INFLUENCE OF SOWING TIME WITH ORGANIC AND INORGANIC FERTILIZER ON THE GROWTH AND YIELD OF FENNEL (*Foeniculum vulgare*)

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JUNE, 2021

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REGISTRATION NO. 14-06145

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfil of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
HORTICULTURE

SEMESTER: JANUARY–JUNE, 2021

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CERTIFICATE

*This is to certify that thesis entitled, "**INFLUENCE OF SOWING TIME WITH ORGANIC AND INORGANIC FERTILIZER ON THE GROWTH AND YIELD OF FENNEL (Foeniculum vulgare)**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in HORTICULTURE** embodies the result of a piece of bona-fide research work carried out by **MOST. JAKIA SIDDIKA**, Registration no. **14-06145** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Date:
Place: Dhaka, Bangladesh

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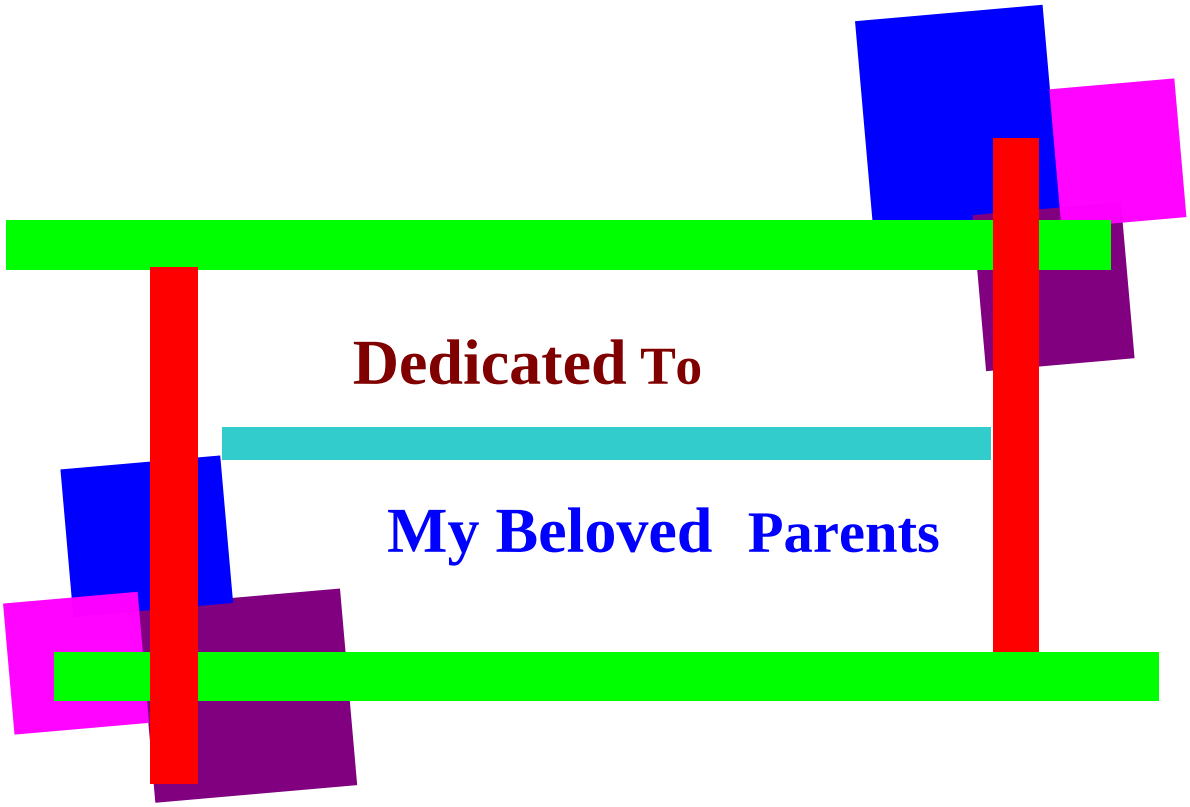
Dedicated To
My Beloved Parents

ACKNOWLEDGEMENTS

All praises are putting forward to The Almighty Who is the Supreme Planner and has blessed the author to complete this piece of study as required for the degree Master of Science.

It is a great pleasure for the author to make delighted her respected parents, who had been shouldering all kinds of hardship to establish a favorable platform thereby receiving proper education until today.

The author is happy to express her sincere appreciation and profound gratitude to her respective supervisor ***Prof. Dr. Khaleda Khatun****, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka for her dynamic guidance, constant encouragement, constructive criticism and valuable suggestions encompassed the research work and thesis writing times.*

It is a great pleasure for the author to express her deep sense of gratitude and sincere regards to her Co-Supervisor ***Prof. Dr. A.F.M. Jamal Uddin****, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka for his adept guidance, supervision, kind cooperation, and valuable suggestions in preparation of the thesis.*

It is highly appreciating words for ***Prof. Dr. Khaleda Khatun****, Chairman, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka along with faculties of the Department of Horticulture, Sher-e-Bangla Agricultural University for their rendered noble services towards me as their student.*

The author also expresses heartfelt thanks to the staff of Department of Horticulture Farm, SAU, for their cordial help and encouragement during the period of research work.

*The author would also like to convey her sincere thanks and gratitude to the Ministry of Science and Technology (****NST fellowship****) for sponsoring the research, which enabled her to do it proficiently.*

The author expresses her heartfelt thanks to her brothers, sisters, uncles, aunts and other relatives who continuously prayed for her success and without whose love, affection, inspiration and sacrifice this work would not have been completed.

May Allah bless and protect them all.

The Author
June, 2021

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ABSTRACT

The present research work was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during October, 2019 to July, 2020 to study the influence of sowing time with organic and inorganic fertilizer on the growth and yield of fennel (*Foeniculum vulgare*). The experiment consisted of two factors: Factors-A: Sowing time (4 levels): S_1 = First week of November, S_2 = Last week of November, S_3 = First week of December and S_4 = Last week of December; Factors-B: Nutrients (4 levels): T_0 = Control, T_1 = Vermicompost (2.50 t ha^{-1}), T_2 = NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}) and T_3 = Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}). The result revealed that S_2 treatment exhibited its superiority to other tested sowing time first week of November and first week of December in terms of seed yield, the former out-yielded over S_1 by 9.75% and S_3 by 15.38% higher yield. S_2 treatment also showed the tallest plant at harvest (107.44 cm), maximum number of leaves (12.68), maximum number of umbellet $umbel^{-1}$ (24.53), number of umbel $plant^{-1}$ (22.94), maximum weight of 1000-seeds (5.96 g), the highest seed yield $plant^{-1}$ (32.36 g) and the highest seed yield $plot^{-1}$ (0.16 kg). On the other hand, treatment S_4 returned with 19.46% lower yield than S_2 which was significantly the lowest compare with other treatments under study. Significant differences existed among different levels of nutrient application where a yield advantages of 0.66 t ha^{-1}, 1.06 t ha^{-1} and 1.36 t ha^{-1} over T_2, T_1 and T_0 treated plot, respectively was recorded from the T_3 treatment; which was possibly aided by the tallest plant at harvest (114.83 cm), maximum number of leaves (14.02), maximum number of umbellet $umbel^{-1}$ (25.58), number of umbel $plant^{-1}$ (24.39), maximum weight of 1000-seeds (5.97 g), maximum seed weight $umbel^{-1}$ (1.92 g), the highest seed yield $plant^{-1}$ (47.76 g) and the highest seed yield $plot^{-1}$ (0.24 kg) recorded in T_3 treatment. Significantly the highest seed yield (2.34 t ha^{-1}) was found in S_2T_3 interaction due to the tallest plant at harvest (117.59 cm), number of leaves (15.07), maximum number of umbellet $umbel^{-1}$ (27.72), number of umbel $plant^{-1}$ (26.75), maximum weight of 1000-seeds (6.38 g), maximum seed weight $umbel^{-1}$ (2.09 g), the highest seed yield $plant^{-1}$ (56.04 g) and the highest seed yield $plot^{-1}$ (0.28 kg) production. From economic point of view, S_2T_3 and S_1T_3 combination was found profitable for fennel cultivation in Bangladesh and S_2T_3 treatment [(Last week of November sowing with Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})] was the most profitable than rest of the combination.

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[1]The title of thesis paper presented for the partial fulfillment of MS degree

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LIST OF ABBREVIATIONS

Abbreviated form	Full form
%	Percentage
@	At the rate of
AEZ	Agro-Ecological Zone
Agril.	Agricultural
Agric.	Agriculture
Agron.	Agronomy
Annu.	Annual
Appl.	Applied
BBS	Bangladesh Bureau of Statistics
Biol.	Biology
Chem.	Chemistry
cm	Centi-meter
CV	Coefficient of Variance
cv.	Cultivar (s)
DAP	Days After Planting
DAS	Days After Sowing
Dev.	Development
Ecol.	Ecology
eds.	editors
Environ.	Environmental
et al.	et alia (and others)
etc.	et cetera (and other similar things)
Exptl.	Experimental
FAO	Food and Agricultural Organization
g	Gram (s)
Hortc.	Horticulture
i.e.	id est (that is)
J.	Journal
kg	Kilogram (s)
L.	Linnaeus
LSD	Least Significant Difference
M.S.	Master of Science
M^2	Meter squares
mg	Milligram
MoP	Muriate of Potash
Nutr.	Nutrition
Physiol.	Physiological
Progress.	Progressive
Res.	Research
SAU	Sher-e-Bangla Agricultural University

LIST OF ABBREVIATIONS

Abbreviated form	Full form
Sci.	Science
Soc.	Society
SRDI	Soil Resource Development Institute
t ha^{-1}	Ton per hectare
TDM	Total Dry Matter
TSP	Triple Super Phosphate
UNDP	United Nations Development Programme
var.	variety
viz.	videlicet (L.), Namely
Vm	Vermicompost
µMol	Micromole

CHAPTER I

INTRODUCTION

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INTRODUCTION

Foeniculum vulgare Mill., universally known as fennel, is a medicinal and aromatic plant belonging to the *Apiaceae* (*Umbelliferae*) family. All parts of the plant such as root, stem, leaves and especially seeds are aromatic and can be used in many ways (Badgujar *et al.*, 2014). It is a traditional and popular herb which can be used to reduce different disease (Badgujar *et al*., 2014) The valuable properties of fennel plant are due to its different chemical compounds (Kooti *et al.*, 2015). Phenols, phenolic glycosides and volatile aroma compounds such as trans-anethole, estragole and fenchone have been reported as the major phytoconstituents of this species (Rather *et al.*, 2016).

Fennel is widely cultivated in Europe, Asia, the USA and many African countries as well as Brazil and Argentina for medicinal and feeding purposes (Kapoor *et al*., 2004). In Bangladesh, the area under spices cultivation is 3.96 lakh hectares with annual production of 24.88 lakh metric tons (BBS, 2016) and the annual demand of spices seeds are 30 lakh metric tons. But fennel production is very low compared to that other spices. Fennel is a minor spices crop in Bangladesh and is cultivated throughout the country in winter season.

Sowing date are very important parameters in crop production. Adjustment in sowing time creates favourable environmental condition for better performance of all physiological processes in plant and for escaping from pest and diseases which provides great opportunity to maximize the production. Some researchers recommend autumn (October-November) as the suitable sowing date for fennel given the optimum temperature for its germination (6-8°C), although in the case of the occurrence of long chilling, the roots might be struck by hypothermia which may lead to desiccation of the plants (Thomas, 1994; Ayub *et al*., 2008). In this respect, El-Khayat and Gouda (2005), Sudeep *et al.* (2005), Tunio *et al.* (2005), Omidbaigi *et al.* (2006), Sudeep *et al.* (2006), Ayub *et al.* (2008), Singh

et al. (2009), Blazewicz (2010) and Sanjeet *et al.* (2010) they noticed that the early sowing has positive effect on plant growth, seed yield, oil production and plant chemical constituents.

Plant nutrient one of the most important factors that increase plant production. Adequate supply of nutrients increases the yield. Vermicompost has the potential to be an important soil conditioner in agriculture, as its nutrient-rich nature foster plant growth. The main purpose of vermicompost is to recycle organic residues into a nutritive product (Yadav and Singh, 2014). Application of nutrient such as NPK and vermicompost will induce the fennel production. The application of nitrogen not only increased seed yield but also improved oil contents (El-Wahab and Mohamed, 2007). According to Omidbaigi and Hornok (1992) and Abdallah *et al.* (2021) nitrogen application had a positive effect on plant height and seed yield of fennel. Phosphorus is an important constitutive of bio-molecules such as ATP, phospholipids and nucleic acids in plant. To overcome the phosphorus disability, different types of phosphate fertilizers are utilized to the soil (Gentili *et al*., 2006 and Rotaru and Sinclair, 2009). Potassium is necessary in young growing tissues for cell elongation and possibly for cell division. Potassium is very mobile in plants. It also helps in several physiological processes and uptake of other nutrient elements (Sadanandan *et al*., 2002) and (El-Bassiony,2006). Some studies were conducted for evaluating fennel cultivars (Fawzy et al., 2006; Osman,2009 and Zakinet al., 2009). Integrated nutrient management system required judicious use of nutrients from soil, mineral and biological resources to obtain maximum production with no deleterious effect on biological properties.

Objectives:

1. To identify the sowing time for maximum growth and yield of fennel.
2. To find out the correct dose of nutrient for more seed yield of fennel.
3. To determine the combined effect of appropriate sowing time and nutrient to increase the seed yield of fennel.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Among the spice crops, fennel is very popular for adding sweet smell and flavour in various foods. The proper nutrient supplement through different sources and suitable sowing time essentially influence its morphological characters, yield attributes and seed yield. Improvement work on fennel is limited in Bangladesh. However, a good number of investigations were done under the agro-climatic situations of Egypt, Pakistan, India and elsewhere in the world. Some the relevant research studies performed on fennel so far were reviewed and described under the following headings and sub-headings in this chapter.

2.1 Effect of sowing time on growth, yield contributing and yield attributes of fennel

Abdul-Hafeez *et al.* (2020) conducted a field trial to assess the effect of humic acid concentrations (0, 1.5, 3.0 and 4.5 $g \cdot L^{-1}$) on growth, yield and volatile oil constituents of fennel sown on 15th October, 1st November and 15th November. The earliest date of sowing (15^{th} October) was recorded with the best results regarding all fennel growth, yield and fruit constituents of volatile oil yield. Fennel seed sown in mid-October was recorded to be the best treatment for getting higher fruit yield and high quality of volatile oil.

Makukha (2020) carried out field experiments to determine the effect of presowing seeds bacterization with the phosphate mobilizing biopreparations and sowing dates on the crop productivity and quality indicators of the fennel yield. The experimental design included the following factors and their variants: Factor A: presowing seeds inoculation with biopreparations: without inoculation (control); inoculation with Albobakteryn; inoculation with Polimiksobakteryn; Factor B: sowing date: early (the third ten-day period of March at the right soil tilth stage); mid-time (the first ten-day period of April); late (the second ten-day

period of April). The research findings indicated a tendency to lower the quantitative and qualitative indicators of fennel seed yield from early to late sowing. The most favourable conditions for the productive processes of fennel plants and accumulation of essential oil were ensured by the interaction of seeds bacterization with the Polimiksobakteryn biopreparation and early spring sowing at the right soil tilth stage in the third ten-day period of March. In this variant, the yielding capacity was 1.41 t ha^{-1}, the weight of 1000 seeds reached 5.61 g, the essential oil content in the seeds amounted to 6.13% in dry matter, the relative yield of essential oil being 76.1 kg·ha^{-1}.

Tamboli *et al.* (2020) set up a field experiment to study the effect of sowing time, variety and spacing on growth, yield attributes and yield of *rabi* fennel (*Foeniculum vulgare* Mill.). Eighteen treatment combinations comprising of three sowing times *i.e.,* 3rd week of October (D_1), 1st week of November (D_2) and 3rd week of November (D_3), three varieties *viz.,* Gujarat Fennel-2 (V_1), Gujarat Fennel-11 (V_2) and Gujarat Fennel-12 (V_3) and two spacings *i.e.,* 45 cm (S_1) and 60 cm (S_2) were evaluated. The results showed that the crop sown in 3rd week of October (D_1) was recorded with significantly superior value for the growth parameters, yield attributes and the highest seed yield (1423 kg ha^{-1}) and stover yield (4080 kg ha^{-1}) and as well as economics. The harvest index was not influenced by different times of sowing but the test weight was remarkably influenced by different times of sowing.

Albukhder and Al-Refai (2019) conducted the experiment to study the effect of planting dates and the levels of NPK fertilizer and its interaction on some vegetative and fruits characters of *Foeniculum vulgare* L. The experiment including two factors; the first factor the planting dates were represented by four dates (1st November, 15th November, 30th November and 15th December) respectively, whereas the second factor included four levels of the NPK fertilizers (N_0 P_0 K_0), (N_{60} P_{50} K_{30}), (N_{90} P_{75} K_{45}) and (N_{120} P_{100} K_{60}) Kg Ha^{-1} respectively. The results showed that the planting of fennel plant in the first date (1st November) resulted in increase of all studied vegetative and fruits characters

as compared with plants which was planted at fourth date (15th December). There was significant increment of the studied plant characters which was fertilized by the higher level of fertilizer (N_{120} P_{100} K_{60}) as compared with control treatment.

Makukha *et al.* (2018) carried out field experiments with the objective of determining the effect of seeding dates and depth on the duration of interphase and vegetative periods, biometric characteristics of Common Fennel plants, yielding capacity and seed quality features. The target of research was the common fennel variety Oksamyt Krymu. The experimental design included the following factors and their variants: Factor A: seeding date: early (the third ten-day period of March at the right soil tilth stage); mid-time (the first ten-day period of April); late (the second ten-day period of April); Factor B: seeding depth, cm: 1–2; 2–3; 3–4; 4–5. In the experiment, the biometric characteristics of plants reached their maximum values in the variant of early spring sowing in the third ten-day period of March: plant height was 97.8 cm; leaf surface area made up 27.6 thousand $m^2 \cdot ha^{-1}$; central umbel diameter was 9.4 cm; first order umbels diameter was 7.0 cm. The highest crop productivity and seed quality indices were also recorded under early spring sowing: crop yield was 1.31 $t \cdot ha^{-1}$, 1000-seed weight: 5.21 g. Later sowing (in the first or second ten-day periods of April) led to a decrease in the above-mentioned parameters.

Wafaa *et al.* (2017) set up the research work on Dutch fennel plant strains to detect the effect of sowing dates, organic fertilization, foliar spray of *Spirulina platensis* algae extracts and the interaction among treatments on fruits and essential oil productivity. Seeds of Dutch fennel (*Foeniculum vulgare* spp. *vulgare*) type were sown. The experiment was planned in split split-plot design where the main plots were consisted of three different sowing dates as October 15th, November 1st and November 15th. The subplots included applying of two levels of compost manure before sowing as 10 m^3 and 20 m^3 per feddan. The sub-subplot involved foliar spray of *Spirulina platensis* algae extract as without and with, respectively. The interaction results showed that significantly the

maximum increments in growth, fruits and oil yields were obtained when plants were sown in the early sowing date (15th of October) and received the higher level of compost manure (20 $m^3 \cdot feddan^{-1}$) combined with foliar spray of *Spirulina platensis* extract.

Moosavi *et al.* (2016) conducted an experiment in order to study the effect of sowing date and plant density on essential oil, yield and water use efficiency (WUE) of fennel. The main plot was sowing date at three levels of March 19, April 9 and April 20. The sub-plot was plant density at three levels of 6.7, 10 and 20 plants m^{-2}. According to the results of analysis of variance, seed, biological and essential oil yield and WUE were significantly affected by sowing date, plant density and their interaction. As means comparison showed, delay in sowing from March 19 to April 20 led to 85.6% and 85.6% loss of seed yield and biological yield, respectively. The sowing date of March 19 had higher water use efficiency (WUE) for seed and oil production than the sowing date of April 20 by 5.5% and 3.67%, respectively. However, it increased biological yield and WUE for seed, biomass and essential oil production by 71.8%, 64%, 44.9% and 74.9%, respectively. In general, it was recommended to use sowing date of March 19 for the cultivation of fennel because of having the highest seed and essential oil yield and WUE.

Raj *et al.* (2016) carried out this experiment to study the effect of times and methods of sowing on quality parameters of fennel. The experiment consisted of five dates of sowing (10th October, 20th October, 30th October, 9th November and 19th November) and two planting methods (direct seeding and transplanting). Genetically pure seed of fennel variety HF-33 (Hisar- Swarup) were sown in the experimental field. The results showed that seed quality parameters of fennel were influenced significantly by sowing dates. The seed quality parameters like test weight, germination percentage, seedling length and seed vigour index-1 were higher at 10th October sowing with transplanting crop. Test weight of all the main, primary and secondary umbels decreased with delayed sowing and was the maximum in case of main umbel seed than primary

and secondary umbels. Germination percentage and seed vigour index decreased with delay in sowing from umbels of all categories, irrespective of date of sowing and planting methods. It was concluded that crop sown on 10th October with direct sown method produced bold seed with better seed quality.

Moosavi *et al.* (2014) set up an experiment in order to study the effect of sowing date and plant density on morphological traits and yield of fennel. The main plot was sowing date at three levels of March 19, April 9 and April 30. The sub-plot was plant density at three levels of 6.7, 10 and 20 plants m^{-2}. The results showed that sowing date and plant density significantly affected fennel morphological traits. Plant height decreased by 48.2% at third sowing dates as compared with that at the first sowing date. 21-day delay in sowing decreased auxiliary branch number per plant by 59.2% and stem diameter from 5 mm to 1.8 mm. According the results, single-plant seed and biomass yield and seed yield per hectare were significantly affected by sowing date, plant density and their interaction. Harvest index was not affected by sowing date. As means comparison showed, the delay in sowing from March 19 to April 30 led to 86.7%, 86.8% and 85.6% loss of seed yield per plant, single-plant biomass, seed yield, respectively.

