EFFECT OF TRANSPLANTING DATE AND ORGANIC MANURE ON GROWTH, YIELD AND ESSENTIAL OIL CONTENT OF MINT *(Mentha piperita L.)*

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CERTIFICATE

This is to certify that the thesis entitled '**Effect of Transplanting date and Organic manure on Growth, Yield and Essential Oil Content of Mint (*Mentha piperita* L.)**' submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the results of a piece of bona fide research work carried out by **SUMA DAS**, Registration No. **17-08188** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2018
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TO

MY BELOVED PARENTS

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EFFECT OF TRANSPLANTING DATE AND ORGANIC MANURE ON GROWTH, YIELD AND ESSENTIAL OIL CONTENT OF MINT (*Mentha piperita L.*)

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SUMA DAS

ABSTRACT

The present experiment was conducted at the Horticultural farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2017 to April 2018 to evaluate the effect of transplanting date and organic manure on growth, yield and essential oil content of mint. The experiment consisted of two factors: Factor A: Transplanting date (4 levels) as; T_1: Transplanting at 15 November, T_2: Transplanting at 30 November, T_3: Transplanting at 15 December; $T_{4:}$ Transplanting at 30 December; and Factor B: Organic manure (3 levels) as; M_0: 0 kg/ha manure (control), M_1: Vermicompost @ 3 t/ha, M_2: Bio-fertilizer @370 kg/ha. The two factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Transplanting date and organic manures significantly influenced on different growth and yield parameter of mint. In case of transplanting date, the highest herbage yield (6.79 t/ha), oil content (5.71%) and oil yield (33.93 L/ha) were found from T_3 and the lowest herbage yield (4.99 t/ha), oil content (4.26%) and oil yield (18.33 L/ha) from T_1. Considering the organic manure application, M_2 produced the highest herbage yield (7.34 t/ha), oil content (5.81%) and oil yield (33.89 L/ha) and the lowest herbage (3.76 t/ha), oil content (4.20%) and oil yield (17.69 L/ha) was from M_0. Regarding the interaction effect, the highest herbage yield (8.88 t/ha), oil content (6.55%) and oil yield (45.06 L/ha) were obtained from treatment combination T_3M_2 and the lowest herbage yield (3.42 t/ha), oil content (3.46%) and oil yield (13.71 L/ha) from T_1M_0. The highest net return (BDT 1,105,679/ha) and benefit cost ratio (5.89) were obtained from the treatment combination T_3M_2 and the lowest (BDT 307,970/ha) net return and benefit cost ratio (2.50) were obtained from T_1M_0. So, the transplanting at 15 December with bio-fertilizer @ 370 kg/ha can be used for herbage and essential oil production for mint.

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LIST OF ACCRONYMS AND ABBREVIATIONS

ACCRONYM	ABBREVAITION
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Cm	Centimeter
Cm^2	Centi-meter square
CV	Coefficient of Variance
DAT	Days After Transplanting
et al	and others
G	Gram (s)
Hortc.	Hotriculture
i.e.	*id est* (L), that is
J.	Journal
Kg	Kilogram (s)
HSD	Honestly Significant Difference
V	Vermicompost
Physiol.	Physiological
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
t ha^{-1}	Ton per hectare
RCBD	Randomized Completely Block Design
%	Percentage
@	At the rate of
Df	Degrees of freedom

Chapter I
Introduction

CHAPTER I

INTRODUCTION

Peppermint (*Mentha piperita* L.) is a perennial herb, popularly known as "Mint" in Bangladesh belongs to Labiatae family. It is an important oil bearing herb which is native to Mediterranean countries and the World most valuable flavoring agent (Fenarolics ,1971). Bangladesh is rich in medicinal plant (Ghani, 2002) & there are about 5000 species of plant in Bangladesh (ICUN, 2003). Dhaka, Rajshahi, Shylet & Chittagong divisions are rich in medicinal plants. Mint plants are one of the most interesting research plants; they are between medicinal and aromatic plants (Aflatuni, 2005) and it is grown primarily for the oil produced from its leaves. Peppermint is grown for commercial production of peppermint essential oil, for production of peppermint dry leaves, or for the fresh herb market (Lawrence, 2006; Mustjatse, 1985; Topalov, 1989). Peppermint essential oil is a major aromatic agent used extensively in chewing gum, toothpaste, mouth washes, confectionary and aromatherapy products (Lawrence, 2006; Topalov, 1989; Mint Industry Research Council, 2009).

Peppermint oil is one of the most popular in traditional medicine as herbal tea, essential oil & menthol which are used as pharmaceuticals & oral preparation (Edris *et al*., 2003). The oil and aroma chemicals in pure form command a massive demand especially in food and allied industries. Tea is prepared by using the mint leaves in a dry or fresh form. Its leaves can be used either in raw form or it can be cooked and it also contains the essential oil. The essential oil of the herb also used to season salad and other cooked food. Mint is usually taken after a meal for its credibility to reduce indigestion and colonic spasms by decreasing the gastro-cholic refluxes. Its pleasant taste makes it an excellent gastric stimulant (Budavari, 1989 and Gupta, 1991).

The essential oil is valued for two main reasons firstly, due to its antiseptic properties and also because, it is useful in treating digestion related disorders. Its shoots and leaves are used in flavoring food items: beverages, jellies, syrups, candies, ice creams, perfumes and medicines (Dorman *et al.* 2003 and Ohloff, 1994). Its leaves are also used in therapeutic uses related to its spasmolytic, carminative, stomachic, antiemetic and anthelmintic properties (Mckav and Blumgerb, 2006).

Vermicomposting is one of the most valuable ecological endeavors we have engaged in as it caters not only environmental protection but also it improves soil aeration and texture thereby reducing soil compaction. It improves water retention capacity of soil because of its high organic matter content. It also promotes better root growth and nutrient absorption and improves nutrient status of soil, both macro-nutrients and micro-nutrients. So, nutrition is vital that increases plant productivity and the concentration of bioactive compounds both quantitatively and qualitatively (Shah *et al.* 2010).

The beneficial applications of bio-fertilizers on medicinal plants as well as enhancement on quality of plants yield (Copetta *et al.,* 2006; Freitas *et al.,* 2004; Kapoor *et al.,* 2004). Bio-fertilizers add nutrients through the natural process of nitrogen fixation, solubilizing phosphorus and stimulating plant growth through the synthesis of growth promoting substances (Mazid and Khan, 2015). It can be expected to reduce the use of synthetic fertilizers and pesticides. Through the use of bio-fertilizers healthy plants can be grown, while enhancing the sustainability and health of the soil. The uses of bio-fertilizer before the planting of mint propagules produced beneficial effects on crop growth. Due to their availability and capacity to supply both macro and micronutrients, it improves physical, chemical and biological properties of soil in addition to providing adequate nourishment if added in required amount.

In addition, yield and the essential oil composition of mint species were influenced by interaction between the genotype and environment, method of distillation, kind of storage, crop age, time of harvest and season (Alsafar and Hassan, 2009). Among the various factors which affect, planting time and nutrient sources are important. Yields of fresh material and essential oil were enhanced by planting time and the optimization of this factor can lead to a higher yield in the mint. Although mint can plant anytime during the growing season, root divisions will be established faster if planted on a cool, moist day in spring or fall. The effect of optimum planting time on growth and development is largely due to change in the season of planting and consequently to the greater growth of peppermint. Composition of essential oil is strongly dependent on developmental stage of the plant (ontogeny), and therefore harvesting time is one of the most important factors influencing mint oil (Clar and Menary, 2006).

The herb yield and essential oil biosynthesis in Mint is strongly influenced by several intrinsic and extrinsic factors including fertilizer, planting time, harvesting time and other agro-climatic factor (Singh *et al.* 1995). However, the studies investigating to know the effect of transplanting date and organic fertilizers on the growth and yield of peppermint fresh herb and oil under Bangladesh climate condition.

