit *et al.* (2014).

5.8 Siliqua length

Statistical analysis of data depicted significant differences for method of seed production, dates of transplanting and method of seed production x dates of transplanting interaction effect. Maximum siliqua length was observed in *in-situ* method of seed production, which was significantly superior to the *ex-situ* method of seed production. Ranjit *et al.* (2014) also reported the same results. For dates of transplanting maximum siliqua length was recorded in 30th September transplanting and it decreased with delay in transplanting. These results are in agreement with findings of Hossain *et al.* (2015) and Chandra and Shukla (2013).

The method of seed production x dates of transplanting interaction effect indicated significant effects and reported that maximum siliqua length was observed with *in-situ* method of seed production and 30th September transplanting (M_1D_1).

5.9 Number of seeds per siliqua

Data for number of seeds per siliqua depicted significant differences for method of seed production, dates of transplanting and their interaction effects**.** *In-situ* method of

seed production produced significantly more number of seeds per siliqua**.** Similar results were obtained earlier by Ranjit *et al.* (2014) and Mohanty and Srivastava (2002), who recorded significant improvement in number of seeds per siliqua over *ex-situ* method. For dates of transplanting, the earlier planting i.e. 30th September transplanting gave significantly higher number of seeds per siliqua. It reduced with delay in planting. This may be attributed to the fact that plants sowing on 30th September got the optimum growing period which produced the optimum size of siliqua as well as maximum number of seeds per siliqua. Patil *et al.* (1995) reported that plants grown in early winter produced large sized pod and increased number of seeds per pod because of proper growth and development of the cauliflower plants. Similar results were also obtained by earlier workers like Hossain *et al.* (2014), Chandra and Shukla (2013), and Halim *et al.* (1995).

Interaction effect of method of seed production x dates of transplanting showed significant differences for number of seeds per siliqua. Maximum number of seeds per siliqua was obtained with treatment combination M_1D_1 i.e. *in-situ* method of seed production and 30th September transplanting dates.

5.10 Seed yield per plant (g)

The data depicted significant differences for main effects i.e. method of seed production, dates of transplanting as well as for their interaction effects (M x D). Highest seed yield per plant was recorded in *in-situ* method of seed production, which was statistically superior to *ex-situ* method due to proper growth and development and more number of branches per plant. Bhushan *et al.* (2020), Ranjit *et al.* (2014) and Verma *et al.* (1996) also obtained the similar results. For dates of transplanting 30th September transplanting gave the highest yield and 30th October planting gave the lowest yield per plant. Similar result was observed by Hossain *et al.* (2015) and obtained highest seed yield per plant in 1st October due to higher number of branches per plants as well as pod per plant. This difference in yield caused by time of planting may be due to the variation in temperature that prevailed during the growing period. These results are in accordance with the earlier work of Chandra and Shukla (2013) and Halim *et al.* (1995).

The interaction effect (M x D) showed that highest seed yield per plant was obtained with treatment combination M_1D_1 i.e. *in-situ* method of seed production and 30th September transplanting. These results are in agreement with the findings of Mohanty and Srivastava (2002).

5.11 Seed yield per hectare (kg)

Data on seed yield per hectare showed significant differences for method of seed production, dates of transplanting and their interaction (M x D). Maximum seed yield was recorded in *in-situ* method which was statistically superior to *ex-situ* method. The various seed attributing characters such as number of siliqua per plant, siliqua length, number of seeds per siliqua being favourable resulted in higher seed yield per hectare. The results are in agreement with the findings of Mohanty and Srivastava (2002) and Verma *et al.* (1996). For dates of transplanting maximum seed yield per hectare was recorded in the 30th September transplanting, which was statistically superior to the 15th October planting. Seed yield per hectare decreased with delay in planting from 15th October onwards. This may be due the fact that early transplanting dates have improved growth and yield attributes favorably. Similar results were reported by Hossain *et al.* (2015) and Chandra and Shukla (2013).

The methods of seed production x dates of transplanting (M x D) interaction effects showed that maximum seed yield was recorded with treatment combination M_1D_1 and minimum seed yield was reported in M_2D_3 treatments combination. These results are in agreement with the findings of Mohanty and Srivastava (2002).