Selim *et al.* (2013) carried out the field work to study the effect of sowing dates (15th Sep., 7th Oct. and 1st Nov.), sow spacing (25, 35 and 50 cm between hills with two plants on a hill) and bio-fertilization (spraying the plants with active dry yeast at 0, 2 and 5 $gm \cdot L^{-1}$ thrice per season) on growth, fruit yield and oil production of fennel plants (*Foeniculum vulgare*, Mill). The results showed that sowing fennel plants on 7th Oct. at 50 cm and spraying with 5 $gm \cdot L^{-1}$ of yeast gave the highest vegetative growth and fruit yield$\cdot plant^{-1}$. The highest number of branches$\cdot plant^{-1}$ was obtained from sowing the plants on 15th Sept. at 50 cm spacing and sprayed with yeast at 5 $gm \cdot L^{-1}$. As well as, the same treatment (sowing the plants on 15th Sept. and sprayed with yeast at 5 $gm \cdot L^{-1}$.) and culture at a distance of 25 cm resulted in the highest values of plant height, number of umbels$\cdot plant^{-1}$ and essential oil percentage$\cdot plant^{-1}$.

Al-Dalain *et al.* (2012) conducted a study to evaluate the effect of planting date and plant spacing and their interactive effects on yield, yield components and growth of fennel under irrigation. Three planting dates (Oct. 1st, Nov. 1st and Dec. 1st) and four plant spacings (10 cm, 20 cm, 30 cm and 40 cm with constant row width, 60 cm) were used. Fruit yield was significantly influenced by plant spacing, planting date and their interaction. Early planting significantly increased the fruit yield combined with higher number of branches per plant, number of umbrellas per plant, number of fruits per plant and plant height. The percentage of increases in Oct. 1st were 34.4% and 32.2% in fruit and biological yield respectively compared with Dec. 1st planting. Harvest index and thousand fruit weight was not significantly affected by planting date. The early planting date with 30 cm plant spacing resulted in· higher fruit (4136 kg·ha^{-1}) and biological yield (10114 kg·ha^{-1}).

Soleymani and Shahrajabian (2012) set up a field trial to study the responses of different fennel cultivars to disruption of irrigation and planting dates. Main plots were irrigation disruption in different stages (I_1: Irrigation until the beginning of stem elongation, I_2: Irrigation until the end of stem elongation, I_3: Irrigation until umbel formation, I_4: Irrigation until seed filling and I_5: Full irrigation), the sub-plots were 30 March and 25 April sowing and sub-sub-plots were five different cultivars, namely, Isfahan, Yazd, Shiraz, CN.uk and B.uk. Planting date had significant effect on number of seeds. Plantation of CN.uk cultivar on 30 March obtained the highest number of umbels, number of umbellets per umbel, number of seeds and seed yield. Also, the maximum 1000-seed weight was related to 30 March. It was concluded that cultivation of CN.uk on 30 March with full irrigation was suitable.

Błażewicz-Woźniak (2010) conducted a field experiment to observe the effect of soil and plant covering and sowing time on the yield of fennel bulbs (*Foeniculum vulgare* var. *azoricum* Mill.) grown from sowing directly in the field. The experiment included the following factors: three kinds of covers — soil covering with black polyethylene film (PE 0.05 mm), soil covering with

black polypropylene non-woven fabric (PP 50 g·m^{-2}) and flat covering of plants with white polypropylene non-woven fabric (PP 17 g·m^{-2}); three sowing terms — April, May and June; two fennel cultivars — 'Rudy F_1' and 'Zefa Fino'. For fennel growing, the most favourable sowing time was April. The lowest yield was obtained from the June sowings.

Ayub *et al.* (2008) set up a field experiment to evaluate the effect of four sowing methods *viz*., broadcast, line sowing (45 cm), ridge sowing (45 cm) and bed sowing (45/45 cm) on growth and yield of fennel sown on 14th September, 14th October and 14th November. The fennel sown on 14th November produced significantly the lowest seed yield than 14th September and 14th October mainly due to lower stand density, number of umbels per plant and number of seeds per umbel. The line sowing of fennel in mid-October was recorded to be the best combination for getting higher fennel seed yield.

Omidbaigi *et al.* (2006) carried out a research work to study the effect of sowing date on fennel CV. Soroksari. The effects of sowing dates of 6 of March, 20 of March, 4 of April, 19 of April, 5 of May, 21 of May, 5 of June and 21 of June, were studied on growth, development, seed yield and essential oil and anethole content of fennel CV. Soroksari. The results showed that sowing dates had significant effect on growth, development and quality and quantity of active substances of fennel. On the basis of the results the seeds were sown on 21 of May the seeds were germinated and developed faster. The tallest plant (150.8 cm) and the largest number of branches per plant (10.1) was obtained from the plants which were sown on 4 of April. There was no significant effect of different sowing dates on 1000-seeds weight. The maximum seed yield (1864.3 kg·ha^{-1}) was obtained from the seeds which were sown on 4 of April. According to the results of this research trial, the most suitable date for sowing of fennel cv. Soroksari was recommended 20 of March to 4 of April.

Ahmad *et al.* (2004) conducted the research to study the effect of different sowing seasons and row spacing on seed production of fennel (*Foeniculum*

vulgare). Two sowing seasons i.e. autumn (15th October) and spring (16th March) and four row spacings i.e. 40, 50, 60 and 70 cm were studied for observing the effect on seed germination, plant height, umbel appearance, umbel maturity, seed weight·umbel^{-1} and seed yield. Autumn sowing resulted in minimum days to germination (8.3), maximum plant height (134.8 cm), days to first and last umbel appearance (137 and 182), days to first and last umbel maturity (67 and 32), seed weight·umbel^{-1} (2.5 g) and seed yield (418.7 kg·ha^{-1}).

Leto *et al.* (1996) set up a trial in 1990–93 at Villalba in Sicily, where a local fennel ecotype was sown on 20 November, 20 December, 20 January and 20 February each year. Seed yields were the maximum (589.2 kg·ha^{-1}) in 1991–92 and from sowing on 20 November (439.9 kg·ha^{-1}).

Bianco *et al.* (1994) carried out two experiments on Florence fennel crop (*Foeniculum vulgare* Mill. var. *azoricum* Thell.) to examine the effect of plant-cutting time (at maturity of 'crown', 7 and 14 days after or 14 and 28 days after) and the effect on plant-cutting of plants grown at three plant densities (5.0; 2.5 and 1.7 plants m^{-2}) sown in August and September on seed yield and quality. In the experiment (sowing dates, plant density and plant-cutting), the crop sown on September flowered 14 days after the crop sown on August, and 'crown' cutting postponed flowering by 9 days. Seed yield decreased with second sowing date and with 'crown' cutting. 'Crown' cutting reduced germination percentage and on the first sowing date increased the time to reach 25%, 50%, 75% and 95% of the final germination.

Suhonen and Kokkonen (1990) conducted an experiment to study the growth and development of sweet fennel ('ZEFA-Fino' and 'ZEFA-Tardo') seedlings which were raised under greenhouse conditions (night temperature 16–18°C) and planted out at 3–4 true leaf stage on May 21st, June 10th, July 7th and July 27th. Plant and bulb weights, bulb width and thickness, stem height inside the bulb and the bulb height in the earliest plantings increased as the growth period lengthened. The ratio between the height of stem inside the bulb and bulb height

increased the fastest in the lot planted under cover in May and in the lot planted out in June; at the fourth harvest the relationship was 0.8. The largest number of bolters (8%) was found in the latter lot. The yield estimates for 'ZEFA-Fino' at the third and fourth harvest was 170–360 kg·are^{-1} depending on planting date and length of the growing season. All lots of 'ZEFA-Tardo' except that planted in July bolted quickly after the bulb width had grown to 60–70 mm.

El-Gengaihi and Abdallah (1978) carried out a two-year experiment to study the effect of date of sowing and plant spacing on yield of seed and volatile oil of fennel (*Foeniculum vulgare* Mill.). Fennel was sown in hills at 20 cm, 30 cm or 40 cm apart on 20 September, 5 October or 20 October. The earliest sown seed produced the tallest plants with the highest number of compound umbels while significantly higher yield of seed was obtained.

2.2 Effect of vermicompost on growth, yield contributing and yield attributes of fennel

Kumar *et al.* (2020) conducted a field experiment to observe the influence of integrated nutrient combinations on relative storability of fennel (*Foeniculum vulgare*) seed. The seed material comprised a single variety Hisar Sawrup. The field experiment consisted of sixteen treatments, viz. T_1 {100% RDN through FYM + *Azotobacter*}, T_2 {75% RDN through FYM + *Azotobacter*}, T_3 {100% RDN through Vermicompost + *Azotobacter*}, T_4 {75% RDN through Vermicompost + *Azotobacter*}, T_5 {RDF (100%) + *Azotobacter*}, T_6 {RDF (75%) + *Azotobacter*}, T_7 {100% RDN through FYM + *Azotobacter* + PSB}, T_8 {75% RDN through FYM + *Azotobacter* + PSB}, T_9 {100% RDN through vermicompost + *Azotobacter* + PSB}, T_{10} {75% RDN through vermicompost + *Azotobacter* + PSB}, T_{11} {RDF (100%) + *Azotobacter* + PSB}, T_{12} {RDF (75%) + *Azotobacter* + PSB}, T_{13} {100% RDN through FYM}, T_{14} {100% RDN through vermicompost}, T_{15} {Recommended dose of fertilizer (N 50 : P 25 kg/ha)} and T_{16} {Control} combinations on the basis of recommended dose of fertilizer (N 50 : P 25 kg/ha), vermicompost, farmyard manure, *Azotobacter* and

PSB of fennel. After accelerated ageing for 24, 48, 72, 96 and 120 hour, the seed received from the treatment T_9: 100% RDN through vermicompost + *Azotobacter* + PSB showed highest standard germination (87.83, 77.34, 69.39, 52.34 and 27.17%), seedling length (20.95, 18.93, 16.15, 14.95 and 12.50 cm), seedling dry weight (3.77, 3.44, 2.84, 2.21 and 1.87 g) and seed vigour index-I (1837, 1474, 1119, 780 and 339) and seed vigour index-II (330.7, 265.7, 196.9, 115.2 and 50.6). The least value observed in treatment T_{16}: control. The lowest value of electrical conductivity at 24, 48, 72, 96 and 120 hours (144.8, 233.0, 353.1, 497.7, 697.78 $\mu S \cdot cm^{-1} \cdot g^{-1}$) was observed in treatment T_9: 100% RDN through vermicompost + *Azotobacter* + PSB the same treatments while the highest value was observed in (T_{16}) control (190.1, 302.9, 434.1, 602.2, 841.8 $\mu S \cdot cm^{-1} \cdot g^{-1}$) on pooled mean basis.

El-Rheem *et al.* (2019) carried out two field experiments to investigate the effect of vermicompost as an alternative to organic compost and its effect on quality and quantity yield and nutritional status of sweet fennel plants (*Foeniculum vulgare* var. Dulce). Six treatments were added, where compost and vermicompost were added at a rate of 100% (5 ton per feddan, which is the recommended doses in the Ministry of Agriculture). Vermicompost was added at rates of 25% and 50%. The compost and vermicompost were mixed at 75% and 25% and 50% to 50% respectively. Seeds of head sweet fennel (cv. Dulce) were sown. The results indicated that the addition of vermicompost to organic compost gave higher results than adding them individually. The highest values of branches number per plant, plant length (cm), fresh and dry weight of shoot and bulb (g) and total green yield ($ton \cdot fed^{-1}$) were obtained when using 50% vermicompost and 50% compost. The addition of vermicompost (100%) improved the bulb dimensions (Length, width and thickness) of sweet fennel.

Mohammadi and Rezaei-Chiyaneh (2019) set up a field experiment to compare the replacement intercropping patterns of fennel (*Foeniculum vulgare* Mill.) and faba bean (*Vicia faba* L.) at different levels of vermicompost. Experimental treatments included six planting ratios: sole cropping of fennel and faba bean,

one row of fennel + one row of faba bean, two rows fennel + two rows faba bean, three rows faba bean + two rows fennel, four rows faba bean + two rows fennel, and two levels of vermicompost: 0 and 10 t·ha^{-1}. Application of vermicompost could increase seed yield by 20.48% in comparison with control (no application of vermicompost).

Patel *et al.* (2019) laid out a field trial to study the effect of integrated weed management in fennel production system and its residual effect on succeeding summer green gram. The fennel cv. 'GF 12' was transplanted in the experimental field. The experiment comprised of ten treatments in which two were organic manure *viz.,* M_1: Farm yard manure @20 t·ha^{-1} and M_2: Vermicompost @8.0 t·ha^{-1} allotted to main plot. Significantly, the highest fennel seed yield (2.09 t·ha^{-1}) was recorded with vermicompost 8.0 t·ha^{-1} application. Higher fennel equivalent yield (2.43 t·ha^{-1}) was recorded with application of vermicompost 8.0 t·ha^{-1}.

Beykkhormizi *et al.* (2018) investigated the interaction between amount of salinity (0, 40, 80, 120 mM NaCl) and vermicompost extract (VCE) on five fennel landraces (Urmia, Mashhad, Shiraz, Boushehr, Isfahan) to find the best salt-tolerant landrace and potential alleviating role of VCE. Application of VCE improved germination and growth of salt-treated fennels. It was concluded that VCE have the potential to alleviate adverse effects of salinity stress on fennel.

Kalasare *et al.* (2018) conducted field experiment to study the effect of integrated nutrient management on fennel. The study involved twelve treatment combinations comprising of integrated nutrient management *viz.,* T_1: Recommended Dose of Fertilizer (RDN-90:30:00 NPK kg·ha^{-1}), T_2: 100% RDN + *Azospirillum* + Vermicompost @ 2 t·ha^{-1}, T_3: 50% RDN + *Azospirillum* + Vermicompost @ 2 t·ha^{-1}, T_4: 100% RDN + *Azospirillum* + PSB (Phosphate solubilizing bacteria) + Vermicompost @ 2 t·ha^{-1}, T_5: 50% RDN + *Azospirillum* + PSB + Vermicompost @ 2 t·ha^{-1}, T_6: 100% RDN + Two spray of vermiwash @ 50 lit·ha^{-1} at 45 and 75 DAS, T_7: 50 % RDN + Two spray of

vermiwash @ 50 lit·ha^{-1} at 45 and 75 DAS, T_8: 100% RDN + 15 kg Humic acid·ha^{-1}, T_9: 50% RDN + 15 kg Humic acid·ha^{-1}, T_{10}: 50% RDN + NADEP @ 5 t·ha^{-1} + 15 kg Humic acid·ha^{-1}, T_{11}: 100% RDN + NADEP @ 5 t·ha^{-1} and T_{12}: 50% RDN + NADEP @ 5 t·ha^{-1}. Result indicated significant differences in seed and haulm yields which was influenced due to residual effect of integrated nutrient management. Treatment T_4 (100% RDN + *Azospirillum* + PSB + Vermicompost @ 2 t·ha^{-1}) produced significantly higher seed and haulm yields among all the treatments except treatment T_2 (100% RDN + *Azospirillum* + Vermicompost @ 2 t·ha^{-1}) and T_{11} (100% RDN + NADEP @ 5 t·ha^{-1}).

Bajya *et al.* (2017) carried out an experiment to study the effect of integrated nutrient management on growth, yield and quality of Fennel (*Foeniculum vulgare* Mill). Treatment consisted of T_1: 100% RDN through fertilizer, T_2: 100% RDN through FYM, T_3: 100% RDN through VC, T_4: 50% RDN through FYM + 50% RDN through fertilizer, T_5: 50% RDN through VC + 50% through fertilizer, T_6: 75% RDN through FYM + 25% through fertilizer and T_7: 75% RDN through VC + 25% through fertilizer. Integrated application of 50% recommended dose of nitrogen (RDN) through vermicompost (VC) + 50% RDN through fertilizers showed higher values of all the growth, yield and quality attributes, viz. plant height, branches·plant^{-1}, fresh weight, dry weight, umbels·plant^{-1}, umbellates·umbel^{-1}, seeds·umbel^{-1}, 1,000-seed weight, seed yield, stover yield, biological yield, harvest index over the absolute 100% RDN through FYM, respectively, closely followed by 50% RDN through FYM + 50% RDN through fertilizers. Therefore, it was recommended to apply 50% RDN through VC + 50% RDN through fertilizers which could reduce chemical fertilizers to 50%.

Abha and Sharma (2016) conducted a two-year experiment to find out the effect of vermicompost, phosphorus and zinc on yield and nutrient uptake of fennel. Thirty-two treatment combinations i.e. two levels of vermicompost (0 and 2 t·ha^{-1}), four levels of phosphorus (0, 20, 40 and 60 kg P_2O_5·ha^{-1}) as main plot treatment and four levels of zinc (0, 3.0, 6.0 and 9.0 kg Zn·ha^{-1}) as sub plot

treatment was laid out. The fennel variety RF-125 was sown. The results of the experiment showed that application of vermicompost 2 t·ha^{-1} significantly increased all the growth parameters *viz.,* plant height, dry weight at different growth stages and branches per plant over control. Yield attributes (number of umbels per plant, number of seeds per umbel and test weight) were found significantly higher at the same level of vermicompost. Application of 2 t vermicompost·ha^{-1} gave 22.23% and 14.35% higher seed and stover yield, respectively over control. Application of 40 kg P_2O_5·ha^{-1} had 43.16% and 25.89% higher seed and stover yield, respectively over control. Combined application of 2 t vermicompost·ha^{-1} and 40 kg P_2O_5·ha^{-1} resulted in the highest seed yield (1377 kg·ha^{-1}).

Kalasare *et al.* (2016) set up a field experiment to study the integrated nutrient management on *rabi* fennel (*Foeniculum vulgare* Mill.). The Fennel variety Gujarat Fennel-2 (GF-2) was sown in second week of November. The experiment comprised of twelve treatment of an integrated nutrient management *viz.,* T_1: Recommended Dose of Fertilizer (RDN-90:30:00 NPK kg·ha^{-1}), T_2: 100% RDN + *Azospirillum* + Vermicompost @ 2 t·ha^{-1}, T_3: 50% RDN + *Azospirillum* + Vermicompost @ 2 t·ha^{-1}, T_4: 100% RDN + *Azospirillum* + PSB (Phosphate solubilizing bacteria) + Vermicompost @ 2 t·ha^{-1}, T_5: 50% RDN + *Azospirillum* + PSB + Vermicompost @ 2 t·ha^{-1}, T_6: 100% RDN + Two spray of vermiwash @ 50 lit·ha^{-1} at 45 and 75 DAS, T_7: 50 % RDN + Two spray of vermiwash @ 50 lit·ha^{-1} at 45 and 75 DAS, T_8: 100% RDN + 15 kg Humic acid·ha^{-1}, T_9: 50% RDN + 15 kg Humic acid·ha^{-1}, T_{10}: 50% RDN + NADEP @ 5 t·ha^{-1} + 15 kg Humic acid·ha^{-1}, T_{11}: 100% RDN + NADEP @ 5 t·ha^{-1} and T_{12}: 50% RDN + NADEP @ 5 t·ha^{-1}. Experimental results revealed that application of 100% RDN (Recommended Dose of Nitrogen) with *Azospirillum* + PSB + vermicompost @ 2 t·ha^{-1} recorded significantly higher plant height at 60 DAS (41.80 cm), 90 DAS (109.20 cm), at harvest (148.00 cm), number of umbels·plant^{-1} (20.57), number of umbellates·umbel^{-1} (23.16), number of seeds·umbel^{-1} (173.69), seed yield (2719 kg·ha^{-1}) and stover yield (3084 kg·ha^{-1})

as well as significantly the highest number of branches·plant^{-1} (9.60) as compared to rest of the treatments.

Gholami *et al.* (2015) conducted an experiment in order to evaluate the effects of vermicompost application, humic acid and mycorrhizal fungi on quantitative and qualitative aspects of fennel yield. This experiment was included with 12 treatments. Vermicompost levels included: V_1 (no application), V_2 (4 t·ha^{-1}) and V_3 (8 t·ha^{-1}). Mycorrhizal fungi included: M_1 (no inoculation) and M_2 (inoculation) and humic acid included: H_1 (no application) and H_2 (application). Plant height, umbels per plant, seed weight per plant, seed and biological yield were significantly affected by the main effects of mycorrhiza, vermicompost and humic acid. The result showed that the highest plant height was obtained with application of 8 t·ha^{-1} vermicompost with mycorrhizal inoculation and humic acid application. There was significant effect of mycorrhiza, vermicompost and their interaction on the number of seeds per umbel; vermicompost, humic acid and mycorrhiza × vermicompost on 1000-seed weight and on seed yield. The highest 1000 seed weight and grain yield were obtained from combination of mycorrhizal inoculation and 8 t·ha^{-1} vermicompost (about 21% and 45% increase in compare with control). The highest value of biological yield was recorded from combination of all factors. Mycorrhizal inoculation with humic acid and 8 t·ha^{-1} vermicompost application produced 4823 kg·ha^{-1} biological yield compared with the control plots (2463 kg·ha^{-1}).

Shivran and Jat (2015) laid out a field experiment to investigate the effect of integrated nutrient management on growth, productivity, quality and economics of fennel (*Foeniculum vulgare* Mill.). Integrated application of 50% recommended dose of nitrogen (RDN) through vermicompost (VC) + 50% RDN through fertilizers showed higher values of all the growth and yield attributes, viz. plant height, branches·plant^{-1}, umbels·plant^{-1}, umbellates·umbel^{-1}, seeds·umbellate^{-1} and 1,000-seed weight to the magnitude of 14.0, 22.0, 45.5, 24.9, 25.4 and 20.6% over the absolute control, respectively, closely followed by 100% RDN through fertilizers. Among the different nutrient-management

practices, significantly the highest mean seed yield (1.82 t·ha^{-1}), stover yield (3.78 t·ha^{-1}) and biological yield (5.60 t·ha^{-1}) were recorded with 50% RDN through VC + 50% RDN through fertilizers realizing 54.4, 51.8, 52.6, 54.4, 59.9, 17.3, 81.1 and 12.9% increase over absolute control, respectively. It was recommended to apply 50% RDN through VC + 50% RDN through fertilizers and reduce chemical fertilizers to 50%.

Valiki *et al.* (2015) carried out an experiment in order to investigate the influence of different level of vermicompost and NPK fertilizer fertilizers on yield, growth parameters and essential oil of fennel (*Foeniculum vulgare* Miller.). The experimental treatments were chemical fertilizer (150 kg N·ha^{-1} + 150 kg phosphate·ha^{-1} + 100 kg potash·ha^{-1}), vermicompost (5, 10, 15 and 20 t·ha^{-1}) and control (without fertilizer). Analysis of variance showed that plant height, number of main and lateral branches, number of umbrellas per plant, number of umbellets per umbrella, seed yield, biological yield and harvest index at different levels of vermicompost and NPK fertilizer statistically significant. Results indicated that using 15 t·ha^{-1} of vermicompost showed more positive effect on recorded traits of fennel than other treatments.