OBJECTIVES:

This study has been taken under consideration to achieve the following objectives:

1. To find out the optimum transplanting date of mint.
2. To evaluate the influence of organic manures on growth and yield of mint.
3. To study the effect of transplanting date and organic manures on oil content of mint.

Chapter II
Review of literature

CHAPTER II

REVIEW OF LITERATURE

Mint is an important medicinal herb and popularly used as salad, herbal tea, condiments etc. in Bangladesh. It is useful in treating digestion related disorders and its shoots and leaves are used in flavoring food items. The organic production of different mint species and related crops was studied by various authors. The valued conclusions of those assessments are appraised critically and highlighted in this chapter selectively under diverse headings as the users' friendly manner.

2.1 Concept of Organic farming

Organic farming is not merely a non-chemical agriculture; instead, it is a system of farming based on integrated relationships. So, the relationship among soil, water, plants and soil micro flora should be known and then the overall association of both the plant and the animal kingdoms could be established of which human being are at the apex who can bring the integrated system in agriculture. The totality of these liaisons is the backbone of organic farming.

The uses of organic manures to meet the nutrient requirements of crops would be inevitable in the years to come for sustainable agriculture. Organic manures generally improve the physical, chemical and biological properties of soils beside conserving and improving the moisture holding capacity. Organic manures provide nutrients and are considered as one of the vital keys to increase biomass production, especially for the quality of essential oils in medicinal plants and spices, as well as being safer for the humans and animals health and the environment, providing benefits in the form of improvement in soil physical, chemical and biological properties (Priyadarshani *et al.* 2013; Rosal *et al.* 2011; Al-Fraihat *et al.* 2011; Brant *et al.* 2010 and Correa *et al.* 2010).

According to the USDA (2012), the organic farming is a production system which avoids or largely excludes the uses of synthetic fertilizers, pesticides, growth regulators and livestock feed additives. To the maximum extent possible, organic farming systems rely on crop rotations, crop residues, animal manures, legumes, green manures, off farm organic wastes and the means of biological pest control strategies. This is to maintain the soil productivity and the good tilth of the field to get plant nutrients and control insects, weeds and other pests too (Anon., 1980).

An additional benefit of using organic compost to provide nutrients for plant growth is that those provide an alternative measure to manage and dispose farm residues. The growing demand for food produced without the uses of pesticides as well as the pollution free environment is a global issue. In general, consumers are increasingly purchasing organic products including herbal and medicinal plants (Naguib, 2011), which have a growing global market as those are a source of biologically active natural products.

As per Lampkin (1990), the principal elements considered while practicing organic farming are: a) creating a healthy crop field, b) making nutrient and energy flows in the soil ecosystem, c) keeping the life in the cycle, and d) sustainable yield.

2.2 Effect of Organic manure on yield and yield contributing characters of *Mentha*

Suresh *et al.* (2018) Studied on the organic nutrition for the growth and yield of the Japanese mint and pointed out that the application of vermicompost @ 2.5 t /ha + humic acid 0.2% + panchagavya 3% resulted in improving the growth characteristics like plant height, plant spread, number of lateral branches, number of leaves and leaf area, the herbage yield and dry matter production as well.

Arafa *et al*. (2017) studied the effect of some organic manures and bio-fertilizers on *Mentha* plant which suggested that bio-fertilizers produced higher fresh herb in terms of g/plant and ton/ha. The maximum total fresh yield g/plant for two cuts was gained from FYM + N (298.6 and 309.6) g/plant in both seasons. The treatment of FYM + N recorded the tallest plants; the highest mean value was (70.3 and 69.0 cm) in both seasons respectively. The highest branches number/plant was (19.8 and 20.8) in both seasons respectively from FYM + N.

Hussein *et al.* (2015) conducted a study on the effects of foliar organic fertilization on the growth, yield and oil contents of *M. piperita* var. *citrate* in Malaysia. The results showed that there was significantly clear positive trend in increasing growth traits by spraying humic acid. The interaction effect was significant in both cuts, the highest values of plants, herbage fresh and dry weights (g/plant) were obtained from the treatment sprayed with humic acid @ 5g/ L + amino spot at 1.5 ml followed by the treatment sprayed with 2.5 g/ L humic acid + 1.5 ml/ L amino spot at the two cuts.

Mahmoodabad *et al.* (2014) investigated the changes in the yield and the growth of green mint under foliar application of urea and soil application of vermicompost showed the highest (295 g) and the lowest (217.33 g) plant dry weights, respectively in the application of vermicompost @ 10 t/ha over the control treatment.

Olfati *et al*. (2014) conducted an experiment on mint and reported that vermicompost had the highest essential oil yield (24.21 ml/m), the highest number of lateral branches (18), fresh (10.51 g) and dry weight (4.64 g) of plant, fresh (2,102.9 kg/ha) and dry (928.67 kg/ha) yield, leaf area index (0.17) and the highest oil per plant (0.24 ml/plant) and oil yield (18.49 ml/m).

Rahman *et al.* (2014) stated that in case of production of Pudina, cowdung, poultry manure and cowdung+ NPK fertilizer produced statistically identical yield. cowdung and poultry manure showed its superiority on plant height, Leaf length,1000-fresh leaf yield and fresh yield of Tulsi and Pudina (Mint) medicinal plant to the control cowdung treatment gave the highest no. of branch/plant as the value 15.33 no. of branch/plant. The maximum leaf number (150.00) was appeared in cowdung treatment.

Research on the quality yield of the herbal mint (*M. piperata L*) under the influence of mineral and organic fertilization in Germany showed that the yield of the mint herbage was positively influenced by the increasing nitrogen rates up to 120 kg/ ha, which was the highest production rate. It was worth noting that the use of foliar fertilization on peppermint herbage achieved a production of 18,666 kg /ha (Valeriu and Ovidiu, 2011).

An investigation with the roots of *Asparagus racemosus* grown under organic manures- cowdung, compost and vermicompost without using mineral or chemical fertilizer showed that the total phenol and total flavonoid content was highest in the plants from vermicompost treated soil. The antioxidant activity was highest in the plants from compost treated soil (Saikia and Upadhyaya, 2011).

An Iranian investigation revealed that inoculation of *Ocimum basilicum* roots with plant growth-promoting rhizobacteria (PGPR) improved growth and accumulation of essential oils. Treatments were *Pseudomonas putida* strain 41, *Azotobacter chroococcum* strain 5 *and Azosprillum lipoferum* strain OF. In comparison to the control treatment, all factors were increased by PGPR treatments. The maximum root fresh weight (3.96 g/plant), N content (4.72%) and essential oil yield (0.82%) were observed in the *Pseudomonas* + *Azotobacter* + *Azosprillum* treatment. All factors were higher in the *Pseudomonas* + *Azotobacter* + *Azosprillum* and *Azotobacter* + *Azosprillum* treatments (Ordookhani *et al*., 2011).

Kumar and Sood (2010) conducted an experiment on this crop with three organic fertilizers: FYM (10 t/ha), vermicompost (10 t/ha) and Azotobacter (10 kg/ha); and one standard dose of NPK (120:50:40 kg/ha). The use of vermicompost resulted in enhanced plant height, yield, oil content and oil yield of 39.48 cm, 190.11 q/ha, 0.34% and 57.29 kg/ha.

An experiment with application of saline water in addition to bio and organic fertilization on geranium plant revealed that peanut compost slightly increased plant fresh and dry weights. The oil percentage decreased at high salinity level of 6000 ppm but at 3000 ppm the oil percentage reached 0.4 when treated with (half dose of compost+Bio) and 0.6% when plants were supplied with full dose of peanut compost compared to the control (Leithy *et al*., 2009).