5.12 Test weight

For test weight, the data showed significant differences only for method of seed production and dates of transplanting. Highest test weight (3.23 g) was observed in *in-situ* method (M_1) which was statistically higher than the *ex-situ* method (M_2) of seed production. Among dates of transplanting, 30th September (D_1) gave the maximum test weight (3.29 g). These results corroborate the findings of Bhushan *et al.* (2020) and Mohanty and Srivastava (2002).

The interaction effects (M x D) showed non-significant effects for test weight.

5.13 Germination percentage

Significant differences were recorded for seed germination percentage with respect to methods of seed production, dates of transplanting and their interaction effects. *In-situ* method (M_1) of seed production observed maximum germination percentage (94.58). And among dates of transplanting maximum germination percentage (97.02) was recorded in 30th September transplanting. The results are in agreement with the findings of Mohanty and Srivatstava (2002).

The method of seed production x dates of transplanting interaction effect indicated significant effects and reported that maximum seed germination percentage (97.95) was observed with *in-situ* method of seed production and 30th September transplanting (M_1D_1).

Chapter-6

Summary and Conclusions

CHAPTER-6

SUMMARY AND CONCLUSION

The present study entitled **"Seed production in broccoli (*Brassica oleracea* var. *italica*) under Jammu sub-tropics"** was conducted at Vegetable Experimental Farm, SKUAST Jammu with the objective of getting information on suitable seed production method and the transplanting dates for maximum seed yield. The experiment was conducted in Randomized Block Design (factorial), during the year 2019-2020, with two method of seed production namely *in-situ* (seed to seed) and *ex-situ* (head to seed) and three dates of transplanting viz. 30th September, 15th October and 30th October. Six treatment combinations were replicated four times in plot size 3 x 3 m at a plant spacing of 60 x 45 cm. The variety taken for study was Jammu Broccoli-07 which has been developed by Department of Vegetable Science and Floriculture and released during 2017. Various seed related characters were observed in the study namely days to 50% bolting, days to 50% flowering, plant height, plant spread, number of primary branches per plant, days to seed maturity, number of siliqua per plant, siliqua length, number of seeds per siliqua, seed yield per plant, seed yield per hectare and different procedures like test weight and germination percentage were taken on ten randomly selected plants of each treatment and each replication.

Analysis of Variance (ANOVA) exhibited significant differences, with the exception of test weight, for all the characters under study. Overall, the results showed that *in-situ* (M_1) seed production method significantly influenced days to 50 % bolting (107.17), days to 50% flowering (130.92), plant height at maturity stage (85.39cm), plant spread (51.79cm), number of primary branches per plant(25.58), days to seed maturity(193.11), number of siliqua per plant (712.32), siliqua length (6.13), number of seeds per siliqua (12.71), seed yield per plant (27.59 g), seed yield per hectare (715.33 kg), test weight (3.23 g) and germination percentage (94.58%).

For dates of transplanting, 30th September transplanting proved significantly superior for most of the characters viz., Plant height at maturity (82.23 cm), plant spread

(55.97 cm), number of primary branches per plant (27.07), siliqua length (6.18), number of seed per siliqua (13.49), seed yield per plant (28.51 g), seed yield per hectare (739.12 kg), test weight (3.29g) and germination percentage (97.02%) and 30th October transplanting showed superior results in traits like days to 50 % bolting (104.62) and days to 50% flowering (130.38) and days to seed maturity (187.74) whereas 15th October transplanting proved superior for number of siliqua per plant (851.60).

As far as interaction effect is concerned between methods of seed production and dates of transplanting, best performance was observed in treatment combination M_1D_1 (*in-situ* method of seed production x 30th September transplanting dates), which significantly influence the plant height at maturity (95.63 cm), plant spread (63.38 cm), number of primary branches per plant (29.35), siliqua length (6.27), number of seeds per siliqua (14.54), seed yield per plant (31.83g), seed yield per hectare (825 kg) and germination percentage (97.95%). Whereas, the treatment combination M_1D_2 (*ex-situ* method x 15th October transplanting) was best performance for number of siliqua per plant (851.60). The treatment combination M_1D_3 (*in-situ* method x 30th October transplanting) showed best performance for days to 50% bolting (103), days to 50% flowering (127.50) and days to seed maturity (184.25). The interaction effect of dates of transplanting and method of seed production showed non- significant differences for test weight.