Godara *et al.* (2014) conducted the experiment to evaluate the effect of organic and inorganic sources of nutrients on growth, yield and economics of fennel cultivation. The investigation comprising of eight treatments: [T_1: Absolute control (No nutrition), T_2: 100% recommended dose of nitrogen (RDN) through fertilizers (90:45:0 kg NPK·ha^{-1}), T_3: 100% RDN through farm yard manure, T_4: 100% RDN through poultry manure, T_5: 100% RDN through vermicompost, T_6: 50% RDN through fertilizers + 50% RDN through farm yard manure, T_7: 50% RDN through fertilizers + 50% RDN through poultry manure and T_8: 50% RDN through fertilizers + 50% RDN through vermicompost]. The fennel variety RF-101 was sown manually. Results revealed that RDN through fertilizers and combinations of different organic and inorganic sources produced significantly higher grain yield over absolute control. RDN (100%) applied through fertilizers exhibited highest vegetative growth and yield attributes with maximum yield

(2325 kg·ha^{-1}) closely followed by 50% RDN through fertilizers + 50% RDN through vermicompost.

Moradi *et al.* (2011) set up an experiment in order to evaluate the effects of different organic and biological fertilizers on quantity and quality of fennel essential oil. The experimental treatments included two organic (compost and vermicompost) and two biological (*Pseudomonas putida* and *Azotobacter chroococcum*) fertilizers, their all twin combinations (*Ps. putida* + *A. chroococcum*, *Ps. putida* + compost, *Ps. putida* + vermicompost, *A. chroococcum* + compost, *A. chroococcum* + vermicompost and compost + vermicompost) and control (non-fertilized). Results showed that there was a negative and significant correlation between essential oil percentage and seed yield. The control treatment had the lowest seed yield and the highest essential oil percentage. The essential oil yield was increased with vermicompost + compost by 49% compared with control treatment. The highest and the lowest percentages of essential oil were obtained in control (2.9%) and *A. chroococcum* + vermicompost (2.2%) treatments, respectively. The highest essential oil yield (29.9 L·ha^{-1}) was obtained from compost + vermicompost treatment.

Darzi *et al.* (2006) carried out an experiment in order to study the effects of biofertilizers on yield and yield components in fennel. The factors were mycorrhizal inoculation (inoculated and non-inoculated), bio-phosphate fertilizer (0, 30 and 60 kg·ha^{-1}) and vermicompost (0, 5 and 10 ton·ha^{-1}). Also, these treatments were evaluated with a fertilizer control treatment (NPK: 90, 60 and 90 kg·ha^{-1}). Bio-phosphate fertilizer showed significant effects on plant height and biological yield. Results showed that the tallest plant and maximum biological yield were obtained with consumption of 60 kg·ha^{-1} from bio-phosphate fertilizer. In case of vermicompost. the tallest plant, maximum number of umbels·plant^{-1}, 1000-seed weight, biological yield and seed yield were obtained from vermicompost (10 ton·ha^{-1}). Interactions of two factors of mycorrhizal inoculation and bio-phosphate fertilizer on 1000-seed weight and mycorrhizal inoculation and vermicompost on harvest index were significant.

Comparison of control versus biofertilizer treatments was significant and number of umbels·plant^{-1}, biological yield and seed yield in two treatments of fifteenth (mycorrhizal inoculation-30 kg·ha^{-1} bio-phosphate fertilizer-10-ton ha^{-1} vermicompost) and eighteenth (mycorrhizal inoculation-60 kg·ha^{-1} bio-phosphate fertilizer-10 ton·ha^{-1} vermicompost) from biofertilizer treatments were higher than that of control. There was a positive and significant correlation between seed yield with plant height, number of umbels·plant^{-1}, 1000-seed weight and biological yield.

2.3 Effect of nutrients on growth, yield contributing and yield parameters of fennel

Abdallah *et al.* (2021) undertook a two-season field study to investigate the response of fennel crop to two different herbicides under the application of biofertilizers. The three biofertilizer rates were F_1: Biofertilizer at ratio of (1:1:1), F_2: Biofertilizer at ratio of (2:1:1) and F_3: Biofertilizer at ratio of (1:1:2) (v/v/v) obtained from the highly efficient bacterial strains of; *Azotobacter Croccuccum* and *Azospirillum brasilense* (mixed well together by 1:1 (v/v)) used for atmospheric nitrogen fixation, *Bacillus megatherium* var. *phosphaticum* for phosphorus-dissolving and *Bacillus circulans* as potassium-solubilizing bacteria, respectively. The two herbicides were pendimethalin (at reduced rate), fluazifop-p butyl and a combination of sequential application of both of them. The results indicated that under all rates of the biofertilizers, the two herbicides applied individually caused significant reduction in growth parameters of the fennel plant estimated. Hand weeding (untreated check) increased fruit yield by 63% and oil yield by 78% compared to unweeded control, while sequential application of pendimethalin + fluazifop increased fruit yield by 45% and oil yield by 83% under biofertilizers at the rate of 2:1:1 (v/v/v). However, fluazifop alone showed no significant differences (13.63 and 13.13%) during both seasons under the biofertilizer rate of 2:1:1. The obtained results concluded that using

proper level of biofertilizer combined with herbicides would increase the seed yield of fennel.

Rajpoot *et al*. (2021) conducted a front-line demonstration to demonstrate the improved package of practice of fennel var. A.F.-2. There were two treatments in which the first one was local check and the second one was cultivation of improved variety of fennel with full package of practice under drip and fertigation. Fertigation was done as per the recommended dose of NPK with 60 ∶ 50 ∶ 120 kg of NPK·ha^{-1} and was applied throughout the cropping period once in three days. Water soluble fertilizers like 19 ∶ 19 ∶ 19, 0 ∶ 0 ∶ 50 and urea were used. Locally cultivated variety of fennel as practiced by the farmers with their own management system was taken as the farmers practice. The result revealed that local check gave a yield of 4.12 q·ha^{-1}. While fennel cultivation with full package of practices along with drip and fertigation gives a yield of 16.56 q·ha^{-1}, which shows that by adopting package of practices there were 308.73% increase in fennel seed yield. By conducting front line demonstration (FLDs) of proven technologies, yield potential of fennel can be increased up to great extent. The extension gap and technology gap ranged between 12.51 to 13.07 and 82.25 to 98.25 q·ha^{-1}, respectively, with the technology index of 6.90% during the demonstration years.

Abdou *et al*. (2020) carried out an experiment with the aim of studying the effect of organic fertilizer (compost) and bio-fertilization treatments {phosphorein (PHOS) – Effective microorganisms (EM) - Minia azoteine (MA) and their combinations} and their interaction on oil production and some chemical compounds, namely, photosynthetic pigments (chlorophyll a, b and carotenoids) and nutrients percentage (N, P and K %) on fennel plants. The main plots (A) included four levels of compost, (0, 10, 15 and 20 ton·feddan^{-1}.) while seven treatments of bio-fertilization: Phosphorein (PHOS), Effective microorganisms (EM), Minia azotein (MA), (PHOS + EM), (PHOS + MA), (PHOS + EM + MA) and control treatments occupied the sub-plots (B). The obtained results indicated that the application of compost significantly increased oil productivity in the

seeds (oil%, oil yield per plant and per feddan) and the studied chemical components (chlorophyll a, b and carotenoids; and N, P and K%), the best treatment was 20-ton compost·feddan^{-1}. All studied parameters were significantly affected by bio-fertilization; the best treatment was PHOS + EM + MA. Also, the interaction effect between the two factors was significant and the best interaction treatment was compost at 15 or 20 ton·feddan^{-1} with (PHOS + EM + MA) of bio-fertilization.

Barzegar *et al*. (2020) investigated the effect of different levels of nitrogen (N) and potassium (K) fertilizers on vegetative fresh bulb yield, quality and biochemical attributes of sweet fennel in spring 2017 and 2018. Treatments consisted of 0, 50, 100, or 150 kg ha^{-1} of N and K. Results showed that, the bulb fresh yield increased with application of N and K in both years, while the higher level of K had significant adverse effect in first year. In both years, alone or combined application of N and K increased total soluble solids (TSS) content as compared to control, and this effect was more pronounced in 2017 season. Macronutrient contents of bulb including magnesium (Mg), phosphorus (P), K, N and calcium (Ca) were significantly enhanced by NK fertilizer, however an alone application of K decreased Ca and Mg nutrient contents. Therefore, to improve fresh bulb yield, quality and antioxidant capacity in sweet fennel, 150 kg ha^{-1} K and 100 kg ha^{-1} N was recommended.

Ibrahim *et al*. (2020) conducted a study to investigate the effect of nitrogen and biofertilizers (nitrobein) as well as the irrigation intervals on fennel growth, oil yield and its quality. Fertilization treatments were as follows: T_1 (Control treatment without any fertilizers), T_2 (25% the recommended dose nitrogen fertilizer), T_3 (50% nitrogen fertilizer), T_4 (75% nitrogen fertilizer), T_5 (100% nitrogen fertilizer), T_6 (the biofertilizer only), T_7 (25% nitrogen fertilizer + the biofertilizer), T_8 (50% nitrogen fertilizer + the biofertilizer), T_9 (75% nitrogen fertilizer + the biofertilizer) and T_{10} (100% nitrogen fertilizer + the biofertilizer). The results showed that, the increase in the nitrogen level added accompanied by a significant increase in plant growth and yield of seeds. The treatment of the

100% nitrogen of the recommended dose gave the highest seed yield. Application of biofertilizers increased the growth measurements and the yield of seeds (2.1 kg·ha^{-1}).

Salama and Khater (2020) set up a research work to study the effect of harvesting time, different sources of potassium and their interaction on plant growth, seed yield, volatile oil production and constituents of Dutch fennel plants. The experiment included 8 treatments, two treatments for harvest time (120 and 160 days after planting) in the main plots and four treatments for different sources of potassium in the sub-main plots. The different sources of potassium (control, KCl 60%, K_2NO_3 44.5% and K_2SO_4 48%). Results revealed that the maximum values of plant height (cm), number of umbels, fruit yield·plant^{-1} (g) and fruit yield·feddan^{-1} (kg) were obtained from interaction treatments of second harvest time + KNO_3.

Abdelkader *et al.* (2019) carried out a study to evaluate the effect of different phosphorus fertilization rates at [0.0, 30 and 45 kg·feddan^{-1} as P_2O_5, Nano-micronutrients concentrations (0.0, 250, 500 and 1000 mg·L^{-1}) as well as their combinations on growth and production of fennel (*Foeniculum vulgare*, L.). Phosphorus fertilization as main plots and Nano-micronutrients called "Magro NanoMix" which contained (Fe 6%, Zn 6%, B 2%, Mn 5%, Cu 1% and Mo 0.1%) as subplots were considered. Fennel plants treated with phosphorus fertilizer or/and nano micronutrients instigated critical increments in vegetative growth (plant height and branch number·plant^{-1} as well as dry weight of herb·plant^{-1}) and yield (number of inflorescences·plant^{-1}, fruit yield·plant^{-1} and fruit yield·feddan^{-1}), as contrasted and untreated plants. In general, 45 kg P_2O_5·feddan^{-1} + 500 or 1000 mg·L^{-1} of nano-micronutrients as foliar spray had significant effects in above mentioned parameters of fennel plant compared to the other combinations.

Bhagvanbhai (2019) conducted a field experiment to assess the effect of potassium and sulphur nutrition on growth and yield of drilled rabi fennel

(*Foeniculum vulgare* Mill.). The field experiment comprising of four levels of potassium viz., 0, 20, 40 and 60 kg·ha^{-1} and three levels of sulphur viz., 0, 20 and 40 kg·ha^{-1}. The results revealed that the yield attributes and yield were significantly influenced by the various levels of potassium and sulphur. Application of potassium @ 60 kg·ha^{-1} was observed superior over rest of the levels in increasing plant height, number of branches per plant, days to 50% flowering, days to maturity, number of umbels per plant, number of umbellates per umbel, number of seeds per umbellate, 1000-seed weight, seed yield (1918 kg·ha^{-1}) and stover yield (2148 kg·ha^{-1}) over the control. The sulphur application @ 40 kg·ha^{-1} significantly increased plant height, days to 50% flowering, maturity, number of umbels per plant, number of umbellates per umbel, number of seeds per umbellate, 1000-seed weight, seed yield (1866 kg·ha^{-1}) and stover yield (2076 kg·ha^{-1}). While number of branches per plant was not influenced by S application.

Mohammadi *et al.* (2019) set up an experiment to investigate the effects of different nitrogen and potassium fertilizer rates on nitrogen use efficiency (NUE), nitrogen uptake efficiency (NUPE), nitrogen utilization efficiency (NUTE) and N, K, P, Ca and Mg nutrient contents in sweet fennel. The applied fertilizers included 50, 100, and 150 kg·ha^{-1} of N and K from urea and potassium sulfate sources, respectively. N and K application had significant effect on NUE and N, P, Ca, P, and Mg contents. Increasing nitrogen application rate levels decreased NUE, NUPE, and NUTE. Increasing of K application rate caused increment of N efficiency. Application of N and K fertilizers increased N, K and P concentrations on bulb tissues. Increasing N application rates resulted in more Ca and Mg concentrations, but application of K decreased Ca and Mg contents in bulb tissue. Regarding short growing period of sweet fennel, lower rates of N fertilizer is recommended to improve NUE.

Sakarvadia *et al.* (2019) conducted a field experiment to study the effect of nitrogen and sulphur levels on yield attributes, yield and quality of fennel (*Foeniculum vulgare* Mill.). The treatments comprised all possible combinations

of four levels of nitrogen viz., 0, 60, 90 and 120 kg·ha^{-1} and three levels of sulphur viz., 0, 20 and 40 kg·ha^{-1}. Fennel var. 'Gujarat Fennel-11' was selected for the experiment. Application of 120 kg nitrogen·ha^{-1} was recorded to be the superior treatment over rest of the levels of N in increasing plant height, number of branches per plant, number of umbels per plant, number of umbellate per umbel, number of seeds per umbellates, weight of 1000-seed, protein content, seed yield and stover yield. Application of 40 kg sulphur·ha^{-1} significantly increased plant height, number of branches per plant, number of umbels per plant, number of umbellates per umbel, number of seeds per umbellates, weight of 1000-seed, seed yield and stover yield. Interaction effect of nitrogen and sulphur was found significant with respect to umbellates per umbel, seed yield and stover yield. Combined application of 90 kg N·ha^{-1} along with 40 kg S·ha^{-1} recorded significantly higher number of umbellates per umbel, seed yield and stover yield than rest of the treatment combination.

Zamani *et al.* (2018) studied the effect of biofertilizers on the seed yield and yield components of fennel (*Foeniculum vulgare* L.). The first factor included three Landraces (Urmia, Hamdan and Germany) and second factor included four biofertilizers: complete biofertilizers (Azetobarvar1, Phosphatebarvar2, Pota barvar-2), mycorrhizal fungi (*Glomus intraradices*), complete biofertilizers + mycorrhizal fungi and control. Results indicated that application of biofertilizers enhanced the seed yield and yield components. Among treatments, combined usage of biofertilizers showed significant increase in studied traits than individual consumption. The highest biological yield (520.38 g·m^{-2}) and seed yield (146.68 g·m^{-2}) were obtained from combined usage of biofertilizers.

Talukder *et al.* (2017) carried out a field experiment to find out an optimum dose of N, P, K and S for yield maximization of fennel during the rabi season of 2011–2012 and 2012–2013. Seeds of fennel of high yielding local variety were sown in the last week of September in plots at 50 cm × 30 cm spacing. Treatments comprising four levels of N (0, 30, 60, 90 kg ha^{-1}), four levels of P (0, 10, 20, 30 kg ha^{-1}), four levels of K (0, 25, 50, 75 kg ha^{-1}) and four levels of S (0, 5, 10, 15

kg ha^{-1}). The combined effect of NPKS significantly increased yield and yield attributes of fennel. The highest seed yield of 1804 kg ha^{-1} during 2011–2012 and 1569 kg ha^{-1} during 2012–2013 was obtained from T_3 treatment (N_{60} P_{30} K_{50} S_{10} kg ha^{-1}). From the regression analysis, it was concluded that around 50 kg nitrogen, 15 kg phosphorous, 50 kg potassium and 10 kg sulphur per hectare of land was found optimum for fennel production in terrace soil of level Barind tract, Bogura.

Waskela *et al.* (2017) conducted an experiment to study the effect of row spacing and NPK levels on the growth and yield of fennel. The experiment consisted of 3 levels of row spacing (30 cm, 45 cm and 60 cm) and 4 levels of NPK (0 + 0 + 0, 30 + 20 + 20, 60 + 40 + 40 and 120 + 60 + 60 kg·ha^{-1}). The seeds of cultivar NRCSS AF-1 were sown. Influence of NPK application indicated that increasing level of NPK up to 60:40:40 kg·ha^{-1} significantly improved days to 50% flowering, number of umbels per plant, number of umbellets per umbel, number of seeds per umbel, test weight and seed yield. Among the various NPK levels tried, 60 + 40 + 40 kg·ha^{-1} exhibited significantly the higher seed yield (12.29 q·ha^{-1}) of fennel in comparison to lower NPK levels. Levels of NPK application indicated that increasing level of NPK up to (120:60:60 kg·ha^{-1}) significantly improved straw and biological yield. A perusal of results indicated that increasing levels of NPK increased seed yield and straw yield of the crop up to 60:40:40 kg·ha^{-1}. These increased could be ascribed to its direct influence on dry matter accumulation at successive growth stages while indirect influence seems to be *viz*. improvement in various morphological and yield attributing characters.

Bhardwaj (2016) undertook a study in farmer's field to observe the effects of potassium (K) fertilization on transplanted fennel (*Foeniculum vulgare* Mill.) production. Four treatments (K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}, K_4 = 80 kg K ha^{-1}) were compared. 45 days old seedlings of fennel local cultivar 'Abu saunf' were transplanted. The highest value of plant height, primary branches·plant^{-1}, secondary branches·plant^{-1}, number of leaves, number of roots·plant^{-1}, tap root length, fresh weight of shoot, fresh weight of root and

the minimum root ∶ shoot ratio was recorded from the application of potassium @ 60 kg ha^{-1}. The maximum value of number of umbels·$plant^{-1}$, umbellate·$umbel^{-1}$, number of seeds·$umbel^{-1}$, test weight, seed yield, straw yield and harvest index was also observed in same treatment.

Delfieh *et al.* (2016) carried out a field experiment in order to investigate the effects of different nitrogen nutritional systems including chemical, organic and biologic ones on yield and essential oil content, yield and constituents of Fennel (*Foeniculum vulgare* Mill.). Different nitrogen system treatments consisting of: 1. N_1 or control (Uniformly spreading urea fertilizer in the plot, 50% at planting time and 50% at stem elongation), 2. N_2 (Uniformly spreading 50% of urea fertilizer in the plot at planting time and spraying the other 50% of urea fertilizer at stem elongation on fennel foliage), 3. N_3 or cow manure, 4. N_4 or bio-fertilizer (Inoculation of fennel seeds with *Azotobacter* and *Azospirillum*), 5. N_5 or Integrated-1 (Cow manure + uniformly spreading urea fertilizer in the plot at stem elongation), 6. N_6 or Integrated-2 (Cow manure + bio-fertilizer) were applied. Results showed that urea spraying has led to 13.4% more seed yield production than control. Moreover, the findings showed that replacing 50 percent of required nitrogen with cow manure in fennel, could lead to a favourable quantitative and qualitative seed production as well as the treatments which used 100 percent of nitrogen as chemical fertilizers. Other findings of the study showed that seed inoculation with biofertilizer (*Azotobacter* + *Azospirillum*) had no positive effect on plant seed yield.

Ayub *et al.* (2015) conducted a field experiment to study the effects of nitrogen and phosphorus fertilizer treatments (NP in ratio of 0∶0, 30∶0, 0∶30, 30∶15, 30∶30, 60∶30, 60∶60, 90∶45 and 90∶90 kg·ha^{-1}) on growth, seed yield and quality of fennel. The nitrogen and phosphorus were applied as urea and single super phosphate (SSP), respectively. Fertilizer NP dose (90∶45 kg ha^{-1}) increased plant height by 44%, number of leaves per plant by 76%, 1000-seed weight by 44%, biological yield by 50%, seed yield by 296% and harvest index by 162%. It was

concluded that addition of NP fertilizer had the potential to increase fennel seed yield.

Amin and Singh (2015) set up an experiment to study the response of drilled *rabi* fennel (*Foeniculum vulgare* Mill.) to spacing under varying levels of nitrogen. Three main plot treatments were row spacing i.e. 30 cm, 45 cm and 60 cm while sub plot treatment were five levels of nitrogen i.e. 60 kg, 75 kg, 90 kg, 105 kg and 120 kg of nitrogen ha^{-1}. Sowing was done in last week of October using crop variety GF-2. The levels of nitrogen on plant height and yield attributing characters showed significant effect and yield increased with increasing level of nitrogen application. Significant effect on plant height was observed when plant was fertilized with 90 kg of nitrogen ha^{-1}. The numbers of primary, secondary and tertiary branches were reported maximum in 120 kg nitrogen ha^{-1}. Application of 90 kg of nitrogen ha^{-1} reported par result to 105 and 120 kg nitrogen ha^{-1} for these growth attributing characters. The maximum number of umbels per plant and maximum number of umbellate per umbel was reported in application of 120 kg nitrogen ha^{-1} and it was at par with application of 90 kg nitrogen ha^{-1}. The effect of nitrogen levels from 60 to 120 kg ha^{-1} was significant on seed and stover yield, but increase in yield from 90 kg nitrogen ha^{-1} to 120 kg nitrogen ha^{-1} was at par.