An investigation with marjoram (*Majorana hortensis* L.) indicated that the use of combined treatment of bio-fertilizers gave better results for all studied traits. The oil percentage and yield per plant for three cuttings was almost twofold higher on fresh weight basis as a result of aqueous extracts of compost at low level + bio-fertilizers compared with control. The chemical composition of marjoram essential oil did not change due to the fertilization type or level (Gharib *et al*., 2008).

In an Iranian experiment, the effects of different levels of vermicompost and irrigation were evaluated on morphological characteristics and essential oil content of “Goral” an improved German chamomile. The results indicated that the vermicompost application improved plant height, early flowering; flowers dry weight, anthodia height and diameter significantly. The highest essential oil yield detected in 10% vermicompost and irrigation 4 mm per two weeks. This experiment revealed that 15% vermicompost plus 2 mm irrigation per two weeks was the best treatment to produce the flower yield in Goral cultivar of German chamomile in organic system (Azizi *et al*., 2008).

In a study, vermicomposted coirpith and coirpith composted with microorganisms were used as a growth medium for growing the medicinal plant and *Rographis paniculata.* The results indicated that vermicomposted coirpith could be helpful for the reclamation of soils from industrial sites in a small scale nursery (Vijaya *et al*., 2008).

El-Sherbeny *et al*. (2005) stated that by increasing levels of compost fertilizer to *Sideritis montana* L., vegetative growth and major components of essential oils also increased.

Poultry manure application significantly increased the herbage, essential oil content and dry matter yield in *Java citronella* plants (Adholeya and Prakash, 2004).

The percentage of essential oil, fresh and dry matter of marjoram plants positively responded to increased levels of composted manure compared with chemical fertilizer (Edris *et al*., 2003).

Ram *et al*. (2001) conducted a field experiment with peppermint (*Mentha piperita* L.) in a sandy loam soil at Lucknow, India where suggested to get sustainable production of peppermint, application of Vermicompost 9 t/ha along with 112.5 kg N/ha through synthetic fertilizer is recommended for light textured sandy loam soils as it produced maximum essential oil (94.3 kg/ha), increased the herb and essential oil yields by 104 and 89%.

Chand *et al.* (2001) recorded the highest herbage yield (28.81 and 24.71 t/ha) and oil yield (216.0 and 222.4 t/ha) in mint with the combined uses of FYM (6.7 t/ha) and NPK (133:40:40 kg/ha).

Singh *et al.* (1988) noted that the uses of FYM @ 40 t /ha increased the oil yield (75.4 l/ha) with higher net returns ha-1 (Rs. 34322/ha) in *M. arvensis.*

2.3 Effect of organic manures on the quality of medicinal and aromatic crops

In *O. gratissimum*, the maximum plant height, number of leaves, number of branches and dry matter production were found with the treatment combination of *Glomus fasciculatum, Azotochroccocum, Aspergillus awamori* each @ 2 kg/ha (Rashmi *et al.* 2008).

An investigation was conducted to evaluate the response of *Dracocephalum moldavica* L. (dragonhead) to various plant densities and compost applications. Compost had a positive effect on vegetative growth and induced essential oil accumulation (Hussein *et al*., 2006).

Shivakumar *et al.* (2006) reported that the combined application of *Aspergillus awamori* (105 CFU/ ml), *Trichoderma harzianum* (1010 CFU/ml), *Glomus mossease* (30g) and compost (4 g/kg soil) produced the largest plant and leaf yield in coleus.

In coleus, Sudhakara (2005) reported that the use of FYM @ 15t, vermicompost @ 1t and neem cake @ 1t along with bio-fertilizers @ 10 kg *(Azotobacter chroococum, Bacillus megetarium, Glomus bhagyaraj*) per ha resulted in the tallest plant (49.96 cm), plant spread (2635.9 cm^2), leaf area (9732.45 cm^2), total dry matter/plant (284.25 g), number of tuberous roots/plant (34.23) and dry weight of tubers roots/ha (13.49 t).

Mohanchandra (2003) obtained the maximum alkaloid content (0.51 %) in makoi with the incorporation of 75 % NP + full dose of K along with *Azotobacter, Azospirillum* and FYM.

The utilization of vermicompost @ 2.5 t/ha along with inorganic fertilizers resulted in the higher oil yield (57.88 kg/ha) in sweet basil (Singh and Ramesh, 2002).

The application of vermicompost @ 2.5 t/ha along with inorganic fertilizers resulted in the tallest plant, herbage and oil yields (70.2 cm, 11.98 t/ha and 31.61 kg/ha, respectively) in sweet basil (Munnu and Ramesh, 2002).

2.4 Effect of transplanting date of *Mentha*

Shwetha *et al.* (2018) conducted a field experiment in Karnataka, India to determine the effect of different dates of planting (1st October, 1st November and 1st December) and observed that maximum plant height, spread and number of branches (63.30, 52.11 cm and 25.92, respectively) and yield parameters like fresh and shade dried herbage yield (9.04 and 7.23 t/ha), oil yield and content (80.08 kg/ha and 1.09 %) when crop planted on 1st November.

Salim *et al*. (2015) reported that the highest oil content obtained from summer due to that the season conditions activate the physiological process, which lead to oil gland formation and collection of oil in oil glands. The difference in oil content was due to climatic factors such as temperature, rainfall and light.

Nasima *et al.* (2009) conducted an experiment to find out the effect of essential oil percentage content and morphogenesis of *Mentha piperita* with foliar treatment of different concentration of zinc solution (1 ppm, 1.5 ppm, 2 ppm, 2.5 ppm, 3 ppm and 3.5 ppm as zinc chloride) in earthen wear pots in three seasons of Bangladesh (winter, summer and monsoon) and reported that In monsoon the maximum increase of leaves/hector (37.31 t/ha) and 6.7% essential oil with 3 ppm Zn chloride solution.

Ozel and Ozguven (2002) conducted an experiment on mint to find out the Effect of different planting times on essential oil components of different mint (*Mentha* spp.) and reported that the essential oil components were affected by planting times, mint varieties and cutting numbers. The highest menthole ratio was obtained from *M. arvensis* var. *piperascens* (33.50-38.89%), from second cutting and autumn transplantation.

Zheljazkov and Topalov (1996) conducted a field experiment to find out the effect of planting time and density on yields from rooted mint cutting and said that yields of fresh material and essential oil were enhanced by planting on September 1 and by increasing the planting density.

2.5 Essential oil yield of *Mentha*

Chemat and Boutekedjiret (2015) reported that the traditional way of isolating volatile compounds as essential oils from plant material is distillation and by applying this method the yield of essential oils from plants is between 0.005 and 10%.

Muhammad *et al.* (2015) observed that the higher essential oil percentage (3.53%) was obtained with the lowest densities of planting.

Mansoori (2014) stated that the value of fresh biomass and essential oil yield were increased by increasing plant density from 8 (plant m^{-2}) to 20 (plant m^{-2}). Maximum oil yield and dry matter was obtained in the first harvesting.

Kumar (2010) said that distillation method was found to be one of the promising techniques for the extraction of Essential Oil from plants as this process will preserve the original qualities of the plant.

Nasima *et al.* (2009) observed that 3 ppm zinc chloride solution as a foliar treatment gave the maximum essential oil 0.50%.

Oil production in mint plants increased when plants were grown with biosolid (Scavroni *et al.*, 2005).

The impact of environmental factors such as temperature, relative humidity, irradiance, photoperiod and cultivation practices influence the composition of essential oils. The influence of the method of extraction on oil composition and the labiality of the constituents of essential oil explains why the composition of the product obtained by hydro distillation is most often different from that which is initially present in the secretary organs of the vegetable (Bruneton, 1995)

Shah and Gupta (1989) said that harvesting a crop early or late resulted in a low yield of leaves as well as the essential oil content because at an earlier or later stage of harvesting, the crop was immature or over mature resulting in a poor yield of herb and oil content.