It can be concluded that *in-situ* method of seed production proved to be significantly superior for maximum seed yield and quality as compared to the *ex-situ* transplanting method whereas amongst dates of transplanting, 30th September transplanting performed better with respect to most of the seed characters under study. With regard to the interaction effect, M_1D_1 i.e. *in-situ* method of seed production and 1st date of transplanting (30th September) performed better for seed production under Jammu Sub-tropics.

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Appendices

APPENDIX I

Meteorological data during the cropping season 2019-2020

Standard Week	Relative Humidity (%)		Temperature (ºC)		Rainfall
	Max.	Min.	Max.	Min.	
27Aug.-2 Sept. 2019	88.0	61.0	35.2	26.7	2.0
3-9 Sept.	85.0	62.0	34.6	25.6	9.0
10-16 Sept.	87.0	63.0	35.0	25.9	3.0
17-23 Sept.	89.0	61.0	32.2	23.0	62.8
24-30 Sept.	93.0	76.0	29.7	23.1	93.4
1-7 Oct.	89.0	65.0	28.8	18.8	21.4
8-14 Oct.	86.0	52.0	30.5	18.6	0.0
15-21 Oct.	87.0	52.0	29.2	17.3	9.2
22-28 Oct.	85.0	44.0	29.3	14.5	0.0
29 Oct.- 4 Nov.	90.0	52.0	28.0	15.8	0.0
5-11 Nov.	83.0	52.0	25.4	13.0	51.8
12-18 Nov.	90.0	62.0	24.0	13.4	2.8
19-25 Nov.	93.0	63.0	22.4	12.4	0.8
26 Nov. -2 Dec.	93.0	52.0	21.9	9.8	22.0
3-9 Dec.	90.0	46.0	22.4	6.4	0.0
10-16 Dec.	94.0	73.0	16.7	7.8	82.6
17-23 Dec.	95.0	77.0	14.2	8.4	1.2
24-31 Dec.	91.0	78.0	10.5	6.6	0.0
1-7 Jan. 2020	92.7	65.9	15.6	5.9	7.8
8-14 Jan.	92.7	66.6	15.7	6.2	55.6
15-21 Jan.	91.6	61.6	17.2	7.6	0.0
22-28 Jan.	90.0	55.6	18.2	6.0	0.0
29 Jan -4 Feb.	92.1	64.0	16.6	5.1	18.2
5-11 Feb.	91.9	49.7	19.0	4.8	0.0
12-18 Feb.	93.3	47.1	24.3	8.5	0.0
19-25 Feb.	86.7	47.3	23.3	10.1	9.2
26 feb-04 Mar.	90.4	52.4	24.5	11.8	20.0
5-11 Mar.	88.6	61.4	20.5	10.7	35.4
12-18 Mar.	81.0	53.6	24.2	10.2	40.8
19-25 Mar.	83.1	51.3	26.0	13.9	9.0
26 Mar -1 Apr.	81.6	61.1	25.3	14.0	50.4
2-8 Apr.	77.1	44.4	28.0	13.2	6.8
9-15 Apr.	74.4	39.4	32.7	17.2	0.0
6-22 Apr.	67.4	44.3	30.9	17.2	15.0
23-29 Apr.	69.3	38.9	32.4	18.6	4.0

Source: Meteorological section, Division of Agronomy, Sher-e Kashmir University of Agricultural Sciences & Technology of Jammu, Chatha-180009

Analysis of variance for method of seed production and date of transplanting in broccoli

APPENDIX II

Days to 50% bolting

Source	D.F	S.S	M.S	F-Cal
Methods	1	442.04	442.04	39.91
Dates	2	816.33	408.16	36.85
Interaction effect	2	86.33	43.16	3.89
Error	15	166.12	11.07	