Koyani *et al.* (2014) conducted a field experiment to find out the optimum requirement of nitrogen and phosphorus for direct seeded rabi fennel. The experiment comprised of the treatments, viz., four levels of nitrogen (0, 60, 90 and 120 kg·ha^{-1}) and three levels of phosphorus (0, 30 and 60 kg·ha^{-1}). The fennel variety 'GF-11' was sown in second week of November. The results indicated that the higher plant height, maximum number of branches per plant, number of umbels per plant, number of seeds per umbel, test weight, seed and stover yields of fennel and higher content of N and P and higher uptake of N, P and K of seed and stover were recorded with fertilizing the crop with 120 kg N·ha^{-1} and 60 kg P_2O_5·ha^{-1}, which was at par with fertilizing the crop with 90 kg N·ha^{-1} and 30 kg P_2O_5·ha^{-1}. The seed and stover yields recorded with application

of 90 kg N·ha^{-1} was 1865 kg·ha^{-1} and 2435 kg·ha^{-1}, respectively; which was 38.24% and 27.48% higher than that recorded with control (0 kg N·ha^{-1}). This might due to positive response of nitrogen and phosphorus increased availability of phosphorus in soil, being a major structural element of cell and helped in cell elongation, greater availability of photosynthates, metabolites and nutrients to develop reproductive structures which ascribed to increased growth parameters and lead to higher yield attributes and yields of fennel crop.

Ehsanipour *et al.* (2012) carried out an experiment in order to determine the effects of nitrogen rates on fennel accessions quality and quantity. The experimental design was a split plot with nitrogen rate (0, 40, 80, 120 and 160 Kg N·ha^{-1}) as main and accession (Isfahan, Tehran, Yazd and EU11486) as sub-plots. Plant height, number of umbels per plant, 1000-seed weight, number of seeds per umbel and seed yield were measured. Nitrogen fertilization increased all the measured traits. On average, the highest seed and foliage essential contents and seed essential yield were produced at 160 kg per N·ha^{-1}.

Khalid (2012) investigated with the main objective to study the effect of different levels of NP fertilizers, trace elements and their interactions on the morphological and biochemical contents of medicinal and aromatic plants including anise (*Pimpinella anisum* L.), coriander (*Coriandrum sativum* L.) and sweet fennel (*Foeniculum vulgare* var. Dolce). Plots were divided into two main groups. The first group was subjected to different levels of NP combinations: N_0P_0, N_1P_1, N_2P_2 and N_3P_3. N_0 = 0 kg N·ha^{-1}, N_1 = 100 kg N·ha^{-1}, N_2 = 150 kg N·ha^{-1} and N_3 = 200 kg N·ha^{-1}; P_0 = 0 kg P_2O_5·ha^{-1}, P_1 = 37.5 kg P_2O_5·ha^{-1}, P_2 = 56.3 kg P_2O_5·ha^{-1} and P_3 = 75 kg P_2O_5·ha^{-1}. The second group was subjected to the same NP treatments but foliar spray (trace elements) was added at 1 g·L^{-1}. N source was ammonium sulphate [$(NH_4)_2SO_4$] (20% N). P_2O_5 source was calcium superphosphate (15% P_2O_5). Foliar spray source was commercial solution (Greenzite) which contains EDTA Na2 Mn (40%), EDTA Na2 Zn (48%), Fe (5.4 mg·L^{-1}), Mg (0.54 mg·L^{-1}), Mn (50.54 mg·L^{-1}), Zn (570.27 mg·L^{-1}), Cu (0.054 mg·L^{-1}), Mo (0.027 mg·L^{-1}), Ni (0.005 mg·L^{-1}) and Co (0.005 mg·L^{-1}). The most

effective treatment was N_3P_3 [200 kg N·ha^{-1} and 75 kg P_2O_5·ha^{-1}] × trace elements interaction, resulting in a positive increase in vegetative growth characters. The highest values of vegetative growth characters i.e. plant height (89.8 cm), leaf number (32.6), branch number (7.8), umbel number (22.9), fresh weight (257.8 g plant^{-1}), dry weight (99.1 g plant^{-1}) and fruit yield per plant (27.8 g) for sweet fennel were recorded from N_3P_3 × trace elements interaction.

Ayub *et al.* (2011) carried out field studies to evaluate the effect of nitrogen on growth, yield, oil contents and profitability of fennel pertaining to know optimum nitrogen level for higher seed yield and oil contents of fennel. Different levels of nitrogen viz., 0, 30, 45, 60, 75, 90, 105 and 120 kg·ha^{-1} were used as treatment in this study. Seed yield and yield components were influenced significantly by different levels of nitrogen application. The treatments of 90 kg N·ha^{-1} produced higher seed yield but it was statistically similar to 105 and 120 kg N·ha^{-1}. The increase in yield was mainly due to taller plant height, greater number of umbels per plant, seeds per umbel and heavier 1000-seed weight.

Mehta *et al.* (2011) conducted a field experiment to study the growth, profitability and productivity of fennel (*Foeniculum vulgare*) as influenced by irrigation (at 12 days interval, 15 days interval and 18 days interval), nutrients levels (N and P_2O_5 each at 60:30, 90:40 and 120:50 kg·ha^{-1}) and crop geometry (40 cm × 25 cm, 50 cm × 25 cm and 60 cm × 25 cm). Sowing was done with fennel var. Ajmer Fennel-1. Growth parameters, yield attributes, yield and N, P and K uptake were significantly higher with application of 120 kg N and 50 kg P_2O_5·ha^{-1}.

Saleh *et al.* (2011) examined essential oils of the fruits of three organically grown cultivars of Egyptian fennel (*Foeniculum vulgare* var. *azoricum*, *Foeniculum vulgare* var. *dulce* and *Foeniculum vulgare* var. *vulgare*) for their chemical constituents, antimicrobial and antioxidant activities. Four m^3 of compost per feddan (4,200 m^2) was added as organic fertilizer. The same kind of organic fertilizer was added at the rate of 4 m^3·feddan^{-1} during the third weeding. The

productivity per feddan was 800 kg of fruits for *azoricum* and *dulce* and 1,200 kg for *vulgare*.

Abou El-Magd *et al.* (2010) set up two field experiments during the two successive winter seasons of 2007–2008 and 2008–2009 on sweet fennel to study the effect of transplanting dates and different rates of potassium sulphate fertilizer on vegetative growth, yield, quality and chemical content of six sweet fennel cultivars (cvs. Dolce, Zefa Fino, Selma, Fino, De Florance and Zwejahrig). Transplanting dates were early (15th September) and late (1st October) combined with four rates of potassium sulphate, i.e. 0, 45, 60 and 75 kg K_2O·feddan^{-1}. (Feddan = 0.40 ha.). Results indicated that transplanting dates differed statistically in their effect on the vegetative growth of sweet fennel plants. The highest vegetative growth expressed as plant height, leaves number·plant^{-1}, fresh and dry weight of the total plant and its organs, bulb dimensions (thickness, width and length) and total green yield were obtained by early plantation (15th September). On the other hand, lower values of vegetative growth, green yield and quality of bulbs were obtained in the late plantation (1st October). With respect to potassium fertilizer rates, results revealed that sweet fennel plants treated with 75 kg K_2O·feddan^{-1}. showed higher vegetative growth parameters (plant length, leaves number and bulb dimensions, thickness, width and length), fresh and dry weight of leaves, bulbs and total plant and total green yield than the lower rates of potassium. The highest values were obtained by early date combined with the highest potassium rate (75 kg K_2O·feddan^{-1}.).

Raj and Thakral (2008) conducted a field experiment to study the effect of nitrogen (N), phosphorus (P) and potash (K) on growth, seed yield and quality of fennel. The experiment consisted of 16 treatment combinations with four levels each of N (25, 50, 75 and 100 kg·ha^{-1}), P (25 and 50 kg·ha^{-1}) and K (25 and 50 kg·ha^{-1}). The results revealed significant differences on growth and yield parameters among the treatments. Application of N at 100 kg·ha^{-1}, P at 50 kg·ha^{-1} and K at 50 kg·ha^{-1} showed the maximum values of plant height, flowering, umbels per plant and umbellets per umbel, while seeds per umbel, seed yield

($q \cdot ha^{-1}$) and harvest index was found to be the maximum at 75 kg nitrogen, 50 kg phosphorus and 50 kg potash per hectare.

Mahfouz and Sharaf-Eldin (2007) carried out field experiments to investigate the effects of biofertilization on growth, fruit yield, and oil composition of fennel plants. Treatments used in the field experiments were identified as follows: T_1 (*Azospirillum lipoferum* + 50% NPK), T_2 (*Azotobacter chroococcum* + 50% NPK), T_3 (*Bacillus megatherium* + 50% NPK), T_4 (mixture of biofertilizer T_1, T_2, and T_3 + 50% NPK), T_5 (50% NPK without inoculation) and T_6 (100% NPK without inoculation). Application of biofertilizer, which was a mixture of *Azotobacter chroococcum*, *Azospirillum lipoferum,* and *Bacillus megatherium* applied with chemical fertilizers (only 50% of the recommended dosage of NPK) increased vegetative growth (plant height, number of branches and herb fresh and dry weight per plant) compared to chemical fertilizer treatments only. The tallest plants, the highest number of branches per plant and the highest fresh and dry weights of plants were obtained from the treatment of biofertilizer plus a half dose of chemical fertilizer (357 kg ammonium sulphate + 238 kg calcium super phosphate + 60 kg potassium sulphate$\cdot ha^{-1}$). The lowest fresh and dry weights of plants occurred with the 50% NPK. Also, addition of biofertilizer with the chemical fertilizer increased these characters more than the half dose of chemical fertilizer alone.

Mohamed and Abdu (2004) set up a field experiment to study the effect of irrigation and organic fertilization on growth and oil production of fennel (*Foeniculum vulgare* Mill). Seeds of the aromatic plant fennel were sown in sandy soil with 0 or 2.5 $kg \cdot m^{-2}$ of organic fertilizer (OF); chicken manure, cattle manure or plant compost. Plants were irrigated two, three, four, five or six times at 21-day intervals commencing 21 days after sowing and continuing until harvest. Increasing the number of irrigations and application of organic fertilizers significantly delayed harvesting. All organic fertilizers increased plant growth, yield parameters and fruit yield.

Kandil *et al.* (2002) conducted a study to find out whether under Egyptian conditions sufficient and high qualities of fennel yields can be produced with the nutrient sources allowed by organic farming. The tested sources allowed by organic farming rules were for N: compost, compost + *Azotobacter* and chicken manure compared with ammonium nitrate; for P: soft rock phosphate (rock-P) alone and rock-P mixed with elemental S compared with superphosphate and for K: feldspar compared with potassium sulphate. Two field experiments were done in an area of newly reclaimed land (Sekem farm) and in comparison, on old cultivated land in the Nile valley (Giza farm) during two successive seasons (1998–1999) and (1999–2000). The investigations yielded the following results: (1) Generally, fertilization with chemical fertilization of N, P and K (ammonium nitrate, calcium superphosphate and potassium sulphate) gave higher fennel growth parameters than did fertilization with the natural sources of N, P and K. (2) Compost/*Azotobacter*, rock-P/S and feldspar as the natural sources of N, P and K were more effective in increasing fennel growth and in many cases giving similar results as chemical fertilization. (3) Ammonium nitrate gave the highest fruit yields in both seasons and on both soils. Fertilization with compost on clay loam soil resulted in 17% and 7% less of the yield obtained after fertilization with ammonium nitrate and 1% and 12% less on sandy soil in both growing seasons respectively. (4) Fertilization with chicken manure gave 92% from the yield of the plots fertilized with ammonium nitrate in both growing seasons in the Nile valley (Giza farm) and 98% and 85% on Sekem farm in the first and second growing season respectively. (5) Fertilization with compost/*Azotobacter* increased the fruit yield by 14% and 5% compared with fertilization with compost alone on Giza farm (Nile valley). Results on sandy soil (Sekem farm) have been −3% and +6% respectively. (6) Fertilization with super-phosphate gave the largest yield of fennel fruits and essential oil in the first season on both soils (Giza and Sekem). While in the second season fertilization with rock-P/S and rock-P alone gave the largest yields on Giza farm and Sekem farm respectively.

Atta-Aly (2001) carried out an experiment where two fennel (*Foeniculum vulgare* Mill.) varieties, Dolce and Azoricum, were field grown for swollen base (SB) production to select the most productive variety and the most suitable source of N fertilizers in fields supplemented with cattle manure, calcium superphosphate and potassium sulfate. Plants were then grown either with or without one of the synthetic N fertilizers, ammonium sulfate (AS), ammonium nitrate (AN) or urea applied at a rate of 170 kg $N \cdot ha^{-1}$. When N was applied as a synthetic source, SB yield and quality were markedly reduced with about a 36% increase in SB nitrate content as compared to the control. The lowest SB yield and quality were obtained when ammonium nitrate (AN) or urea was used. Although AS produced a comparable yield to that of the control, the physical quality of the harvested SBs was adversely affected. Fertilizing with synthetic N-sources during plant growth and development is not advised when the soil has already been supplemented with organic nitrogen as not only are SB yield, quality and flavour reduced but also its safety for human consumption.

Patel *et al.* (2000) set up a field experiment to observe the response of fennel (*Foeniculum vulgare*) to irrigation, nitrogen and phosphorus with 'Guj. Fennel 1' fennel grown on sandy-loam soil. The researcher concluded that potential production and profit could be obtained from 'Guj. Fennel 1' by fertilizing the crop with 90 kg $N \cdot ha^{-1}$ and 30 kg $P_2O_5 \cdot ha^{-1}$.

Omidbaigi and Hornok (1992) laid out a field experiment to determine the effectiveness of the N-portion and find out the most suitable time of N top-dressing, which could be used in fennel (*Foeniculum vulgare* Mill.) nutrition in order to increase its quantity and quality of production (seed yield, yield's essential oil content and composition of the essential oil of fennel). The total N levels were 0, 50, 120 or 200 $kg \cdot ha^{-1}$, applied as a single top dressing, or as split dressings applied at different stages of development: F_1 after germination, F_2 at a plant height of 15–20 cm or F_3 after stem initiation. N applied as a top dressing after germination had a positive effect on seed yield and 1000-seed weight of fennel.

Bhati (1990) set up an experiment to study the effect of stage of umbel picking and nitrogen fertilization on fennel (*Foeniculum vulgare*). Four nitrogen levels (0, 30, 60 and 90 kg·ha^{-1}) and 3 stage of umbel picking (half-length size, full length green seed and full-grown seed turning yellow) were used as experimental treatments. Results of the experiment indicated that application of 90 kg N·ha^{-1} produced the maximum average seed yield (13.77 q·ha^{-1}) followed by 60 kg N·ha^{-1} (11.66 q·ha^{-1} of seed yield) as against 9.30 q·ha^{-1} of seed yield in control.

Samra and Gill (1985) studied the effect of three levels of nitrogen (0, 25 and 50 kg·ha^{-1}) supplied both from organic and inorganic sources on the seed yield of fennel (*Foeniculum vulgare* L.). The significant increase in seed yield was recorded up to 25 kg N·ha^{-1} only. Application of nitrogen at the rate of ⅔ from calcium ammonium nitrate (CAN) and ⅓ from farm yard manure (FYM) produced the highest seed yield of fennel.

CHAPTER III

MATERIALS & METHODS

CHAPTER III

MATERIALS AND METHODS

In this section the materials and methods have been presented with a brief description of location of the experimental site, soil, climate, planting materials etc. The details of research procedure are described under.

3.1 Description of the experimental site

3.1.1 Location

The present research work was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during October, 2019 to July, 2020 to study the effect of seed sowing time and nutrients on the growth and yield of fennel. The location of the site 90°33´ E longitude and 23°77´ N latitude with an elevation of 8.2 m from sea level (Anon, 1989). Location of the experimental site presented in Appendix I.

3.1.2 Climate

The geographical location of the experimental site was under the subtropical climate, characterized by 3 distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris *et al*., 1979). Details of the metrological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix II.

3.1.3 Soil

Soil of the study site was salty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28) with PH 5.8-6.5, ECE-25.28 (Haider *et al*., 1991). The analytical data of the soil sample

collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix III.

3.2 Planting materials

The seeds of fennel cv. BARI Mouri-1 variety were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur.

3.3 Experimental details

3.3.1 Treatments

There are two factors named as factor-A (sowing time) and Factor-B (nutrients).

Factors-A: Different dates of sowing

i. S_1 = First week of November (7^{th} November)
ii. S_2 = Last week of November (24^{th} November)
iii. S_3 = First week of December (7^{th} December)
iv. S_4 = Last week of December (25^{th} December)

Factors-B: Different levels of nutrient

i. T_0 = Control
ii. T_1 = Vermicompost (2.50 t ha^{-1})
iii. T_2 = NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})
iv. T_3 = Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})

There were 16 (4 × 4) treatments combination such as S_1T_0, S_1T_1, S_1T_2, S_1T_3, S_2T_0, S_2T_1, S_2T_2, S_2T_3, S_3T_0, S_3T_1, S_3T_2, S_3T_4, S_4T_0, S_4T_1, S_4T_2 and S_4T_3.

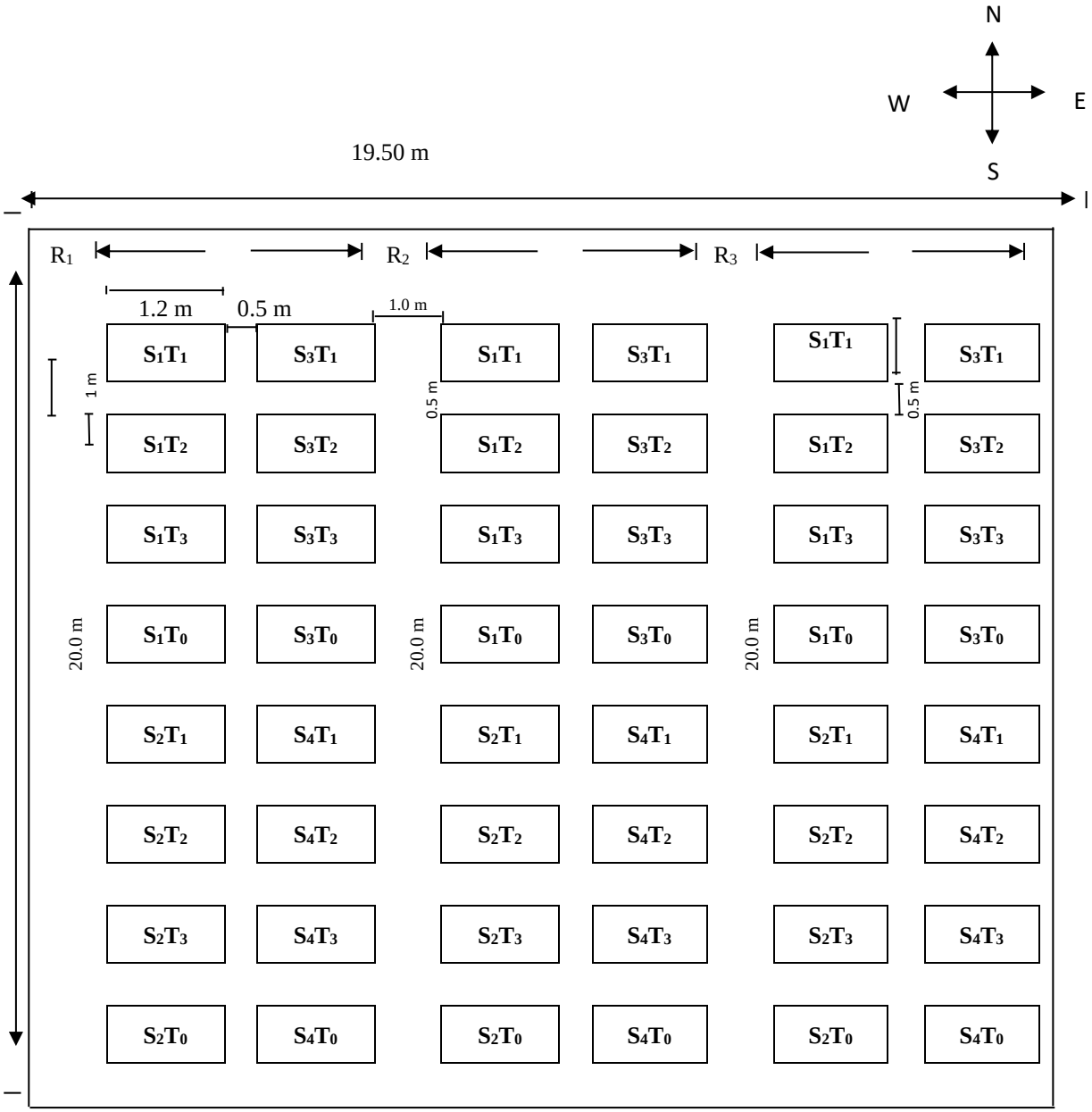
3.3.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with 16 treatment combinations having three replications. First of all, the entire experimental plot was divided into three blocks, each of which was then divided into 48 unit-plots. The treatment combinations were assigned randomly to the unit plots of one block. The size of unit plot was 1.2 m × 1.0 m and number of replications 3. Two adjacent unit plots and blocks was separated by 50.0 cm and 50.0 cm, respectively.

3.4 Cultivation procedure

3.4.1 Land preparation

The plot selected for the experiment was opened in the first week of September, 2019 with a power tiller and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. The land was leveled, corners were shaped and the clods were broken into pieces. The weeds, crops residues and stables were removed from the field. The basal dose of manures and fertilizers was applied at the finally ploughing as per treatment. According to design and layout the plots was prepared. The soil was treated by Furadon 5G @ 8.0 kg/ha to protect the young plants from the attack of mole cricket, ants and cutworm.



Number of treatment combinations = 16, Unit plot size = 1.2 m × 1.0 m
Plot spacing: = 0.5 m
Between replication = 1.0 m

Factor A: Different dates of sowing
S_1 = First week of November
S_2 = Last week of November
S_3 = First week of December
S_4 = Last week of December

Factor B: Different levels of nutrient
T_0 = Control
T_1 = Vermicompost (2.5 t ha^{-1})
T_2 = NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})
T_3 = Vermicompost (2.5 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})

Figure 1. Field layout of the two-factor experiment in RCBD

3.4.2 Fertilizers and manure application

Vermicompost, Urea, TPS and MoP and were applied @ 2.5-ton ha^{-1}, 80, 50 and 60 kg ha^{-1}, respectively as per treatment. The FYM was applied after opening the land. The total amount of TSP and MoP were applied at the final land preparation. Total urea was applied in two installments. The 1st instalments were applied at final land preparation and 2nd installments were applied 45 days after planting as top dressing as per treatment. The fertilizer was thoroughly mixed with the soil.