White *et al.* (1987) conducted an experiment on Peppermint: effect of time of harvest on yield and quality of oil and reported that the best yield of high quality oil in peppermint was obtained in late January – early February when the inflorescence on the main stem was in 10 - 206, 10 bloom and oil yield peaked at 114 kg/ha on 31 January and the composition of extracted oil was: menthol 43.1, menthone 28, menthyl acetate 6.6, cineole 4.1, and menthofuran 3.8%.

Munsi and Mukherjee (1982) reported that a significant increase in the yield of *Mentha* oil by application of 60 kg P_2O_5/ha. The use of vermicompost served as the best substitute for the cultivation of *Mentha piperita* under organic conditions.

Chapter III
Materials and methods

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out to assess the effect of transplanting date and organic manure on growth, yield and essential oil content of mint. The materials and methods i.e. experimental period, location, climate condition and soil of experimental site, planting materials, design of the experiment, data collection and data analysis procedure that were used for conducting the experiment are presented in this chapter under the following headings and sub-headings-

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from November 2017 to April 2018.

3.1.2 Experimental location

The present study was conducted at the Horticultural Research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The GPS (Global Positioning System) experimental site was at 24°09′ N latitude and 90°34′ E longitudes with an elevation of 8.4 meter from sea level which has been shown in the Appendix I.

3.1.3 Climatic condition

The climate of the experimental site is subtropical, characterized by heavy rainfall during the months from April to September (Kharif season) and scanty rainfall during the rest of the year (Rabi season). The average monthly maximum and minimum temperatures were 26.05 ºC and 16.45 ºC, respectively, during the experimental period. Rabi season is characterized by plenty of sunshine. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Bangladesh Meteorological Department, Agargoan, Dhaka-1212 and presented in Appendix II.

3.1.4 Characteristics of soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28) and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the study. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of sandy loam with pH and organic matter capacity 5.9 and 0.78%, respectively and the the soil composed of 26% sand, 43% silt, 31% clay. Details descriptions of the characteristics of soil are presented in Appendix III.

3.2 Experimental details

3.2.1 Planting materials

The stem cuttings of Mint were collected from the Sobuj Bangla Nursery, Agargoan, Dhaka, during October, 2017. Then those cuttings were planted separately in nursery beds to increase their number to use in the experiment. Normal intercultural operations were done in those beds. Then cuttings from those plants were recollected and planted few times to increase the plant number sufficiently.

Plate 1: cuttings of mint as planting materials

3.2.2 Factors of the experiment

This was a 2-factor experiment of which the factors were as follows:

Factor A: Transplanting date

Factor B: Organic Manure

3.2.3 Levels of the factors

Those factors had the following levels-

Factor A: Four levels-

T_1: 15 November, 2017

T_2: 30 November, 2017

T3:15 December, 2017

T_4= 30 December, 2017

Factor B: Three levels-

M_0= Control (No organic manure)

M_1= Vermicompost @ 3 t/ha

M_2=ACI Bio-fertilizer @ 370 kg/ha

3.2.4 Experimental treatments

This two-factor experiment was designed with (4 × 3) treatments i.e.12 treatment combinations. So, the 12 are presented- T_1M_O, T_1M_1, T_1M_2, T_2M_O, T_2M_1, T_2M_2, T_3M_O, T_3M_1, T_3M_2, T_4M_O, T_4M_1 and T_4M_2.

3.2.5 Design and layout of the experiment

The two factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 104.04 m^2 with length 20.40 m and width 5.10 m which were divided into three equal blocks. Each block was divided into 12 plots where 12 treatments combination allotted at random. There were 36 unit plots and the size of each plot was 1.2 m × 1.2 m. The distance was maintained between two blocks and two plots that were 0.5 m and 0.5 m, respectively. The layout of the experiment is shown in plate 2.

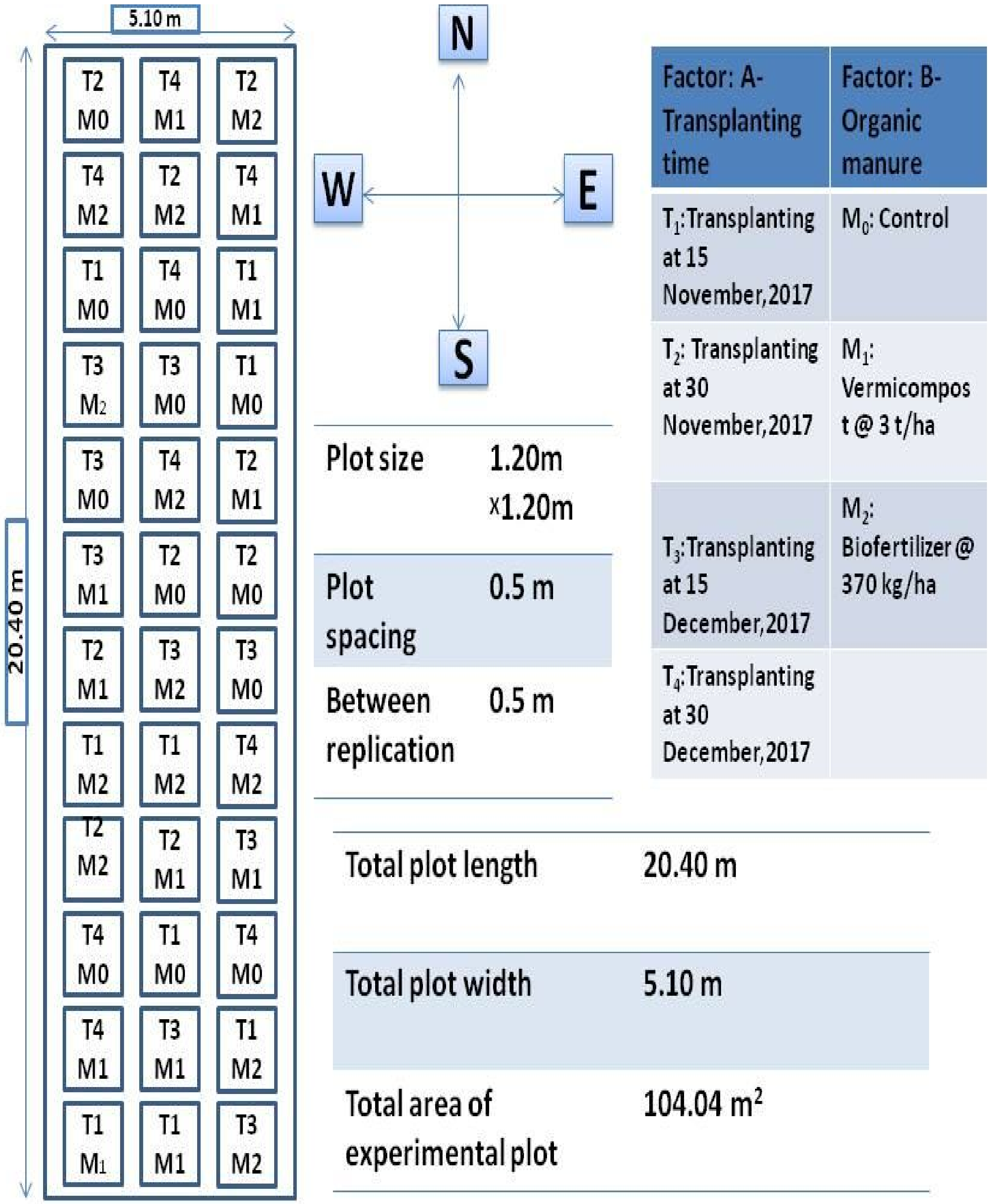


Plate 2: Layout of experimental plot

3.2.6 Preparation of experimental field

The selected plot of the experiment was opened in the last week of October, 2017 with a power tiller, and left exposed to the sun for a week. Subsequently cross ploughing was done followed by laddering to make the land suitable for seed sowing of lettuce. All weeds, stubbles and residues were eliminated from the experimental plot and finally, a good tilth was achieved for transplanting of mint. The experimental field is shown in plate 3.