APPENDIX III

Days to 50% flowering

Source	D.F	S.S	M.S	F-Cal
Methods	1	759.37	759.37	90.55
Dates	2	652.33	326.16	38.89
Interaction effect	2	133.00	66.50	7.93
Error	15	125.79	8.38	

APPENDIX IV

Plant height (cm) at maturity stage

Source	D.F	S.S	M.S	F-Cal
Methods	1	2,790.74	2,790.74	225.58
Dates	2	805.38	402.69	32.55
Interaction effect	2	105.67	52.83	4.27
Error	15	185.56	12.37	

APPENDIX IV

Plant spread (cm)

Source	D.F	S.S	M.S	F-Cal
Methods	1	1,632.52	1,632.52	26,071.69
Dates	2	2,494.90	1,247.45	19,922.12
Interaction effect	2	37.14	18.57	296.60
Error	15	0.93	0.06	

APPENDIX VI

Number of Primary branches per plant

Source	D.F	S.S	M.S	F-Cal
Methods	1	102.75	102.75	91.28
Dates	2	198.67	99.33	88.24
Interaction effect	2	9.99	4.99	4.43
Error	15	16.88	1.12	

APPENDIX VII

Days to seed maturity

Source	D.F	S.S	M.S	F-Cal
Methods	1	690.05	690.05	183.76
Dates	2	1,654.61	827.30	220.31
Interaction effect	2	80.10	40.05	10.66
Error	15	56.32	3.75	

APPENDIX VIII

Number of siliqua per plant

Source	D.F	S.S	M.S	F-Cal
Methods	1	152,944.61	152,944.61	170.82
Dates	2	273,327.02	136,663.51	152.63
Interaction effect	2	19,738.23	9,869.11	11.02
Error	15	13,430.33	895.35	

APPENDIX IX

Siliqua length (cm)

Source	D.F	S.S	M.S	F-Cal
Methods	1	0.96	0.96	74.33
Dates	2	1.70	0.85	65.76
Interaction effect	2	0.42	0.21	16.34
Error	15	0.19	0.01	

APPENDIX X

Number of seeds per siliqua

Source	D.F	S.S	M.S	F-Cal
Methods	1	14.50	14.50	140.39
Dates	2	35.94	17.97	173.92
Interaction effect	2	0.86	0.43	4.16
Error	15	1.55	0.10	

APPENDIX XI

Seed yield per plant (g)

Source	D.F	S.S	M.S	F-Cal
Methods	1	125.49	125.49	150.45
Dates	2	162.46	81.23	97.38
Interaction effect	2	12.85	6.42	7.70
Error	15	12.51	0.83	

APPENDIX XII

Seed yield per hectare (kg)

Source	D.F	S.S	M.S	F-Cal
Methods	1	84,490.67	84,490.67	151.90
Dates	2	108,918.75	54,459.38	97.91
Interaction effect	2	8499.08	4,249.54	7.64
Error	15	8,343.17	556.21	

APPENDIX XIII

Test weight (g)

Source	D.F	S.S	M.S	F-Cal
Methods	1	0.26	0.26	28.88
Dates	2	0.42	0.21	22.87
Interaction effect	2	0.03	0.01	1.80
Error	15	0.14	0.01	

APPENDIX XIV

Germination Percentage (%)

Source	D.F	S.S	M.S	F-Cal
Methods	1	6.93	6.93	14.30
Dates	2	139.26	69.69	143.66
Interaction effect	2	6.52	3.26	6.73
Error	15	7.27	0.48	

Vita

CURRICULUM VITA

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CERTIFICATE-IV

Certified that all the necessary corrections as suggested by the external examiner and the Advisory Committee have been duly incorporated in the thesis entitled **"Seed production in broccoli (*Brassica oleracea* var. *italica*) under Jammu Sub-tropics"** submitted by **Ms. Zahida Parveen, Registration No. J-18-M-588.**

Manoj Kumar

Dr. Manoj Kumar
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