Plate 1. Fertilizers and manure application in the plot

3.4.3 Planting of seed

Healthy and disease-free uniform size seeds were planted in the main field on first week of November, 2019; last week of November, 2019; first week of December, 2019 and last week of December, 2019 at 20.0 cm × 20.0 cm spacing. Two seeds were sown at each point in case of ridge and bed sowing and were

thinned to one plant per site after germination. Broadcasting was done manually by hand using a seed rate of 9-12 kg ha^{-1}.

Plate 2. Planting of seed

3.5 Intercultural operations

3.5.1 Irrigation and drainage

Over-head irrigation was provided with a watering can to the plots once immediately after planting the seeds in every alternate day in the evening. Further irrigation was done when needed. Stagnant water was effectively drained out at the time of heavy rains.

3.5.2 Gap filling and uprooting

Gap filling and uprooting was done for all of the plots at 15 days after planting. Damaged/ dead seeds were removed.

Plate 3. Gap filling

3.5.3 Weeding

Weedings were done to keep the plots free from weeds, which ultimately ensured better growth and development. First weeding was done at 15 days after planting (DAP), 2nd and 3rd weeding was done at 35 and 55 DAP.

3.5.4 Plant protection

Preventive measure was taken against soil borne insects. Furadan 5G @ 8.0 kg ha^{-1} was applied for the prevention of cutworm. After pesticide application no insect infestation was found in the field.

3.6 Harvest

The fennel seeds were harvested when the fruits reached maturity on the central umbel and first order umbels according to the dates of sowing as follows: on 20th May, 2020 for the first sowing date; 6th June, 2020 for the second sowing date; 13th June, 2020 for the third sowing date and 29th June, 2020 for the forth sowing date.

3.7 Data collection

3.7.1 Plant height

The heights of pre-selected five plants were measured with a meter scale from the ground level to the top of the tallest leaf after 45, 90 and 135 days of sowing and the mean height was expressed in cm.

Plate 4. Plant height (at 135 DAS)

3.7.2 Number of leaves plant^{-1}

Total number of leaves per 5 plants was counted after 135 days after sowing and the average number of leaves per plant was recorded.

Plate 5. Number of leaves plant^{-1}

3.7.3 Number of primary branches per plant

The primary branches were counted from the 5 randomly selected plant at harvest time and mean value was determined.

3.7.4 Number of secondary branches per plant

The secondary branches were counted from the 5 randomly selected plant at harvest time and the average number of secondary branches per plant was recorded.

3.7.5 Number of umbellet umbel^{-1}

The number of umbelletes per umbel from five umbels of each of selected plants were counted and calculated as per umbel basis.

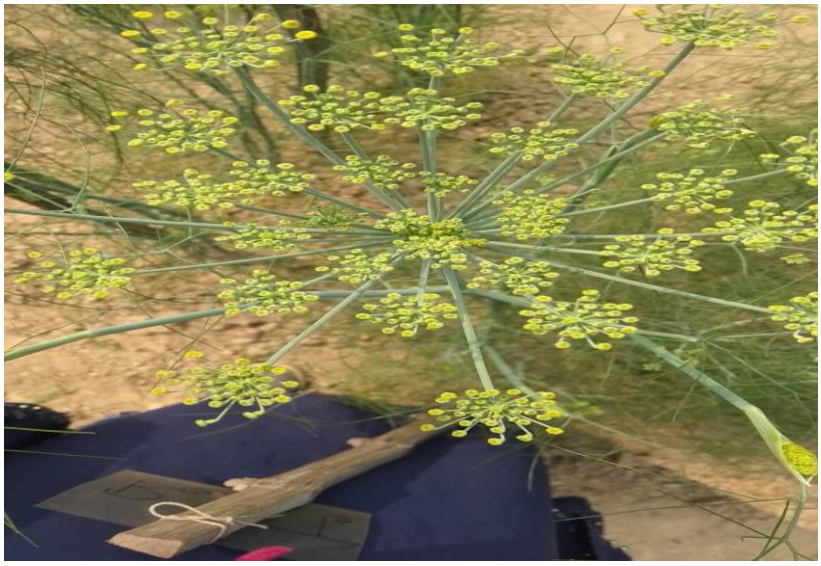


Plate 6. Number of umbellet umbel^{-1}

3.7.6 Number of umbel plant^{-1}

The number of umbels from five plants were counted and calculated as average number of umbels produced by per plant basis.

3.7.7 DAS to first flowering

Days of first flowering on the sample plot was recorded from each plot and the period required in days from the date of sowing was calculated.

3.7.8 DAS to 50% flowering

Days of 50% flowering were recorded from each plot.

3.7.9 Seed weight umbel^{-1}

The fennel seeds were threshed from the plants, cleaned, dried and then weighed. The weight of seeds in g umbel^{-1}. Seeds per umbel were counted from all the umbel and the average data were taken as weight of seeds/umbel.

Plate 7. Seed weight umbel^{-1}

3.7.10 Seed yield plant^{-1} (g)

The fennel seeds were threshed from the plants, cleaned, dried and then weighed. The weight of seeds in g plant^{-1} was adjusted at 12% moisture content of seed.

3.7.11 Seed yield plot^{-1} (kg)

After maturity seeds of all plots were harvested, cleaned and dried. First seed weight plot^{-1} was measured with an appropriate spring scale balance and thus plot yield was obtained in kg. The fennel seeds were threshed from the plants, cleaned, dried and then weighed. The yield of seeds in kg plot^{-1} was adjusted at 12% moisture content of seed.

3.7.12 Seed weight ha^{-1} (t)

The fennel seeds were threshed from the plants, cleaned, dried and then weighed. The yield of seeds in kg plot^{-1} was adjusted at 12% moisture content of seed and then it was converted to t ha^{-1}.

3.7.13 1000-seeds weight

One thousand cleaned and dried seeds were counted randomly form each sample and weight by using a digital electric balance and the weight was expressed in gram.

3.7.14 Fresh weight of plant

The vegetative body (leaf, stem, seeds) of fennel plant was collected from five plants randomly in each unit plot and weight by using a digital electric balance and the weight was expressed in gram.

3.7.15 Dry weight of plant

The vegetative body (leaf, stem, seeds) of fennel plant was collected from five plants randomly in each unit plot sliced finely. Then sliced fennel plant was dried in the sun kept in oven at 72°C for drying. It took 72 hrs and weight by using a digital electric balance and the weight was expressed in gram.

3.7.16 Fresh weight of root

The root of fennel plant was collected from five plants randomly in each unit plot and weight by using a digital electric balance and the weight was expressed in gram.

3.7.17 Germination %

Seed were tested for germination capacity in each month. From each sample, four replicates of one hundred seeds were counted at random from well mixed pure seed fraction. Seeds were spaced uniformly and adequately apart on two layers of moist filter paper substrate in 21 cm and 15.5 cm transparent germination trays. Germination trays were kept in a walk-in germinator maintained at 20°C for 16 hours in dark and 30°C for 8 hours with tight, for a total period of 14 days. Then each and every seedling was evaluated separately with reference to evaluation group and general principles laid down. Classification was made as normal seedlings, abnormal seedlings and dead seeds. Germination percentage was calculated as:

$$\text{Germination (\%)} = \frac{\text{No. of seeds germinated}}{\text{No. of seeds placed}} \times 100$$

Maximum tolerated range for four replicates was consulted. The experiment was conducted on top of paper for ease so that germinating seeds and seedling structures could be observed easily.

3.8 Economic analysis

The cost of production was analysed in order to find out the most economic treatment of sowing time and nutrient application. All input cost was considered in computing the cost of production. The market price of seeds was considered for estimating the return. The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit cost ratio} = \frac{\text{Gross return per hectare (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

3.9 Statistical analysis

The data obtained for different characteristics were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characteristics were calculated and analysis of variance was performed. The significance of the difference among the treatment means was estimated by the Least Significant Different (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSIONS

The experiment was conducted to find out the effect of seed sowing time and nutrients on the growth and yield of fennel. The results obtained from the study have been presented, discussed and compared in this chapter through tables, figures and appendices. The analyses of variance of data in respect of all the parameters have been shown in Appendix IV-VIII. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following sub-headings.

4.1 Plant height (cm)

Plant height is an important parameter which reflects the vegetative growth of plant. The plant height was significantly influenced by different sowing time on fennel (Figure 2 and Appendix IV). It was recorded at 45, 90 and 135 days after sowing (DAS), that is at 45 days interval. Among the treatments it was found that plant height was gradually increased with the advancement of time. At 45 DAS, first week of November (S_1) showed the longest plant (9.25 cm) which was statistically identical to S_2 (9.11 cm) whereas, the shortest plant (7.83 cm) was found from last week of December (S_4) treatment. The last week of November (S_2) showed the longest plant (49.04 cm and 107.44 cm resoectively at 90 and 135 DAS, respectively) and the shortest plant (38.72 and 97.15 cm at 90 and 135 DAS, respectively) was found from last week of December (S_4) treatment. This might be due to the fact that last week of November possibly received favorable condition for quickest growth than those of other sowing time. This result agrees with the result obtained by Albukhder and Al-Refai (2019), they reported that the sowing of fennel in the first date (20th November) resulted in increase of all studied vegetative. Al-Dalain *et al.* (2012) also reported that early planting significantly increased the plant height.

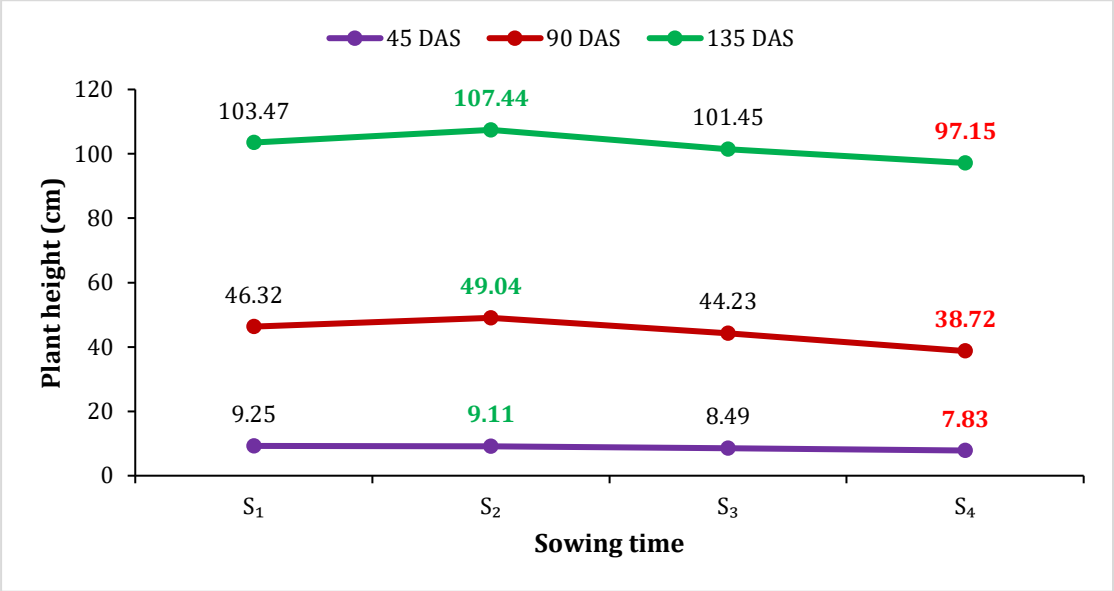


Figure 2. Effect of different sowing time on plant height (cm) at different days after sowing of fennel (LSD value = 0.3619, 0.9546 and 1.0042 at 45, 90 and 135 DAS, respectively).

Here, Sowing time: S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December and S_4 – Last week of December.

The plant height was observed significantly influenced by different nutrients application (Figure 3 and Appendix IV). The tallest plant (10.84, 56.25 and 114.83 cm, respectively) was recorded from T_3 (Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})) application at 45, 90 and 135 DAS, while the shortest plant (6.63, 32.06 and 86.33 cm, respectively) was observed from control (T_0) at the same growth stage. The tallest plant at all dates of observations were found from vermicompost with NKP application. The variation in plant height as influenced by different nutrients was perhaps due to proper utilization nutrients, moisture and light. This result is agreed with the findings of Rajpoot *et al*. (2021) and Barzegar *et al*. (2020). Ibrahim *et al*. (2020) also conducted that the application of vermicompost increased the growth measurements. Bhagvanbhai (2019) recorded that the application of potassium @ 60 kg·ha^{-1} was observed superior over rest of the levels in increasing plant height over the control. Godara

et al. (2014) recorded that the higher values of plant height were recorded with the application of recommended dose of N (RDN) through fertilizers i.e., 90 kg N and 45 kg P_2O_5 ha^{-1}.

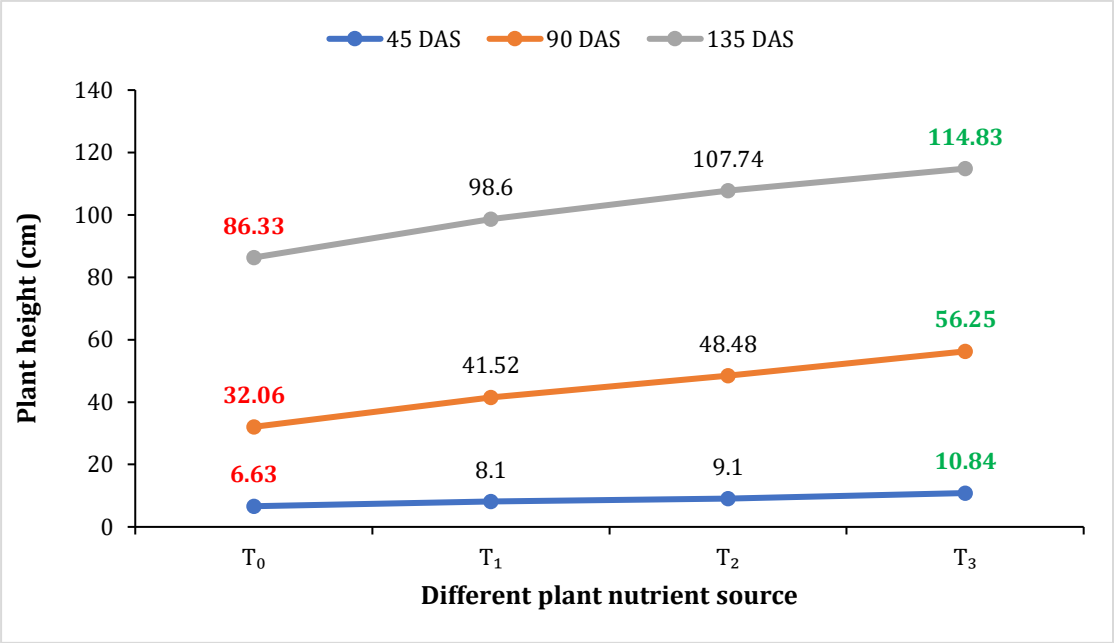


Figure 3. Effect of different nutrients on plant height (cm) at different days after sowing of fennel (*Foeniculum vulgare*) (LSD value = 0.3619, 0.9546 and 1.0042 at 45, 90 and 135 DAS, respectively).

Here, Nutrient: T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}), T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).

The combined effect of different sowing time and nutrients was found statistically significant on all dates of observation (Table 1 and Appendix IV). At 45 DAS, the tallest plant (11.83 cm) was measured from S_2T_3 (last week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment, which was statistically similar to S_1T_3 (11.33 cm) and the shortest plant (6.00 cm) was recorded from S_3T_0 (first week of December with control) treatment, which was statistically similar to S_4T_0 (6.33 cm) and S_2T_0 (7.04 cm). At 90 DAS, the tallest plant (60.73 cm) was measured from S_2T_3 (last week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment which was statistically similar to S_1T_3 (59.20 cm) whereas, the shortest plant (29.27 cm) was recorded

Table 1. Combined effect of different sowing time and nutrients on plant height at different days after sowing of fennel (*Foeniculum vulgare*)

Treatments	Plant height (cm)		
	45 DAS	**90 DAS**	**135 DAS**
S_1T_0	7.17 gh	33.13 j	87.07 i
S_1T_1	8.50 de	42.47 g	98.00 f
S_1T_2	10.00 c	50.47 d	113.53 b
S_1T_3	11.33 ab	59.20 ab	115.27 b
S_2T_0	7.04 hi	35.83 i	92.00 h
S_2T_1	8.41 d-f	46.27 f	105.40 d
S_2T_2	9.13 d	53.33 c	114.77 b
S_2T_3	11.86 a	60.73 a	117.59 a
S_3T_0	6.00 j	30.00 k	84.27 j
S_3T_1	7.77 fg	40.13 h	96.00 fg
S_3T_2	9.13 d	48.27 e	110.47 c
S_3T_3	11.07 b	58.53 b	115.07 b
S_4T_0	6.33 ij	29.27 k	82.00 k
S_4T_1	7.73 f-h	37.20 i	95.00 g
S_4T_2	8.13 ef	41.87 gh	100.20 e
S_4T_3	9.10 d	46.53 ef	111.40 c
LSD $_{(0.05)}$	**0.7238**	**1.9092**	**2.0084**
CV%	**4.91**	**2.49**	**3.08**

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

Here, Sowing time: S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December, S_4 – Last week of December and **Nutrient:** T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}), T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).

from S_4T_0 (last week of December with control) treatment which was statistically similar to S_3T_0 (30.00 cm). At 135 DAS, the longest plant (117.59 cm) was measured from S_2T_3 (last week of November with Vermicompost 2.50 t ha^{-1} +

$N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment while, the shortest plant (82.00 cm) was recorded from S_4T_0 (last week of December with control) treatment. This might be due to the fact that environmental conditions for vegetative growth were favorable for older seedlings for completing vegetative growth.

4.2 Number of leaves $plant^{-1}$

Good foliage indicates higher growth, development and productivity of plant. In the present study, the number of leaves per plant was found to be significantly influenced by the different sowing time (Table 2 and Appendix V). The maximum number of leaves (12.68) $plant^{-1}$ of fennel was observed from S_2 (last week of November) treatment, while the minimum number of leaves (10.42) was observed from S_4 (last week of December) treatment. Similar trend was obtained by Albukhder and Al-Refai (2019), who reported that the planting of fennel plant in the first date (20th November) resulted the increase of number leaves $plant^{-1}$.

The results showed highly significant effect of different nutrients application on the number of leaves $plant^{-1}$ (Table 3 and Appendix V). The maximum number of leaves (14.02) was recorded from T_3 (Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment, while the minimum number of leaves (9.30) per plant of fennel was found from T_0 (control) treatment. It was observed that number of leaves per plant was higher in plants with all nutrient's application. It was probably due to reduced inter plant competition for access to nutrient, moisture and other resources. This result agrees with the findings of Rajpoot *et al*. (2021) and Barzegar *et al*. (2020).

The combined effect of different sowing time and nutrients application was also found to be statistically significant in this respect (Table 4 and Appendix V). The maximum number of leaves (15.07) was recorded from S_2T_3 (last week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment which was statistically similar to S_3T_3 (first week of December with Vermicompost

2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment. On the other hand, the minimum number of leaves (8.20) was observed from S_4T_0 (last week of December with control) treatment of fennel which was statistically similar to S_3T_0 (9.33) and S_4T_1 (9.40) treatment.

4.3 Number of primary branches

Effect of different sowing time significantly influenced number of primary branches $plant^{-1}$ (Table 2 and Appendix V). The highest number of primary branches $plant^{-1}$ (6.99) was recorded from the S_1 (first week of November) treatment. The lowest number (6.00) of primary branches $plant^{-1}$ was recorded from the S_4 (last week of December) treatment. This study revealed that first week of November produced maximum number of primary branches $plant^{-1}$. These findings are in accordance with the results of Ayub *et al.* (2008), Selim *et al.* (2013).

Effect of different nutrients application significantly influenced the number of primary branches $plant^{-1}$ (Table 3 and Appendix V). The highest number (7.42) of primary branches $plant^{-1}$ was recorded from the Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1} (T_3) treatment. On the other hand, the lowest number (5.56) of primary branches $plant^{-1}$ was recorded from the control (T_0) treatment. This study revealed that all nutrients application produced maximum number of primary branches $plant^{-1}$. Bajya *et al.* (2017) showed that the integrated nutrient management significantly affected different growth and yield attributes of fennel viz., plant height (cm), number of branches per plant. Godara *et al.* (2014) recorded that the higher values of number of primary and secondary branches were recorded with the application of recommended dose of N (RDN) through fertilizers i.e., 90 kg N and 45 kg P_2O_5 ha^{-1}.

The combined effect of different sowing time and nutrients application was also found to be statistically significant in this respect (Table 4 and Appendix V). The highest number (7.99) of primary branches $plant^{-1}$ was recorded from S_1T_3 (first

week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment which was statistically similar to S_2T_3 (7.62) treatment. On the other hand, the lowest number (4.81) of primary branches $plant^{-1}$ was observed from S_4T_0 (last week of December with control) which was statistically identical to S_3T_0 (5.08) treatment.

4.4 Number of secondary branches

Effect of different sowing time significantly influenced number of secondary branches $plant^{-1}$ (Appendix V and Table 2). The maximum number of secondary branches $plant^{-1}$ (17.64) was recorded from the S_2 (last week of November) treatment whereas, the minimum (15.45) was recorded from the S_4 (last week of December) treatment. This study revealed that last week of November produced the highest number of secondary branches $plant^{-1}$. Moosavi *et al.* (2014) reported that the results of analysis of variance for morphological traits like that plant height, primary and secondary branch number per plant were significantly affected by sowing date.

Effect of different nutrients application significantly influenced number of secondary branches $plant^{-1}$ (Table 3 and Appendix V). The maximum number (18.61) of secondary branches $plant^{-1}$ was recorded from the T_3 (Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment whereas, the minimum (13.87) was recorded from the control (T_0) treatment. This study revealed that all nutrients application produced maximum number of secondary branches $plant^{-1}$. Godara *et al.* (2014) was reported that the higher values of number of primary and secondary branches were found with the application of recommended dose of N (RDN) through fertilizers i.e., 90 kg N and 45 kg P_2O_5 ha^{-1}.