Plate 3: Experimental field

3.2.7 Application of manure

Vermicompost and Bio-fertilizer were applied as source of N, P and K. The entire amounts of vermicompost and Bio-fertilizer according to the factor B and in terms of dose of each treatment were applied during final land preparation.

- Vermicompost @432 g/plot.
- Bio-fertilizer @ 53.28 g/plot.

3.2.8 Composition of nutrients

The composition of vermicompost and bio-fertilizer is shown as tabular form in table 1**.**

Table 1. Composition of vermicompost and bio-fertilizer

Manure	Nutrients		
	N(%)	P(%)	k(%)
vermicompost	1.5-2.0	0.9-1.7	1.5-2.4
Bio-fertilizer	0.5-4	0.5-3	0.5-3

Source: ACI fertilizer, 2016

3.3 Growing of crops

3.3.1 Planting of the stem cuttings

The stem cuttings were planted at a spacing of 30 cm × 45 cm on the 15th November, 2017. The cuttings were about 10 cm long and about 5 cm was kept below the soil.

3.3.2 Intercultural operation

After transplanting, various intercultural operations such as irrigation, weeding, plant protection etc. were accomplished for better growth and development of the mint.

3.3.2.1 Watering

The plot was watered immediately after planting. Watering was also done almost daily in the evening with a watering cane as needed.

3.3.2.2 Gap filling

The raised cuttings in the experimental plot were kept under careful observation. Very few cuttings were damaged after few days of transplanting and such cuttings were replaced by new cuttings. Replacement was done with health cutting having a boll of earth which was also planted on the same date by the side of the unit plot. They were given shading and watering for 5 days for their proper establishment.

3.3.2.3 Weeding

The weeding was done every at 15 days interval after transplanting to keep the plots free from weeds.

3.3.2.4 Plant protection measures

No disease or insect pests were noted. So, there was no need to control those.

3.3.2.5 Harvesting

The harvesting was done at 120 days after transplanting (DAT) for every four transplantation by cutting the shoots and suckers at the ground level with a pair of scissors.

Plate 4: Weeding

Plate 5: Data collection

3.4 Data collection

Five plants were randomly selected from each harvesting plants which was recorded plot wise. Data were collected in respect of yield attributes and yields as affected by transplanting date and organic manure. Data on plant height, number of branches/plant, number of leaves/plant, leaf area, number of stolon/plant of mint were collected at 30, 60, 90 and 120 days after transplanting (DAT). Weight of fresh herbage, dry weight of herbage and oil yield of mint was measured after harvest.

3.4.1 Plant height (cm)

Plant height was measured from five randomly selected plants by using meter scale in centimeter from the ground level to the tip of the longest branch at 30 days interval starting from 30 days after transplanting (DAT) and continued up to 120 DAT i.e. at harvest and their mean value was calculated.

3.4.2 Number of branches per plant

Number of branches per plant was counted from five randomly selected plants at 30 days interval starting from 30 days after transplanting (DAT) and continued up to 120 DAT and at harvest and their average value was calculated.

3.4.3 Number of leaves per plant

Number of leaves per plant was counted from five randomly selected plants at 30 days interval starting from 30 days after transplanting (DAT) and continued up to 120 DAT and their mean value was calculated.

3.4.4 Leaf area

Leaf area was estimated from leaf length and leaf breadth. Leaf length and breadth were measured from five randomly selected plants and each time from same plant of same leaf in centimeter and then average was calculated. Data were collected at 30, 60, 90 and 120 DAT and their mean value was calculated and recorded.

3.4.5 Stolon number/plant

Number of stolon per plant was counted at 30 DAT and data were collected at 30, 60, 90, 120 DAT and at harvest and their mean value was calculated and recorded.

3.4.6 Weight of fresh herbage

Weight of individual plant was recorded from five randomly selected plants in grams (g) with a beam balance at final harvest.

3.4.7 Dry weight of herbage

At first selected plants were collected and washed. Then cut into pieces and was dried under sunshine for a 3 days. The final individual dry weight of the sample was taken and express in gram.

3.4.8 Yield/plot

Yield of mint /plot was recorded as the whole plant without roots at final harvest within a plot and was expressed in kilogram (kg).

3.4.9 Total fresh herb yield/hectare

Total yield of mint/hectare was recorded by converted of total yield per plot into yield per hectare and was expressed in ton.

3.4.10 Total dry herb yield/hectare

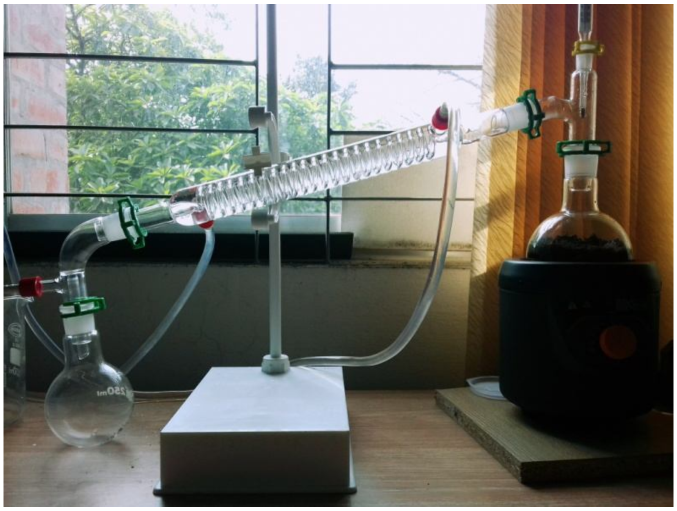
Total dry yield of mint/ha was recorded by converted of total dry yield per plot into yield per hectare and was expressed in ton.

3.4.11 Essential oil yield

Essential oil of mint was extracted by hydro distillation method in laboratory (FAB LAB, SAU) by hydro distiller from dry herb of mint. Oil was extracted from 20 g dry herb from each different plots and measured by measuring cylinder in ml.

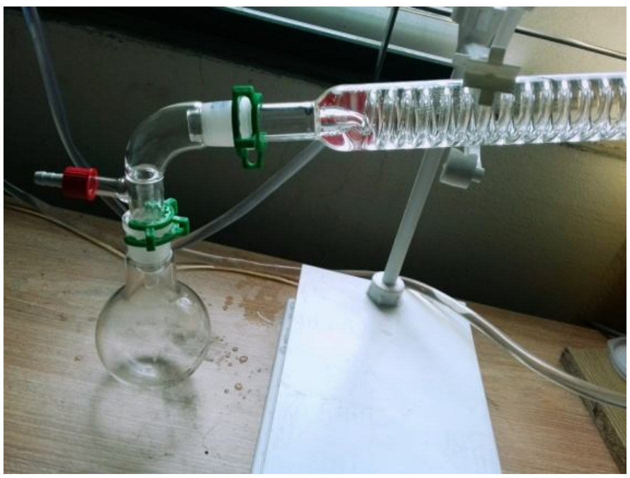
3.4.11.1 Methodology of hydro distillation

In hydro distillation plant material was soaked in water and heated until it boils. The resulting steam from boiling water carried the volatile oils with it. Cooling and condensation subsequently separate the oil from the water. Water, and the steam passes through the plant material. The leaves were carefully distributed on the grill to allow for even steaming and thorough extraction.