Table 2. Effect of different sowing time on number of leaves, number of primary branches, number of secondary branches and number of umbellet umbel^{-1} of fennel (*Foeniculum vulgare*)

Treatments	Number of leaves	Number of primary branches	Number of secondary branches	Number of umbellet umbel^{-1}
S_1	11.67 b	6.99 a	16.40 b	23.51 b
S_2	12.68 a	6.73 b	17.64 a	24.53 a
S_3	11.33 b	6.26 c	15.82 c	22.63 c
S_4	10.42 c	6.00 d	15.45 d	21.65 d
LSD $_{(0.05)}$	**0.6283**	**0.2444**	**0.3389**	**0.5526**
CV %	**6.32**	**4.51**	**2.49**	**2.96**

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

Here, Sowing time: S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December and S_4 – Last week of December.

Table 3. Effect of different nutrients on number of leaves, number of primary branches, number of secondary branches and number of umbellet umbel^{-1} of fennel (*Foeniculum vulgare*)

Treatments	Number of leaves	Number of primary branches	Number of secondary branches	Number of umbellet umbel^{-1}
T_0	9.30 d	5.56 c	13.87 d	20.34 d
T_1	10.77 c	6.38 b	16.03 c	21.85 c
T_2	12.02 b	6.62 b	16.81 b	24.55 b
T_3	14.02 a	7.42 a	18.61 a	25.58 a
LSD $_{(0.05)}$	**0.6283**	**0.2444**	**0.3389**	**0.5526**
CV %	**6.32**	**4.51**	**2.49**	**2.96**

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

Here, Nutrient: T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}), T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).

The combined effect of different sowing time and nutrients application was also found to be statistically significant in this respect (Table 4 and Appendix V). The maximum number of secondary branches plant^{-1} (20.18) was recorded from S_2T_3 (last week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1})

treatment combination which was statistically similar to S_1T_3 (19.61) treatment whereas, the minimum number (12.73) of secondary branches plant^{-1} was observed from S_4T_0 (last week of December with control) treatment.

4.5 Number of umbel plant^{-1}

Different sowing time had significant effect on number of umbel plant^{-1} of fennel (Figure 4 and Appendix V). The highest number of umbel plant^{-1} (22.94) was recorded from S_2 (last week of November) treatment. In comparison, the lowest number of umbel plant^{-1} (17.53) was recorded from S_4 (last week of December) treatment of sowing time. Ayub *et al.* (2008) found that the number of umbels per plant were affected significantly by different sowing date. Rassam *et al.* (2006) reported that delay in planting date caused significant reduction in number of umbels per plant.

Different nutrients application had significant effect on number of umbel plant^{-1} of fennel (Figure 5 and Appendix V). The highest number of umbel plant^{-1} (24.39) was recorded from T_3 (vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment. In comparison, the lowest number of umbel plant^{-1} (16.79) was recorded from T_0 (control). Kalasare *et al.* (2016) recorded that the application of 100 % RDF (Recommended Dose of fertillizer) with vermicompost @ 2.0 t ha^{-1} significantly increased higher growth, yield attributes and yield of rabi fennel. Godara *et al.* (2014) recorded that the higher values of number of umbels plant^{-1} were observed with the application of recommended dose of N (RDN) through fertilizers i.e., 90 kg N and 45 kg P_2O_5 ha^{-1}.

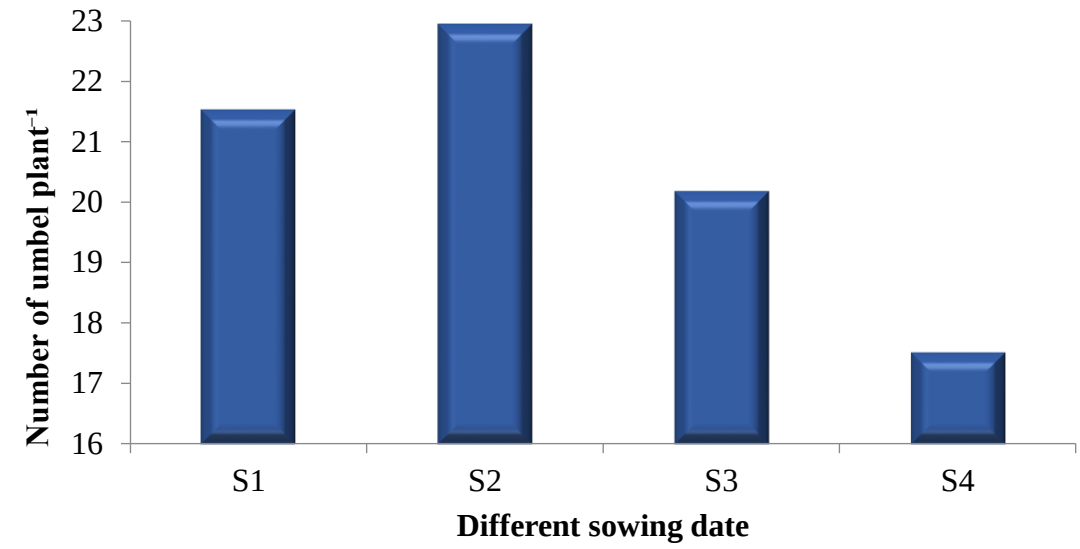


Figure 4. Effect of different sowing time on number of umbel plant^{-1} of fennel (*Foeniculum vulgare*) (LSD value = 0.6279). **Here, Sowing time:** S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December and S_4 – Last week of December.

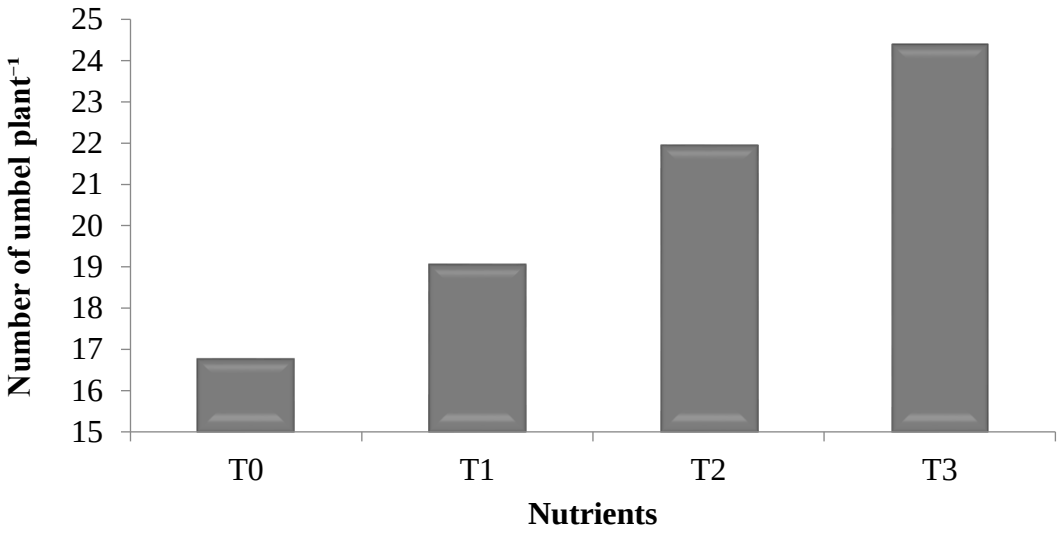


Figure 5. Effect of different nutrients on number of umbel plant^{-1} of fennel (*Foeniculum vulgare*) (LSD value = 0.6279). **Here, Nutrient:** T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}), T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).

Combined effect of different sowing time and nutrients application showed significant effect on number of umbel plant^{-1} of fennel (Table 4 and Appendix V). The highest number of umbel plant^{-1} (26.75) was recorded from treatment combination of last week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1} (S_2T_3) which was statistically similar to S_1T_3 (25.80) treatment. In comparison, the lowest number of umbel plant^{-1} (14.53) was recorded from last week of December with control treatment combination (S_4T_0).

4.6 Number of umbellet umbel^{-1}

Different sowing time had significant effect on number of umbellet umbel^{-1} of fennel (Table 2 and Appendix V). The maximum number of umbellet umbel^{-1} (24.53) was recorded from S_2 (last week of November) treatment and the minimum (21.65) was recorded from S_4 (last week of December) of sowing time. Rassam *et al.* (2006) reported that delay in planting date caused significant reduction in number of umbellets per umbel.

Different nutrients application had significant effect on number of umbellet umbel^{-1} of fennel (Table 3 and Appendix V). The maximum number of umbellet umbel^{-1} (25.58) was recorded from T_3 (vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment whereas, the minimum number of umbellet umbel^{-1} (20.34) was recorded from T_0 (control). Godara *et al.* (2014) recorded the higher values of number of umbellet umbel^{-1} with the application of recommended dose of N (RDN) through fertilizers i.e., 90 kg N and 45 kg P_2O_5 ha^{-1}.

Table 4. Combined effect of different sowing time and nutrients on number of leaves, number of primary branches, number of secondary branches, number of umbel plant^{-1} and number of umbellets umbel^{-1} of fennel (*Foeniculum vulgare*)

Treatments	Number of leaves	Number of primary branches	Number of secondary branches	Number of umbel plant^{-1}	Number of umbellet umbel^{-1}
S_1T_0	9.67 d	6.33 de	14.00 i	17.40 i	20.67 ij
S_1T_1	11.67 c	6.80 cd	15.00 gh	20.20 fg	22.13 gh
S_1T_2	12.00 c	6.88 c	17.00 d	22.73 d	24.67 cd
S_1T_3	13.33 b	7.99 a	19.61 ab	25.80 ab	26.58 b
S_2T_0	10.00 d	6.03 e	15.20 f-h	19.00 gh	21.40 hi
S_2T_1	12.00 c	6.47 c-e	17.00 d	21.13 ef	23.75 d-f
S_2T_2	13.67 b	6.80 cd	18.17 c	24.85 bc	25.25 c
S_2T_3	15.07 a	7.62 ab	20.18 a	26.75 a	27.72 a
S_3T_0	9.33 de	5.08 f	13.53 i	16.23 i	20.20 j
S_3T_1	10.00 d	6.13 e	14.83 h	18.73 h	21.27 h-j
S_3T_2	12.00 c	6.40 c-e	15.80 ef	21.53 de	25.52 bc
S_3T_3	14.00 ab	7.41 b	19.12 b	24.27 c	23.53 ef
S_4T_0	8.20 e	4.81 f	12.73 j	14.53 j	19.07 k
S_4T_1	9.40 de	6.13 e	17.27 d	16.20 i	20.27 j
S_4T_2	10.40 d	6.40 c-e	16.27 e	18.67 h	22.75 fg
S_4T_3	13.67 b	6.68 cd	15.53 fg	20.73 ef	24.50 c-e
LSD (0.05)	**1.2566**	**0.4888**	**0.6777**	**1.2558**	**1.1051**
CV%	**6.32**	**4.51**	**2.49**	**3.48**	**2.96**

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

Here, Sowing time: S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December, S_4 – Last week of December and **Nutrient:** T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}), T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).

Combined effect of different sowing time and nutrients application showed significant effect on number of umbellet umbel^{-1} of fennel (Table 4 and Appendix V). The maximum number of umbellet umbel^{-1} (27.72) was recorded from treatment combination of S_2T_3 (last week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}). On the other hand, the minimum number of umbellet umbel^{-1} (19.07) was recorded from S_4T_0 (last week of December with control) treatment combination.

4.7 DAS to first flower

Significant variation was observed for DAS (days after sowing) to first flower among the different sowing time (Table 5 and Appendix VI). The maximum DAS to first flower (88.43 day) was observed in S_4 (last week of December) treatment, while the minimum (82.76 day) was observed in S_1 (first week of November) treatment. The minimum number of days after sowing to first flower was observed with the crops sown on first week of November.

Significant variation was observed for DAS to first flower among the different nutrient's application of fennel (Table 6 and Appendix VI). The maximum DAS to first flower (88.45 day) was observed in T_0 (control) treatment whereas, the minimum (83.30 day) was observed in T_3 (Vermicompost 2.5 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment.

Combined effect of different sowing time with different nutrients application showed significant variation in DAS to first flower on fennel (Table 7 and Appendix VI). The maximum DAS to first flower (90.83 day) was recorded from S_4T_0 treatment. On the other hand, the minimum DAS to first flower (80.20 day) was observed from S_1T_3 treatment, which was statistically identical to that of S_1T_2 (80.57 day) treatment. The lowest number of DAS to first flower was observed in crops sown on first week of November with Vermicompost 2.5 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1} application.

Table 5. Effect of different sowing time on DAS to first flowering and DAS to 50% flowering of fennel (*Foeniculum vulgare*)

Treatments	DAS to first flower	DAS to 50% flower
S_1	82.76 d	101.44 c
S_2	85.28 c	100.03 d
S_3	86.70 b	104.06 b
S_4	88.43 a	105.51 a
LSD $_{(0.05)}$	**0.5495**	**0.4298**
CV %	**3.79**	**3.51**

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

Here, Sowing time: S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December and S_4 – Last week of December.

Table 6. Effect of different nutrients on DAS to first flowering and DAS to 50% flowering of fennel (*Foeniculum vulgare*)

Treatments	DAS to first flower	DAS to 50% flower
T_0	88.45 a	105.54 a
T_1	86.79 b	103.39 b
T_2	84.64 c	102.09 c
T_3	83.30 d	100.02 d
LSD $_{(0.05)}$	**0.5495**	**0.4298**
CV %	**3.79**	**3.51**

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

Here, Nutrient: T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}), T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).

Table 7. Combined effect of different sowing time and nutrients on DAS to first flowering and DAS to 50% flowering of fennel (*Foeniculum vulgare*)

Treatments	DAS to first flower	DAS to 50% flower
S_1T_0	85.68 fg	104.27 cd
S_1T_1	84.60 gh	102.23 f
S_1T_2	80.57 j	100.87 g
S_1T_3	80.20 j	98.40 hi
S_2T_0	87.53 de	102.20 f
S_2T_1	86.731 ef	101.13 g
S_2T_2	84.27 h	99.03 h
S_2T_3	82.60 i	97.73 i
S_3T_0	89.73 b	107.58 a
S_3T_1	86.73 ef	104.20 cd
S_3T_2	85.53 g	103.73 de
S_3T_3	84.80 gh	100.73 g
S_4T_0	90.83 a	108.10 a
S_4T_1	89.09 bc	106.00 b
S_4T_2	88.20 cd	104.73 c
S_4T_3	85.60 g	103.20 e
LSD (0.05)	**1.0991**	**0.8597**
CV%	**3.79**	**3.51**

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

Here, Sowing time: S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December, S_4 – Last week of December and **Nutrient:** T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}), T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).

4.8 DAS to 50% flower

Significant variation was observed for DAS (days after sowing) to 50% flower among the different sowing time (Table 5 and Appendix VI). The highest DAS to 50% flower (105.51 day) was observed in S_4 (last week of December) treatment whereas, the lowest DAS to 50% flower (100.03 day) was observed in S_2 (last week of November) treatment. The lowest number of days after sowing to 50% flower was observed with the crops sown on last week of November.

Significant variation was observed for DAS to 50% flower among the different nutrient's application of fennel (Table 6 and Appendix VI). The highest DAS to

50% flower (105.54 day) was observed in T_0 (control) while the lowest DAS to 50% flower (100.02 day) was observed in T_3 (Vermicompost 2.5 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment.

Combined effect of different sowing time with different nutrients application showed significant variation in DAS to 50% flower on fennel (Table 7 and Appendix VI). The highest DAS to 50% flower (108.10 day) was recorded from S_4T_0 treatment which was statistically identical to S_3T_0 (107.58 day) treatment. On the other hand, the lowest DAS to 50% flower (97.73 day) was observed from S_2T_3 treatment, which was statistically similar to that of S_1T_3 (98.40 day) and S_2T_2 (99.03 day) treatment. The lowest number of DAS to 50% flower was observed in crops sown on last week of November with Vermicompost 2.5 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1} application.

4.9 Seed weight umbel^{-1} (g)

Different sowing time had significant effect on seed weight umbel^{-1} of fennel (Table 8 and Appendix VII). The maximum seed weight umbel^{-1} (1.48 g) was recorded from S_4 (Last week of December) treatment whereas, the minimum seed weight umbel^{-1} (1.27 g) was recorded from S_3 (first week of December) which was statistically identical (1.33 g) to S_2 (last week of November).

Different nutrients application had significant effect on seed weight umbel^{-1} of fennel (Table 9 and Appendix VII). The maximum seed weight umbel^{-1} (1.92 g) was recorded from T_3 (vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment whereas, the minimum seed weight umbel^{-1} (0.88 g) was recorded from T_0 (control).

Combined effect of different sowing time and nutrients application showed significant effect on seed weight umbel^{-1} of fennel (Table 10 and Appendix VII). The maximum seed weight umbel^{-1} (2.09 g) was recorded from treatment combination of S_2T_3 (last week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment which was statistically identical (2.08 g) to S_4T_3

(Last week of december with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment. On the other hand, the minimum seed weight $umbel^{-1}$ (0.78 g) was recorded from last week of november with control (S_2T_0) which was statistically similar to S_1T_0 (0.89 g) treatment combination.

4.10 Seed yield $plant^{-1}$ (g)

In the present study, the seed yield $plant^{-1}$ was found to be significantly influenced by the different sowing time (Figure 6 and Appendix VII). The highest seed yield $plant^{-1}$ (32.36 g) of fennel was observed from S_2 (last week of November) treatment, while the lowest seed yield $plant^{-1}$ (27.23 g) was observed from S_4 (last week of December) treatment.

The results showed highly significant effect of different nutrients application on the seed yield $plant^{-1}$ (Figure 7 and Appendix VII). The highest seed yield $plant^{-1}$ (47.76 g) was recorded from T_3 (Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment, while the lowest seed yield $plant^{-1}$ (15.05 g) of fennel was found from T_0 (control) treatment.

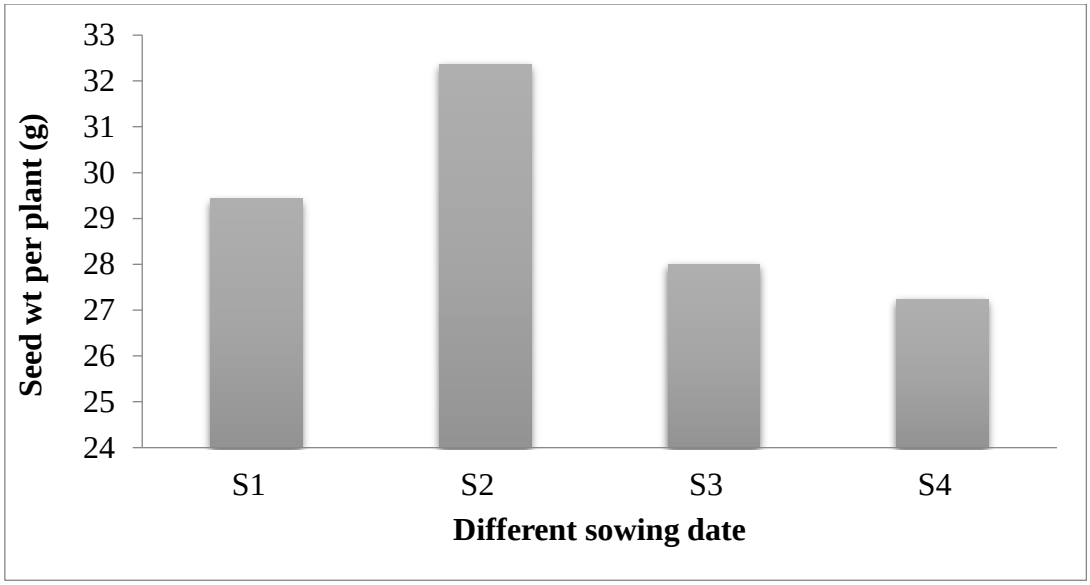


Figure 6. Effect of different sowing time on seed yield plant^{-1} (g) of fennel (*Foeniculum vulgare*) (LSD value = 0.4858). **Here, Sowing time:** S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December and S_4 – Last week of December.

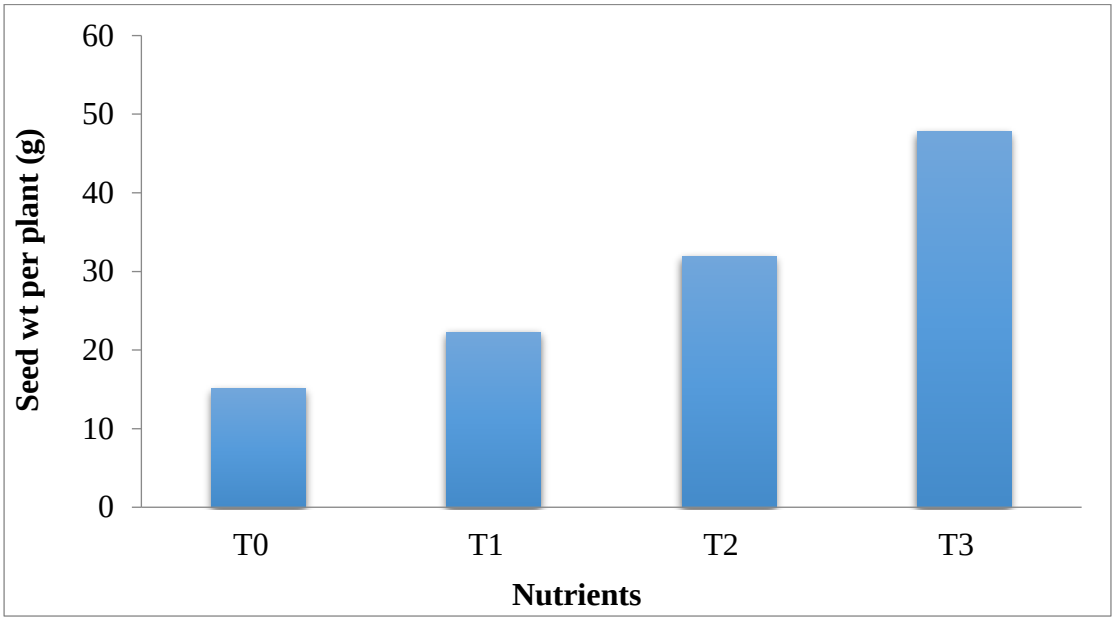


Figure 7. Effect of different nutrients on seed yield plant^{-1} (g) of fennel (*Foeniculum vulgare*) (LSD value = 0.4858) **Here, Nutrient:** T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}), T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).