Hydro Distiller

Heating mantel



Oil collection flask

Oil Separator

Plate 6: Different parts of hydro distiller

3.4.11.2 Distillation Procedure

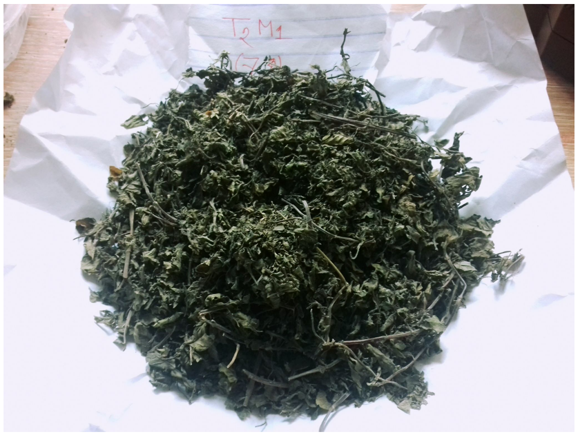
At first, 20 g dry herb of mint was taken in the 500 ml flask and it was filled two third parts with water. Then the flask was seated on heating mantel and it need to adjust the temperature at 100-120°C (boiling point of water). At 70% temperature was measured by thermometer. The total process was continued for 2-3 hours and collected the mixer of oil and water in Florentine flask. Then the essential oil was separated easily by separator where the oil is floating on the water to drop out from separator which is showing in plate 7.

3.4.12 Oil content of mint

Oil content of mint was recorded by converting the percentage of oil yield and was expressed in %.

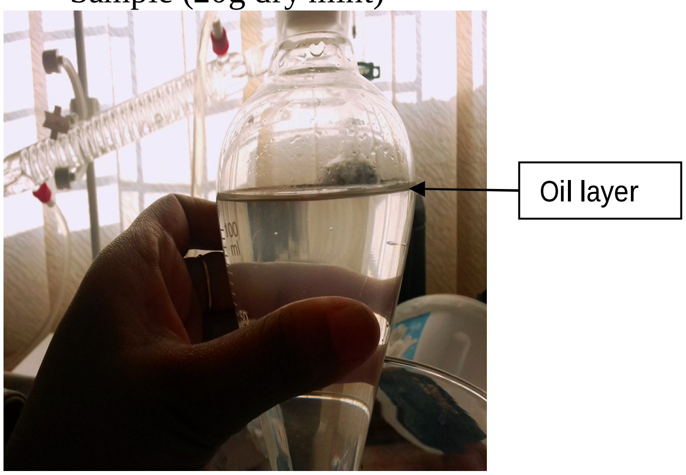
3.4.13 Total oil yield liter/hectare

Total oil yield of mint/hectare was recorded by converted of total oil yield per plot into yield per hectare and was expressed in liter.



Sample (20g dry mint)

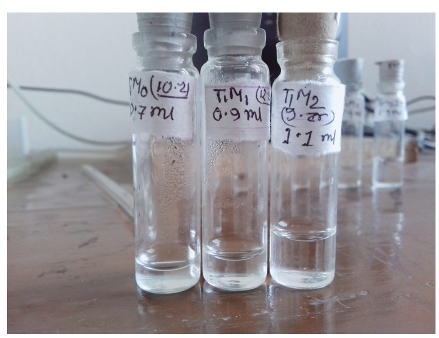
Boiling mint leaf



Floating mint oil

separating mint oil

Extracting mint oil



Essential oil of mint

Plate 7: Procedure of hydro distillation of mint

3.5 Statistical analysis

The recorded data on different parameters were statistically analyzed by using Statistix10 software to find out the significance of variation resulting from the experimental treatments. The mean values for all the treatments were accomplished by Tukey test. The significance of difference between pair of means was tested at 5% and 1% level of probability.

3.6 Economic analysis

The cost of production was analyzed in order to find out the most economic combination of different transplanting date and organic manure for mint cultivation. All input cost and interests on running capital in computing the cost of production. The interests were calculated @ 12% in simple rate. The market price of mint was considered for estimating the cost and return. Economic analyses were done according to the procedure of Alam *et al*. (1989). The benefit cost ratio (BCR) was calculated as follows:

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

Chapter IV
Results and discussion

CHAPTER IV

RESULTS AND DISCUSSION

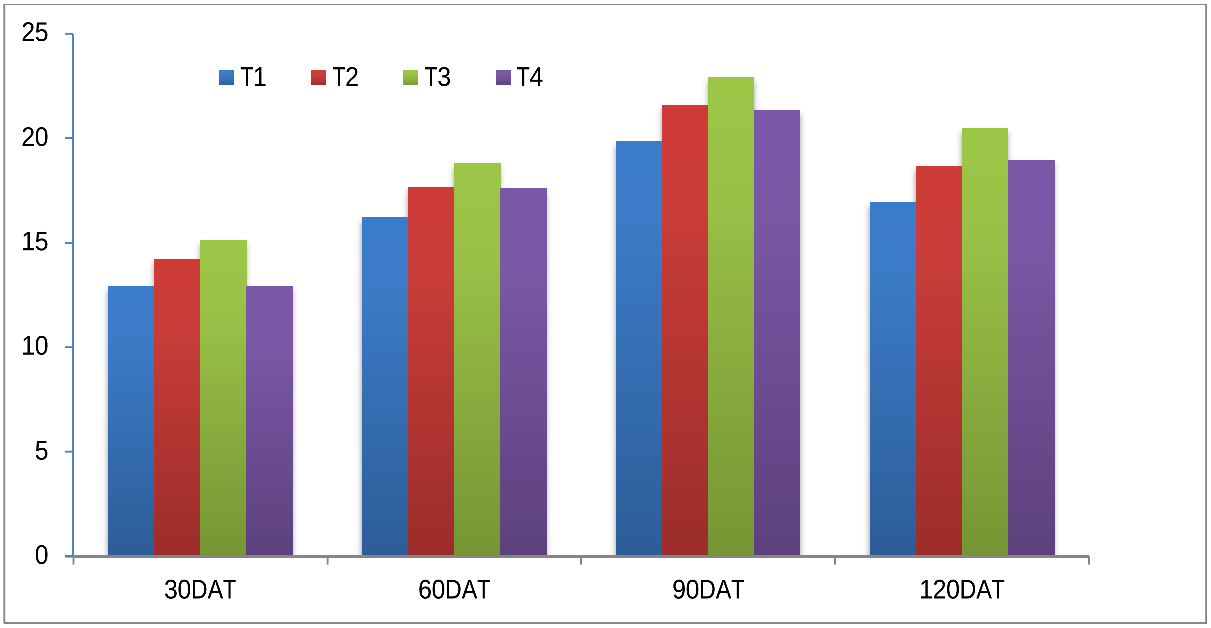
This chapter represents the results and discussion of the present study. The experiment was carried out to assess the effect of transplanting date and organic manure on growth and yield of herbage and essential oil content of mint. The analysis of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendices IV-IX. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following headings:

4.1 Plant height (cm)

Plant height of mint at 30, 60, 90, 120 DAT (Days after transplanting) showed statistically significant differences due to different transplanting date (Figure 1and Appendix x). At 30, 60, 90, 120 DAT the tallest plant (15.13, 18.80, 22.9 and 20.46 cm, respectively) was recorded from T_3 (Transplanting date at 15 December) which was closely followed (14.20, 17.66, 21.60 and 18.67 cm, respectively) by T_2 (Transplanting date at 30 November) which was statistically similar (12.93, 17.62, 21.25 and 18.25 cm respectively) to T_4 (Transplanting date at 30 December) and whereas the shortest plant (12.93, 16.20, 19.84 and 16.93 cm, respectively) was found from T_1 (Transplanting date at 15 November). Data revealed that different transplanting date produced different height of plant. Although plant height is a genetical character but the management practices and planting time also influence plant height of mint (Lal, 2013). At 120 DAT, the plant height was decreased because of generating stolon, new branches from long shoots and shattering the longest leaf from the base of the stem.