The combined effect of different sowing time and nutrients application was also found to be statistically significant in this respect (Table 10 and Appendix VII). The highest seed yield plant^{-1} (56.04 g) was recorded from S_2T_3 (last week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment combination. On the other hand, the lowest seed yield plant^{-1} (13.80 g) was observed from S_4T_0 (last week of December with control) treatment combination of fennel.

4.11 Seed yield plot^{-1} (kg)

Seed yield plot^{-1} exerted significant differences among sowing time on fennel (Table 8 and Appendix VII). The maximum seed yield plot^{-1} (0.16 kg) was observed in S_2 (last week of November). On the other hand, the minimum seed yield plot^{-1} (0.13 kg) was found in S_4 (last week of December) treatment.

Seed yield plot^{-1} of fennel varied significantly due to different nutrients application (Table 9 and Appendix VII). The maximum seed yield plot^{-1} (0.24 kg) was observed in T_3 (Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment. On the other hand, the minimum seed yield plot^{-1} (0.07 kg) was found in T_0 (control).

Statistically significant differences were recorded from the interaction effect of different sowing time and nutrients application on seed yield plot^{-1} of fennel (Table 10 and Appendix VII). The maximum seed yield plot^{-1} (0.28 kg) was observed in S_2T_3 (last week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment combination. On the other hand, the minimum seed yield plot^{-1} (0.06 kg) was found in S_4T_0 (last week of December with control) treatment combination.

4.12 Seed yield ha^{-1} (ton)

In the present study, the seed yield ha^{-1} was found to be significantly influenced by the different sowing time (Table 8 and Appendix VII). The maximum seed yield ha^{-1} (1.35 ton) of fennel was observed from S_2 (last week of November) treatment, while the minimum seed yield ha^{-1} (1.13 ton) was observed from S_4 (last week of December) treatment. Ayub *et al.* (2008) found that the seed yield of fennel was affected significantly by different sowing time. Tamboli *et al.* (2020) observed that seed yield (1423 kg ha^{-1}) were recorded under early sown crop. The obtained results correlated with those given by authors like El-Khayat and Gouda (2005), Sudeep *et al.* (2005), Tunio *et al.* (2005), Omidbaigi *et al.* (2006), Sudeep *et al.* (2006), Singh *et al.* (2009) and Blazewicz (2010) on fennel plants they noticed that the earliest sown plants produced the highest seed yields compared with control plants.

The results showed highly significant effect of different nutrients application on the seed yield ha^{-1} (Table 9 and Appendix VII). The maximum seed yield ha^{-1} (1.99 ton) was recorded from T_3 (Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment, while the minimum seed yield ha^{-1} (0.63 ton) of fennel was found from T_0 (control). It was observed that seed yield ha^{-1} was higher in plants with all nutrient's application. It was probably due to reduced inter plant competition for access to nutrient, moisture and other resources. The findings of present investigation are supported by those of Khoja (2004). These results confirm the findings of Baboo and Rana (1995) and Tiwari and Banafar (1995). Increase in yield attributes due to increasing levels of N and P had direct and positive effect on seed, straw and biological yields of fennel. Patel *et al.* (2003) also recorded higher yield attributes when RDN was applied through inorganic fertilizers in fennel, while Sherin and Ahuja (2009) recorded maximum yield and yield attributes of cluster bean with vermicompost @ 2.5 t ha^{-1} + 75% NPK.

Table 8. Effect of different sowing time on seed weight umbel^{-1}, seed yield plot^{-1}, seed yield ha^{-1} and 1000-seed weight of fennel (*Foeniculum vulgare*)

Treatments	Seed weight umbel^{-1} (g)	Seed yield plot^{-1} (kg)	Seed yield ha^{-1} (ton)	1000-seeds weight (g)
S_1	1.38 b	0.15 b	1.23 b	5.83 ab
S_2	1.33 bc	0.16 a	1.35 a	5.96 a
S_3	1.27 c	0.14 c	1.17 c	5.73 b
S_4	1.48 a	0.13 d	1.13 d	5.39 c
LSD $_{(0.05)}$	**0.0603**	**0.002429**	**0.0145**	**0.1833**
CV %	**2.47**	**2.37**	**2.37**	**3.63**

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

Here, Sowing time: S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December and S_4 – Last week of December.

Table 9. Effect of different nutrients on seed weight umbel^{-1}, seed yield plot^{-1}, seed yield ha^{-1} and 1000-seed weight of fennel (*Foeniculum vulgare*)

Treatments	Seed weight umbel^{-1} (g)	Seed yield plot^{-1} (kg)	Seed yield ha^{-1} (ton)	1000-seeds weight (g)
T_0	0.88 d	0.07 d	0.63 d	5.49 c
T_1	1.17 c	0.11 c	0.93 c	5.65 bc
T_2	1.49 b	0.15 b	1.33 b	5.81 ab
T_3	1.92 a	0.24 a	1.99 a	5.97 a
LSD $_{(0.05)}$	**0.0603**	**0.002429**	**0.0145**	**0.1833**
CV %	**2.47**	**2.37**	**2.37**	**3.63**

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

Here, Nutrient: T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}), T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).

The combined effect of different sowing time and nutrients application was also found to be statistically significant in this respect (Table 10 and Appendix VII). The maximum seed yield ha^{-1} (2.34 ton) was recorded from S_2T_3 (last week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment

combination. On the other hand, the minimum seed yield ha^{-1} (0.58 ton) was observed from S_4T_0 (last week of December with control) treatment combination of fennel.

4.13 1000-seeds weight (g)

1000-seeds weight showed significant difference of fennel due to different sowing time (Table 8 and Appendix VII). The highest weight of 1000 seeds (5.96 g) was recorded from S_2 (last week of November) treatment, which was statistically similar to S_1 (5.83 g), whereas the lowest weight of 1000 seeds (5.39 g) was observed in S_4 (last week of December) treatment. Ayub *et al.* (2008) found that the effect of different sowing time on 1000-seed weight of main, primary and secondary umbels was found to be non-significant.

1000-seed weight of fennel differed significantly due to different nutrients application (Table 9 and Appendix VII). The highest weight of 1000 seeds (5.97 g) was recorded from T_3 (Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment, which statistically similar to T_2 (5.81 g) treatment. On the other hand, the lowest weight of 1000 seeds (5.49 g) was found from T_0 (control) treatment, which was statistically similar to T_1 (5.65 g) treatment. Further increase in 1000-seed weight in treatments receiving NPK compared to control might be due to better availability of nutrients that might have helped in producing bolder and heavier seeds. Almost identical results also been expressed by Panwar *et al.* (2000), Lamo (2009) and Metha (2010).

Table 10. Combined effect of different sowing time and nutrients on seed weight umbel^{-1}, seed yield plant^{-1}, seed yield plot^{-1}, seed yield ha^{-1} and 1000-seeds weight of fennel (*Foeniculum vulgare*)

Treatments	Seed weight umbel^{-1} (g)	Seed yield plant^{-1} (g)	Seed yield plot^{-1} (kg)	Seed yield ha^{-1} (ton)	1000-seeds weight (g)
S_1T_0	0.89 fg	15.53 j	0.08 j	0.65 j	5.61 c-g
S_1T_1	1.18 e	22.33 h	0.11 h	0.93 h	5.78 b-e
S_1T_2	1.63 c	32.13 e	0.16 e	1.34 e	5.80 b-e
S_1T_3	1.84 b	47.73 b	0.24 b	1.99 b	6.12 ab
S_2T_0	0.78 g	16.13 j	0.08 j	0.67 j	5.67 c-g
S_2T_1	1.09 e	23.20 g	0.12 g	0.97 g	5.88 b-e
S_2T_2	1.36 d	34.07 d	0.17 d	1.42 d	5.92 b-d
S_2T_3	2.09 a	56.04 a	0.28 a	2.34 a	6.38 a
S_3T_0	0.90 f	14.73 k	0.07 k	0.61 k	5.53 e-g
S_3T_1	1.11 e	22.20 h	0.11 h	0.93 h	5.60 d-g
S_3T_2	1.40 d	31.13 f	0.16 f	1.29 f	5.80 b-e
S_3T_3	1.68 c	43.93 c	0.22 c	1.80 c	5.97 bc
S_4T_0	0.95 f	13.80 l	0.06 l	0.58 l	5.13 h
S_4T_1	1.32 d	21.33 i	0.11 i	0.89 i	5.35 gh
S_4T_2	1.57 c	30.47 f	0.15 f	1.27 f	5.71 c-f
S_4T_3	2.08 a	43.33 c	0.22 c	1.81 c	5.40 f-h
LSD $_{(0.05)}$	**0.1206**	**0.6967**	**0.00348**	**0.029**	**0.3666**
CV%	**2.47**	**2.37**	**2.37**	**2.37**	**3.63**

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

Here, Sowing time: S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December, S_4 – Last week of December and **Nutrient:** T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}), T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).

Combined effect between different sowing time and nutrients application showed significant variation in weight of 1000 seeds (Table 10 and Appendix VII). The highest 1000-seed weight (6.38 g) was recorded from S_2T_3 (last week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) which was statistically similar to S_1T_3 (6.12 g) treatment combination. On the other hand, the lowest 1000-seed weight (5.13 g) was observed in S_4T_0 (last week of December with control), which was statistically similar to S_4T_1 (5.35 g) and S_4T_3 (5.40 g) treatment combination.

4.14 Fresh weight of plant (g)

Different sowing time showed significant effect on fresh weight of fennel (Figure 8 and Appendix VIII). The maximum fresh weight of plant (47.06 g) was recorded from S_2 (last week of November) treatment, which was statistically similar (46.94 g) to S_1 (first week of November). On the other hand, the minimum fresh weight of plant (42.88 g) was observed in S_4 (last week of December) treatment. Abou El-Magd *et al.* (2010) referred that an earlier planting date gave the highest mean of the fresh weight of the fennel plant.

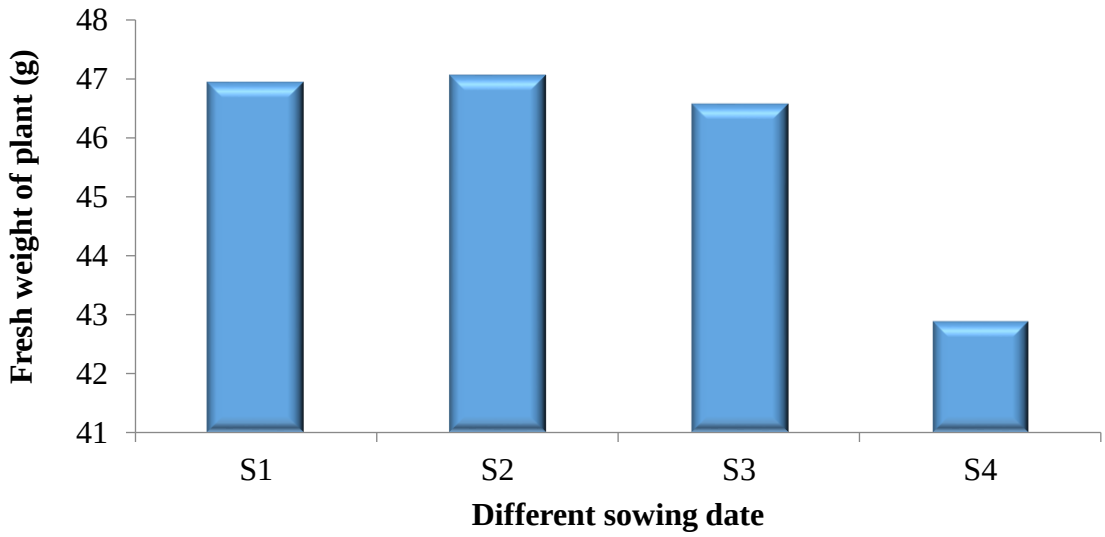


Figure 8. Effect of different sowing time on fresh weight of plant (g) of fennel (*Foeniculum vulgare*) (LSD value = 0.4685). **Here, Sowing time:** S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December and S_4 – Last week of December.

The result showed highly significant effect of different nutrients application on fresh weight of fennel (Figure 9 and Appendix VIII). The maximum fresh weight of plant (51.62 g) was recorded from T_3 (Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment. On the other hand, the minimum fresh weight of plant (36.70 g) was observed in T_0 (control) treatment. Bajya *et al.* (2017) showed that integrated nutrient management significantly affected fresh weight, dry weight during all stages of growth of fennel.

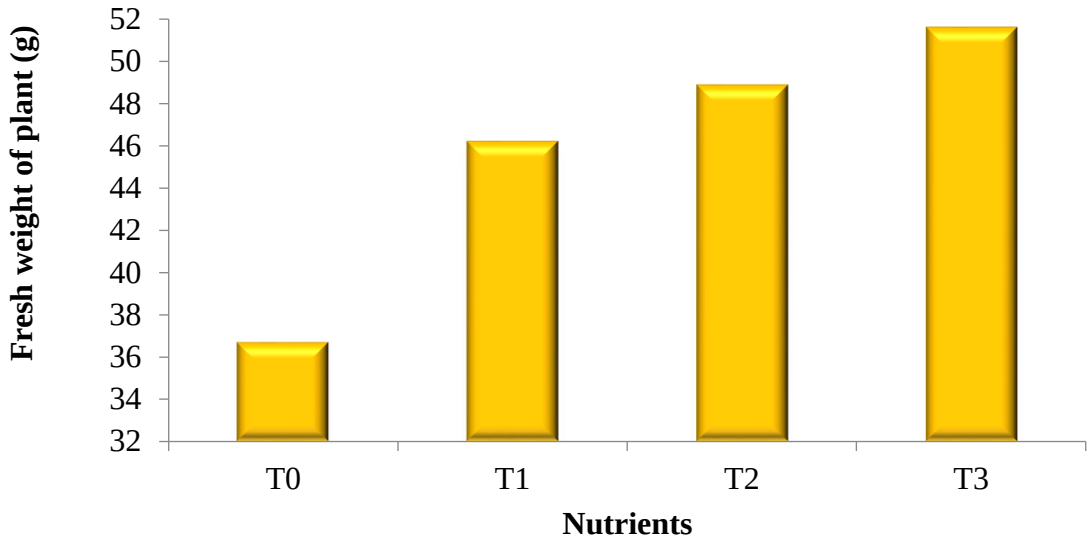


Figure 9. Effect of different nutrients on fresh weight of plant (g) of fennel (*Foeniculum vulgare*) (LSD value = 0.4685). **Here, Nutrient:** T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}), T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).

The combined effect of different sowing time and nutrients application was found to have significant influence on fresh weight of fennel (Table 13 and Appendix VIII). The maximum fresh weight of plant (53.33 g) was recorded from S_2T_3 (last week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment combination which was statistically similar to S_1T_3 (52.41 g) and S_3T_3 (51.55 g) treatment combination. On the other hand, the minimum fresh weight of plant (35.75 g) was observed in S_4T_0 (last week of December with control) treatment combination which was statistically similar to S_3T_0 (36.20 g) and S_2T_0 (37.12 g) treatment combination.

4.15 Dry weight of plant (g)

Significant variation in dry weight of plant at harvest stage was observed due to different sowing time (Table 11 and Appendix VIII). The maximum dry weight of plant (9.14 g) was recorded from S_2 (last week of November) treatment and followed by (8.93 g) S_1 (first week of November) treatment, while the minimum dry weight of plant (8.36 g) was observed in S_4 (last week of December) treatment. Dry weight of plant was found to decrease significantly due to late sowing time. This might be due to the fact that the optimum sowing time had enhanced better growth, which resulted in higher production of dry matter content of vegetative growth.

Different nutrients application showed significant influence on dry weight of fennel (Table 12 and Appendix VIII). The maximum dry weight of plant (9.66 g) was recorded from T_3 (Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment. On the other hand, the minimum dry weight of plant (7.71 g) was observed in T_0 (control) treatment. Bajya *et al.* (2017) showed that integrated nutrient management significantly affected fresh weight, dry weight during all stages of growth of fennel.

Table 11. Effect of different sowing time on dry weight of plant, fresh weight of root and germination % of fennel (*Foeniculum vulgare*)

Treatments	Dry weight of plant (g)	Fresh weight of root (g)	Germination (%)
S_1	8.93 ab	5.48 b	89.58
S_2	9.14 a	5.85 a	90.00
S_3	8.76 b	5.51 b	89.58
S_4	8.36 c	5.22 c	89.17
LSD $_{(0.05)}$	**0.2701**	**0.2488**	**NS**
CV %	**3.60**	**5.39**	**4.80**

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

Here, Sowing time: S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December and S_4 – Last week of December.

Table 12. Effect of different nutrients on dry weight of plant, fresh weight of root and germination % of fennel (*Foeniculum vulgare*)

Treatments	Dry weight of plant (g)	Fresh weight of root (g)	Germination (%)
T_0	7.71 d	4.46 c	88.33
T_1	8.54 c	5.65 b	90.00
T_2	9.29 b	5.89 ab	90.00
T_3	9.66 a	6.06 a	90.00
LSD $_{(0.05)}$	**0.2701**	**0.2488**	**NS**
CV %	**3.60**	**5.39**	**4.80**

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

Here, Nutrient: T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}), T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).

The combined effect of different sowing time and nutrients application was found to be statistically significant on dry weight of fennel (Table 13 and Appendix VIII). The maximum dry weight of plant (10.15 g) was recorded from S_2T_3 (last week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment combination which was statistically similar to S_1T_3 (9.80 g)

treatment combination. On the other hand, the minimum dry weight of plant (7.12 g) was observed in S_4T_0 (last week of December with control) treatment combination which was statistically similar to S_1T_0 (7.32 g) treatment combination.

4.16 Fresh weight of root (g)

Fresh weight of root showed significant difference of fennel due to different sowing time (Table 11 and Appendix VIII). The highest fresh weight of root (5.85 g) was recorded from S_2 (last week of November) treatment, whereas the lowest fresh weight of root (5.22 g) was observed in S_4 (last week of December) treatment.

The result showed highly significant effect of different nutrients application on fresh weight of root of fennel (Table 12 and Appendix VIII). The highest fresh weight of root (6.06 g) was recorded from T_3 (Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment, which was statistically similar to T_2 ($N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment whereas, the lowest fresh weight of root (4.46 g) was observed in T_0 (control) treatment. Bajya *et al.* (2017) showed that integrated nutrient management significantly affected fresh weight, dry weight during all stages of growth of fennel.

Combination effect of different sowing time and nutrients application showed significant effect on fresh weight of root of fennel (Table 13 and Appendix VIII). The highest fresh weight of root (6.66 g) was recorded from treatment combination of last week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1} (S_2T_3) treatment combination, which was statistically similar (6.26 g) to S_1T_3 (first week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment combination. On the other hand, the lowest fresh weight of root (4.08 g) was recorded from last week of December with control (S_4T_0) treatment combination, which was statistically similar to S_3T_0 (4.40 g) and S_1T_0 (4.57 g) treatment combination.

4.17 Germination %

Germination percentage showed non-significant difference due to sowing time (Table 11 and Appendix VIII). Numerically, the maximum germination percentage (90.00) was observed in S_2 (last week of November) and the minimum germination percentage (89.17) was found in S_4 (last week of December) treatment.

Germination percentage was significantly influenced by different nutrients application (Table 12 and Appendix VIII). Numerically, the maximum germination percentage (90.00) was observed in T_1, T_2 and T_3 treatment, while the minimum germination percentage (88.33) was found in T_0 (control) treatment.

Table 13. Combined effect of different sowing time and nutrients on fresh weight of plant, dry weight of plant, fresh weight of root and germination % of fennel (*Foeniculum vulgare*)

Treatments	Fresh weight of plant (g)	Dry weight of plant (g)	Fresh weight of root (g)	Germination (%)
S_1T_0	37.74 i	7.32 gh	4.57 fg	88.33
S_1T_1	47.27 f	9.20 c	5.52 de	90.00
S_1T_2	50.33 c	9.40 bc	5.58 de	90.00
S_1T_3	52.41 ab	9.80 ab	6.26 ab	90.00
S_2T_0	37.12 ij	8.61 de	4.80 f	88.33
S_2T_1	48.47 e	8.54 e	5.84 b-d	90.00
S_2T_2	49.33 de	9.27 bc	6.12 bc	90.00
S_2T_3	53.33 a	10.15 a	6.66 a	91.67
S_3T_0	36.20 jk	7.78 fg	4.40 fg	88.33
S_3T_1	48.40 e	8.33 e	5.67 c-e	90.00
S_3T_2	50.13 cd	9.38 bc	5.97 b-d	90.00
S_3T_3	51.55 b	9.54 bc	5.99 b-d	90.00
S_4T_0	35.75 k	7.12 h	4.08 g	88.33
S_4T_1	40.76 h	8.07 ef	5.58 de	90.00
S_4T_2	45.80 g	9.12 cd	5.92 b-d	90.00
S_4T_3	49.20 de	9.12 cd	5.32 e	88.33
LSD $_{(0.05)}$	**0.9369**	**0.5403**	**0.4976**	**NS**
CV%	**4.26**	**3.60**	**5.39**	**4.80**

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

Here, Sowing time: S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December, S_4 – Last week of December and **Nutrient:** T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}), T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).

Combined effect of different sowing time and nutrients application showed significant variation in germination percentage (Table 13 and Appendix VIII).

Numerically, the highest germination percentage (91.67) was recorded from S_2T_3 (last week of November with Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1} treatment combination) whereas, the lowest germination percentage (88.33) was observed in S_1T_0, S_2T_0, S_3T_0, S_4T_0 and S_4T_3 treatment combination.

4.18 Economic analysis

Input costs for land preparation, seed cost, fertilizer cost, irrigation and manpower required for all the operations from sowing to harvesting were recorded for unit plot and converted into cost per hectare. Price of seed was considered as per market rate. The economic analysis presented under the following headings-

4.18.1 Gross return

The combination of sowing time and nutrient application showed different gross return. The highest gross return (Tk. 3,51,000.00) was obtained from S_2T_3 (Last week of November with Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})) and the lowest gross return (Tk. 87,000.00) was obtained from S_4T_0 (Last week of December with control treatment) (Table 14).