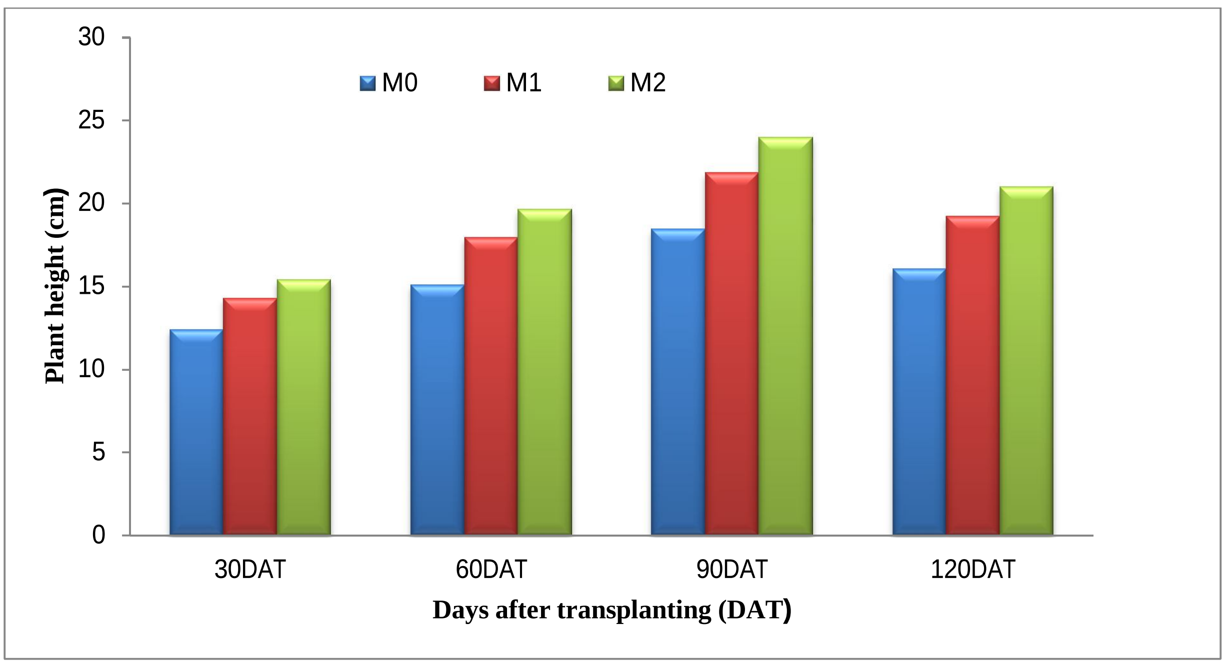
In terms of plant height of mint at 30, 60, 90, 120 DAT showed statistically significant differences due to different organic manures (Figure 2 and Appendix x). At 30, 60, 90, 120 DAT the tallest plant (15.40, 19.65, 23.95 and 21.00 cm, respectively) was recorded from M_2 (Bio-fertilizer @ 370 kg/ha) which was statistically different (14.30, 17.95, 21.83 and 19.20 cm, respectively) from M_1 (Vermicompost @ 3 t/ha), while the shortest plant (12.41, 15.11, 18.46 and 16.06 cm, respectively) was recorded from M_0 (0 kg /ha i.e., control). At 120 DAT, decrease in length could be attributed to the reduction of available nitrogen from both the organic sources and age of the plants. Due to the presence of readily available nitrogen which might have resulted in increase in vegetative growth of plants mainly by elongation of cells and partly by cell division. Nitrogen is a very important constituent of protoplasm and it exerts favourable effect on chlorophyll content of leaves which might have increased the photosynthates/carbohydrate, amino acids etc., from which the phytohormones such as auxins, gibberellins, cytokinins and ethylene have been synthesized resulting in increased plant height (Maynord and David, 1987).

Interaction effect of different transplanting date and organic manure showed statistically significant variation in terms of plant height of mint at 30, 60, 90, 120 DAT (Table 2). At 30, 60, 90, 120 DAT, the tallest plant (16.80, 21.20, 25.80 and 23.20 cm, respectively) was observed from T_3M_2 (Transplanting date at 15 December with bio-fertilizer @ 370 kg/ha) and the shortest plant (11.60, 14.00, 17.20 and 14.80 cm, respectively) was found from T_1M_0 (Transplanting date at 15 November with 0 kg Manure/ha i.e., control) treatment combination. Vermicompost contains less amount of nitrogen compared to bio-fertilizer. So, the supremacy of the bio-fertilizer coupled with the optimum transplanting date over the vermicompost in producing taller plant is quite expected. Zheljazkov *et al.* (2010) found that the application of N and P improved the productivity of *M. piperita*, increasing both the dry biomass production. The increase in the biomass of plants fertilized with bio-fertilizer is most likely related to the higher concentrations of N in this manure.



T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December and T_4:Transplanting date at 30 December

Figure 1: Effect of transplanting date on plant height of mint



M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha

Figure 2: Effect of organic manure on plant height of mint

Table 2. Interaction effect of organic manure and transplanting date on plant height at different days after transplanting (DAT) of mint

Treatments	**Plant height at different days after transplanting(DAT) of**			
	30	**60**	**90**	**120**
T_1M_0	11.60g	14.00g	17.20f	14.80f
T_1M_1	13.00e	16.40d	20.13d	17.20d
T_1M_2	14.20d	18.20c	22.20c	18.80c
T_2M_0	12.60ef	15.20f	18.60e	16.20e
T_2M_1	14.60cd	18.20c	22.20c	19.20c
T_2M_2	15.40b	19.60b	24.00b	20.60b
T_3M_0	13.20e	16.00de	19.60d	17.20d
T_3M_1	15.40b	19.20b	23.40b	21.00b
T_3M_2	16.80a	21.20a	25.80a	23.20a
T_4M_0	12.26f	15.26ef	18.46e	16.06e
T_4M_1	14.20d	18.00c	21.80c	19.40c
T_4M_2	15.20bc	19.60b	23.80b	21.40b
Tukey HSD (0.05)	0.66	0.77	0.77	0.96