Table 14. Cost and return of fennel cultivation as influenced by sowing time and nutrient application

Treatment	Yield (t ha^{-1})	Total cost of production (Tk. ha^{-1})	Gross return (Tk. ha^{-1})	Net Return (Tk. ha^{-1})	Benefit Cost Ratio (BCR)
S_1T_0	0.65	85,344.00	97, 500.00	12,156.00	1.14
S_1T_1	0.93	1,11,744.00	1,39,500.00	27,756.00	1.24
S_1T_2	1.34	92,736.00	2,01,000.00	1,08,264.00	2.16
S_1T_3	1.99	1,19,136.00	2,98,500.00	1,79,364.00	2.50
S_2T_0	0.67	85,344.00	1,00,500.00	15,156.00	1.17
S_2T_1	0.97	1,11,744.00	1,45,500.00	33,756.00	1.30
S_2T_2	1.42	92,736.00	2,13,000.00	1,20,264.00	2.29
S_2T_3	2.34	1,19,136.00	3,51,000.00	2,31,864.00	2.94
S_3T_0	0.61	85,344.00	91,500.00	6,156.00	1.07
S_3T_1	0.93	1,11,744.00	1,39,500.00	27,756.00	1.24
S_3T_2	1.29	92,736.00	1,93,500.00	1,00,764.00	2.08
S_3T_3	1.80	1,19,136.00	2,70,000.00	1,50,864.00	2.27
S_4T_0	0.58	85,344.00	87,000.00	1,656.00	1.01
S_4T_1	0.89	1,11,744.00	1,33,500.00	21,756.00	1.19
S_4T_2	1.27	92,736.00	1,90,500.00	97,764.00	2.05
S_4T_3	1.80	1,19,136.00	2,71,500.00	1,52,364.00	2.27

Market price of fennel: Tk. 150.00/kg

Note: S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December, S_4 – Last week of December, T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}) and T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).

4.18.2 Net return

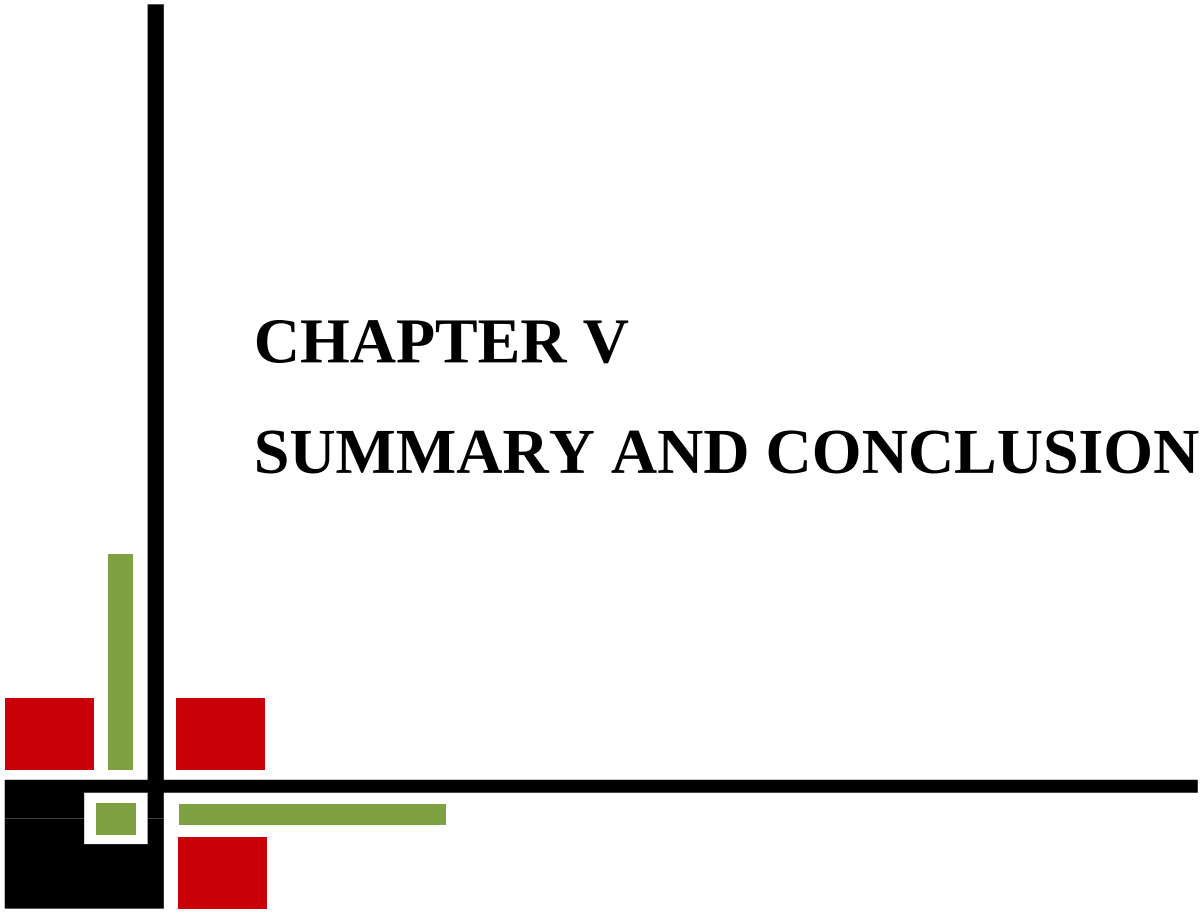
In case of net return different treatment combination showed different concentration of net return. The highest net return (Tk. 2,31,864.00) was found from S_2T_3 (Last week of November with Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})). On the other hand, the lowest (Tk. 1,656.00) net return was obtained from S_4T_0 (Last week of December with control treatment) (Table 14).

4.18.3 Benefit cost ratio

In the combination of sowing time and different nutrient application, the maximum benefit cost ratio (2.94) was noted from S_2T_3 (Last week of November) with [Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})] and the second maximum benefit cost ratio (2.50) was estimated from S_1T_3 (First week of November with NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})). The minimum benefit cost ratio (1.01) was obtained from S_4T_0 (Last week of December with control treatment) (Table 14). From economic point of view, it was apparent from the above results that the combination of Last week of November with Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment was best profitable than rest of the combination.

CHAPTER V

SUMMARY AND CONCLUSION



CHAPTER V

SUMMARY AND CONCLUSIONS

The present research work was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during October, 2019 to July, 2020 to study the effect of seed sowing time and nutrients on the growth and yield of fennel. Fennel variety 'BARI Mouri-1' was used as planting material in this study. The experiment consisted of two factors: Factors-A: Sowing time (4 levels): S_1 = First week of November, S_2 = Last week of November, S_3 = First week of December and S_4 = Last week of December; Factors-B: Nutrients (4 levels): T_0 = Control, T_1 = Vermicompost (2.50 t ha^{-1}), T_2 = NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}) and T_3 = Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}). The experiment was laid out in a Randomized Complete Block Design (Factorial) with three (3) replications. Total 48 unit-plots was made for the experiment with 16 treatments. Each plot was of required size. Data on different growth and yield parameter of fennel were recorded and significant variation was recorded for different treatments.

The result revealed that S_2 (Last week of November) treatment exhibited its superiority to other tested sowing time first week of November and first week of December in terms of seed yield. S_2 (Last week of November) treatment also showed the highest germination (90.00%), tallest plant at harvest (107.44 cm), number of leaves (12.68), number of secondary branches (17.64), maximum fresh weight of plant (47.06 g), maximum dry weight of plant (9.14 g), maximum fresh weight of root (5.85 g), maximum number of umbellet $umbel^{-1}$ (24.53), number of umbel $plant^{-1}$ (22.94), maximum weight of 1000-seeds (5.96 g), the highest seed yield $plant^{-1}$ (32.36 g) and the highest seed yield $plot^{-1}$ (0.16 kg).

Significant differences existed among different levels of nutrient application with respect to yield and yield attributing parameters of fennel.With T_3 [Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})] treatment, the highest

germination (90.00%), tallest plant at harvest (117.83 cm), number of leaves (14.02), number of primary branches (7.42), number of secondary branches (18.61), maximum fresh weight of plant (51.62 g), maximum dry weight of plant (9.66 g), maximum fresh weight of root (6.06 g), minimum days to first flower (83.30), minimum days to 50% flower (100.02), maximum number of umbellet umbel^{-1} (25.58), number of umbel plant^{-1} (24.39), maximum weight of 1000-seeds (5.97 g), maximum seed weight umbel^{-1} (1.92 g), the highest seed yield plant^{-1} (47.76 g) and the highest seed yield plot^{-1} (0.24 kg) recorded in T_3 [Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})] treatment. On the other hand, treatment T_2 [NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})] gave the second-best result in compare to T_3 treatment in some parameters like—weight of 1000-seeds, DAS to first flower, DAS to 50% flower, plant height, number of leaves, number of primary branches, dry weight of plant, fresh weight of root, fresh weight of fennel plant, number of secondary branches, number of umbellet umbel^{-1}, number of umbel plant^{-1}, seed yield plant^{-1}, seed weight umbel^{-1}, seed yield plot^{-1} and seed yield ha^{-1}.

Interaction results of sowing time and different nutrient application indicated that all the studied parameters were significantly influenced by the combined effect. Significantly the highest seed yield (2.34 t ha^{-1}) was found in S_2T_3 (last week of November × Vermicompost 2.50 t ha^{-1} + $N_{80}P_{50}K_{60}$ kg ha^{-1}) interaction due to the tallest plant at harvest (117.59 cm), number of leaves (15.07), number of primary branches (7.99), number of secondary branches (20.18), maximum fresh weight of plant (53.33 g), maximum dry weight of plant (10.15 g), maximum fresh weight of root (6.66 g), minimum days to first flower (80.20), minimum days to 50% flower (97.73), maximum number of umbellet umbel^{-1} (27.72), number of umbel plant^{-1} (26.75), maximum weight of 1000-seeds (6.38 g), maximum seed weight umbel^{-1} (2.09 g), the highest seed yield plant^{-1} (56.04 g) and the highest seed yield plot^{-1} (0.28 kg) production. The highest gross return (Tk. 3,51,000.00) and the highest net return (Tk. 2,31,864.00) was obtained from S_2T_3 (Last week of November with Vermicompost (2.50 t ha^{-1}) + NPK

($N_{80}P_{50}K_{60}$ kg ha^{-1})) treatment combination. The maximum benefit cost ratio (2.94) was noted from S_2T_3 (Last week of November with Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}) and the second maximum benefit cost ratio (2.50) was estimated from S_1T_3 (First week of November with NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})). From economic point of view, it was apparent from the above results that the combination of Last week of November with Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}) treatment was the best profitable than rest of the combination.

It was revealed that Last week of November sowing gave higher yield of fennel seed with higher values in most of the yield attribute parameters. Among the nutrient application treatments, Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})] was high yielder than other nutrient treatments. Among the interactions, S_2T_3 and S_1T_3 were superior in most of the growth and yield attributing parameters along with grain yield. From economic point of view, S_2T_3 and S_1T_3 combination was found profitable for fennel cultivation in Bangladesh and S_2T_3 [(Last week of November with Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1})] treatment was the best profitable than rest of the combination.

RECOMMENDATION

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

- More sowing time of fennel may be used with other nutrient sources for getting sowing time and specific nutrient recommendations.
- Studies of similar experiment could be carried out in different agro-ecological zones (AEZ) of Bangladesh for the evaluation of zonal adaptability.

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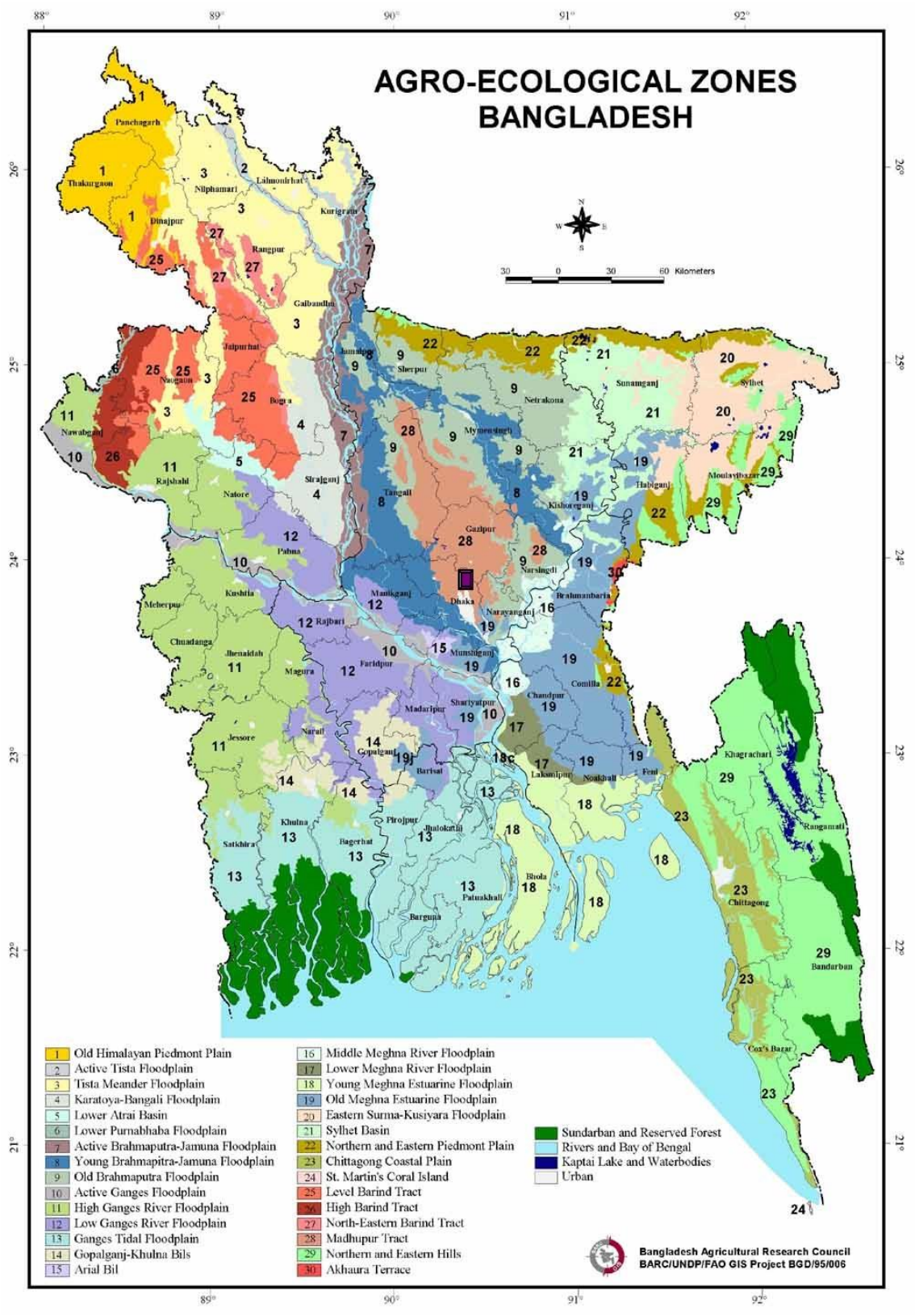
APPENDICES

APPENDICES

Appendix I. Map showing the experimental sites under study



The experimental site under study

Appendix II. Monthly average Temperature, Relative Humidity (RH) and Total Rainfall of the experimental site during the period from October, 2019 to July, 2020

Month	Air temperature (°C)		RH (%)	Total rainfall (mm)
	Maximum	Minimum		
October, 2019	37.89	25.49	81	37
November, 2019	31.82	14.04	78	24
December, 2019	23.40	10.50	75	5
January, 2020	20.18	7.04	72	0
February, 2020	18.20	9.70	74	15
March, 2020	34.70	22.94	82	78
April, 2020	36.28	29.68	86	125
May, 2020	38.95	33.40	89	155
June, 2020	37.55	32.93	92	183
July,2020	35.91	32.57	91	173

Source: Bangladesh Metrological Department (Climate and weather division) Agargaon, Dhaka.

Appendix III. Characteristics of experimental fields soil was analysed by Soil Resource Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly levelled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Boro rice-Fallow-Aman rice

B. Physical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30

C. Chemical properties of the initial soil

Characteristics	Value
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (meq/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI), Farmgate, Dhaka.

Appendix IV and V. Analysis of variance (mean square) of plant height at different DAS and different growth parameters

Source of variation	Degree of freedom	Mean square			Mean square				
		Plant height (cm)			Number of leaves	Number of Primary branches	Number of secondary branches	Number of umbels per plant	Number of umbellet per umbel
		45 DAS	90 DAS	135 DAS					
Replication	2	0.3133	2.65	5.01	1.1700	0.09614	0.1695	1.461	0.0853
Nutrients (A)	2	5.1033**	229.69**	220.01**	10.5078**	2.43229**	10.9855**	63.535**	18.1698**
Different sowing date (B)	3	37.4419**	1270.40**	1924.09**	47.9033**	7.01793**	46.3681**	132.035**	69.8121**
Interaction (AxB)	6	0.8153**	13.83**	17.62**	1.0478**	0.19988**	4.5182**	0.655**	2.2757**
Error	22	0.1812	1.23	1.22	0.5309	0.08572	0.1658	0.511	0.4653

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

Appendix VI and VII. Analysis of variance (mean square) of yield parameter

Source of variation	Degree of freedom	Mean square							
		No of DAS to first flowering	No of DAS to 50% flowering	Seed wt. per umbel (g)	Seed wt. per plant (g)	Seed wt. per plot (kg)	Seed wt. per ha (ton)	Thousand seed wt. (g)	Fresh wt. of vegetative growth (g)
Replication	2	0.1834	0.0904	0.00186	0.752	0.00002	0.00362	0.12790	0.075
Nutrients (A)	2	68.9156**	73.8636**	0.01330**	45.529**	0.00114**	0.21957**	0.69565**	47.995**
Different sowing date (B)	3	62.2886**	64.3257**	0.14596**	400.727**	0.01002**	1.93252**	0.51107**	505.601**
Interaction (AxB)	6	1.6191**	0.8430**	0.00316**	2.046**	0.00005**	0.00987**	0.06096**	5.957**
Error	22	0.4536	0.2790	0.00076	0.314	0.00001	0.00151	0.04330	0.334

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

Appendix VIII. Analysis of variance (mean square) of dry weight of vegetative growth, fresh weight of root and germination (%)

Source of variation	Degree of freedom	Mean square		
		Dry wt. of vegetative growth (g)	Fresh wt. of root (g)	Germination %
Replication	2	0.18660	0.10761	22.3958
Nutrients (A)	2	1.32519**	0.80595**	1.3889 ^{NS}
Different sowing date (B)	3	8.95662**	6.26036**	8.3333 ^{NS}
Interaction (A x B)	6	0.43564**	0.20892**	1.3889 ^{NS}
Error	22	0.10012	0.08832	18.5069

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

Appendix IX. Production cost of fennel per hectare
A. Input cost (Tk/ha)

Treatment combination	Labor cost	Ploughing cost	cost of seed	Cost of irrigation	Cost of manure and fertilizers				Insecticide/ pesticide	Sub-total (A)
					Vermicompost	UREA	TSP	MOP		
S_1T_0	24, 000	8000	3000	8000	00	00	00	00	6000	49000
S_1T_1	24, 000	8000	3000	8000	25000	00	00	00	6000	74000
S_1T_2	24, 000	8000	3000	8000	00	2700	1800	2500	6000	56000
S_1T_3	24, 000	8000	3000	8000	25000	2700	1800	2500	6000	81000
S_2T_0	24, 000	8000	3000	8000	00	00	00	00	6000	49000
S_2T_1	24, 000	8000	3000	8000	25000	00	00	00	6000	74000
S_2T_2	24, 000	8000	3000	8000	00	2700	1800	2500	6000	56000
S_2T_3	24, 000	8000	3000	8000	25000	2700	1800	2500	6000	81000
S_3T_0	24, 000	8000	3000	8000	00	00	00	00	6000	49000
S_3T_1	24, 000	8000	3000	8000	25000	00	00	00	6000	74000
S_3T_2	24, 000	8000	3000	8000	00	2700	1800	2500	6000	56000
S_3T_3	24, 000	8000	3000	8000	25000	2700	1800	2500	6000	81000
S_4T_0	24, 000	8000	3000	8000	00	00	00	00	6000	49000
S_4T_1	24, 000	8000	3000	8000	25000	00	00	00	6000	74000
S_4T_2	24, 000	8000	3000	8000	00	2700	1800	2500	6000	56000
S_4T_3	24, 000	8000	3000	8000	25000	2700	1800	2500	6000	81000

Note: S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December, S_4 – Last week of December, T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}) and T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).

Price: Labor cost – 500 tk./day, Ploughing (4 time) – 2000tk./cultivation, Seed cost – 500 Tk./kg, Vermicompost – 10,000 Tk. ton^{-1}, Urea – 16.00 Tk. kg^{-1}, TSP – 22.00 Tk. kg^{-1}, MoP – 15.00 Tk. kg^{-1} and Other cost of production – 67,800.00 Tk. ha^{-1}.

B. Overhead cost (Tk/ha)

Treatment combination	Cost of lease of land (8 months)	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 months (Tk. 14% of cost/year)	Sub-total (Tk.) (B)	Total cost of production (Tk./ha) [Input cost (A) + overhead cost (B)
S_1T_0	30000	2450	3894	36344	85, 344
S_1T_1	30000	3700	4044	37744	1,11,744
S_1T_2	30000	2800	3936	36736	92,736
S_1T_3	30000	4050	4086	38136	1,19,136
S_2T_0	30000	2450	3894	36344	85,344
S_2T_1	30000	3700	4044	37744	1,11,744
S_2T_2	30000	2800	3936	36736	92,736
S_2T_3	30000	4050	4086	38136	1,19,136
S_3T_0	30000	2450	3894	36344	85,344
S_3T_1	30000	3700	4044	37744	1,11,744
S_3T_2	30000	2800	3936	36736	92,736
S_3T_3	30000	4050	4086	38136	1,19,136
S_4T_0	30000	2450	3894	36344	85,344
S_4T_1	30000	3700	4044	37744	1,11,744
S_4T_2	30000	2800	3936	36736	92,736
S_4T_3	30000	4050	4086	38136	1,19,136

Note: S_1 – First week of November, S_2 – Last week of November, S_3 – First week of December, S_4 – Last week of December, T_0 - Control, T_1 - Vermicompost (2.50 t ha^{-1}), T_2 - NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}) and T_3 - Vermicompost (2.50 t ha^{-1}) + NPK ($N_{80}P_{50}K_{60}$ kg ha^{-1}).