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

T_1: Transplanting date at 15 November

T_2: Transplanting date at 30 November

T3: Transplanting date at 15 December

T_4: Transplanting date at 30 December

M_0: control

M_1: vermicompost @ 3 t/ha

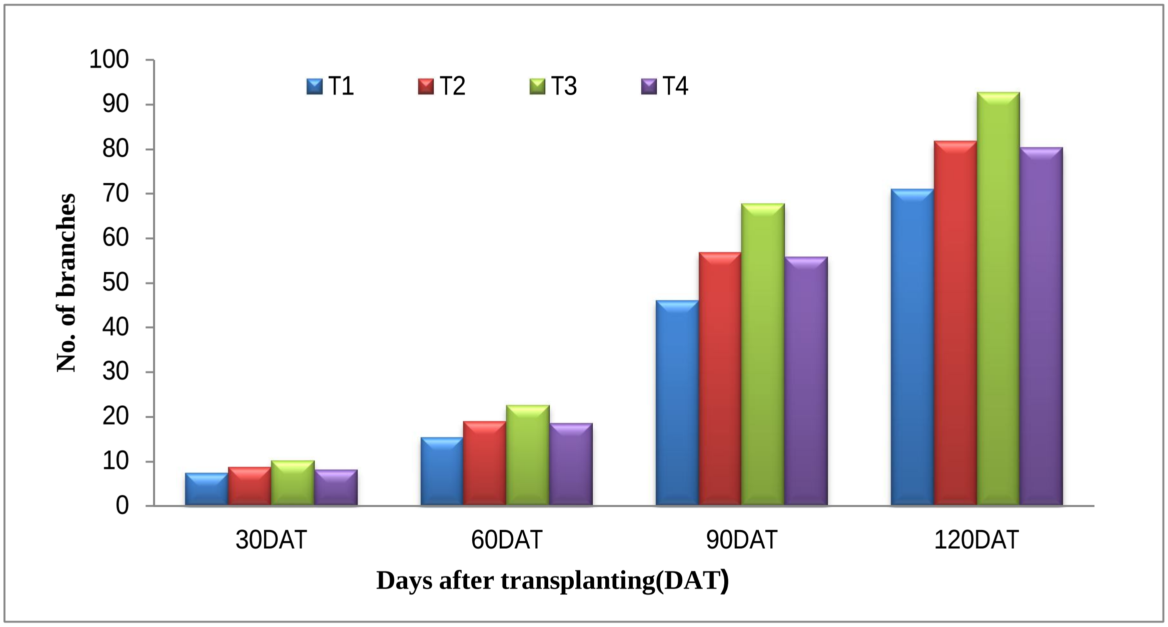
M_2: Bio-fertilizer @ 370 kg/ha

4.2 Number of branches/plant

Number of branches/plant of mint at 30, 60, 90, 120 DAT (Days after transplanting) showed statistically significant differences due to different transplanting date (Figure 3 and Appendix xi). At 30, 60, 90, 120 DAT the highest branch no. /plant (9.97, 22.55, 67.66 and 92.66 respectively) was recorded from T_3 (Transplanting date at 15 December) whereas the lowest branch no. /plant (7.26, 15.33, 46.00 and 71.00 respectively) was found from T_1 (Transplanting date at 15 November). Mint grows well in partial shading place and medium temperature is required for well growth of mint (Farooqi *et al.*, 1990). In case of T_3, plants were getting optimum temperature and rainfall during 90 DAT and 120 DAT and for that the vegetative growth i.e. branch number was increased.

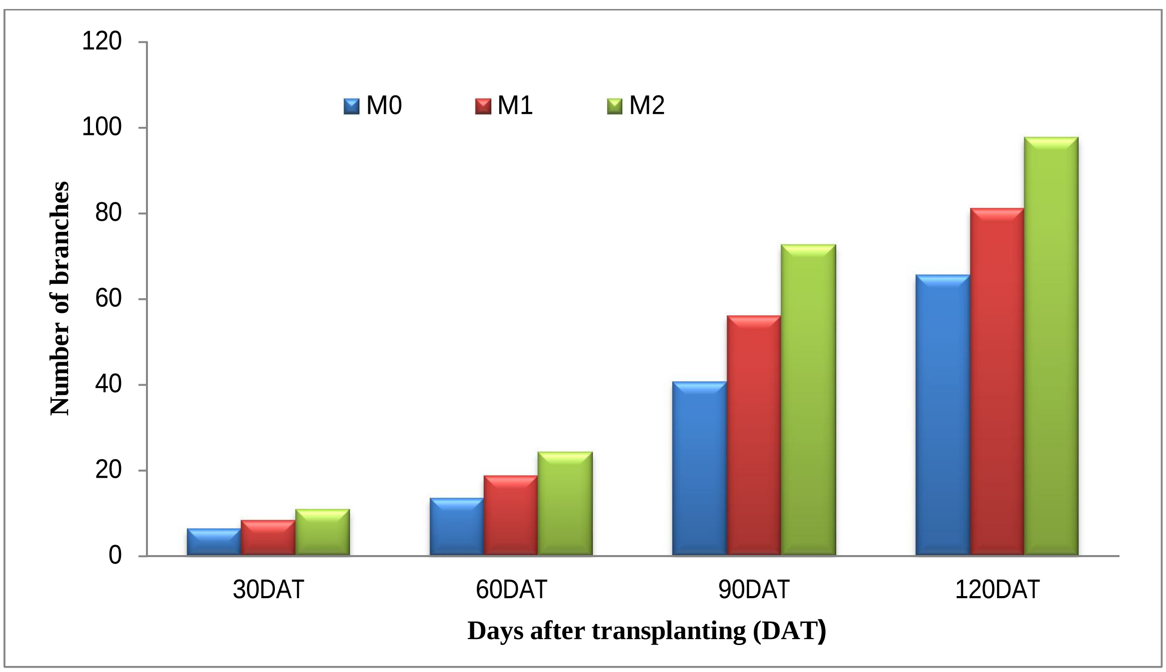
In terms of branch no. /plant of mint at 30, 60, 90, 120 DAT showed statistically significant differences due to different organic manures (Figure 4 and Appendix xi). At 30, 60, 90, 120 DAT the highest branch no./plant (10.76, 24.21, 72.65 and 97.65 respectively) was observed from M_2 (Bio-fertilizer @ 370 kg/ha) which was statistically different (8.30, 18.68, 56.05 and 81.05 respectively) from M_1 (Vermicompost @ 3 t/ha), while the lowest branch no./plant (6.322, 13.53, 40.60 and 65.60 respectively) was recorded from M_0 (0 kg /ha i.e., control).Vermicompost contains less amount of nitrogen compared to bio-fertilizer. So, the supremacy of the bio-fertilizer coupled with the optimum transplanting date over the vermicompost in producing higher branch number/plant is expected. Nitrogen is an element essential to plants and elements such as carbon, oxygen, hydrogen and sulfur combine even more valuable materials such as amino acids, nucleic acids, alkaloids and bases are produced. Chlorophyll as a place for light absorption and synthesis related to this element for plant growth and development is vital. If the nitrogen available to plants than the limit may cause disturbances in the vital processes of plants that may be in different forms such as high growth, reduces, delay or even stop the growth may increase the incidence (Stewart *et al.* 2000).

Interaction effect of different transplanting date and organic manure showed statistically significant variation in terms of number of branches/plant of mint at 30, 60, 90, 120 DAT (Table 3). At 30, 60, 90, 120 DAT, the highest branch number/plant (12.26, 27.53, 82.60 and 107.60, respectively) was observed from T_3M_2 (Transplanting date at 15 December with bio-fertilizer @ 370 kg/ha) and the lowest branch number/plant (5.20, 10.20, 30.60 and 55.60, respectively) was found from T_1M_0 (Transplanting date at 15 November with 0 kg Manure/ha i.e., control) treatment combination. The possible reason for the acceleration of these growth parameters might be due to influence of nitrogen. The chief constituent of protein, essential for the formation of protoplasm which might have lead to cell division and cell enlargement. Moreover, nitrogen is an important component of amino acids and coenzymes which are of considerable biological importance. The positive effect of the added manure was attributed to the 27 beneficial effects of manure on soil structure (Willium and Cooke, 1967; Malik, 1983 and Sharma, 2012) increasing in permeability and diffusivity of water and root penetration and their complexing properties which improve soil fertility status (Bandel *et al.* 1972). So, vermicompost and bio-fertilizer gave higher yields over the control ones.



T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December and T_4:Transplanting date at 30 December

Figure 3: Effect of transplanting date on number of branches of mint



M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha

Figure 4: Effect of organic manure on number of branches of mint

Table 3. Interaction effect of organic manure and transplanting date on number of branches/plant at different days after transplanting (DAT) of mint

Treatments	No. of branches/plant at different days after transplanting (DAT) of			
	30	**60**	**90**	**120**
T_1M_0	5.2 e	10.2 f	30.6 f	55.6 f
T_1M_1	7.2 c-e	15.4 d-f	46.20 d-f	71.2 d-f
T_1M_2	9.4 a-d	20.4 b-d	61.20 b-d	86.20 b-d
T_2M_0	6.2 e	13.8 ef	41.40 ef	66.4 ef
T_2M_1	8.13 b-e	18.06 c-e	54.2 c-e	79.2 c-e
T_2M_2	11.33 a	24.93 ab	74.8 ab	99.8 ab
T_3M_0	7.4 b-e	16.8 de	50.4 de	75.4 de
T_3M_1	10.26 ab	23.33 a-c	70 a-c	95 a-c
T_3M_2	12.26 a	27.53 a	82.6 a	107.6 a
T_4M_0	6.5de	13.33 ef	40 ef	65 ef
T_4M_1	7.6 b-e	17.93 c-e	53.80 c-e	78.8 c-e
T_4M_2	10.06 a-c	24 ab	72 ab	97 ab
Tukey HSD (0.05)	3.04	3.06	3.09	5.36

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

T_1: Transplanting date at 15 November
T_2: Transplanting date at 30 November
T3: Transplanting date at 15 December
T_4: Transplanting date at 30 December

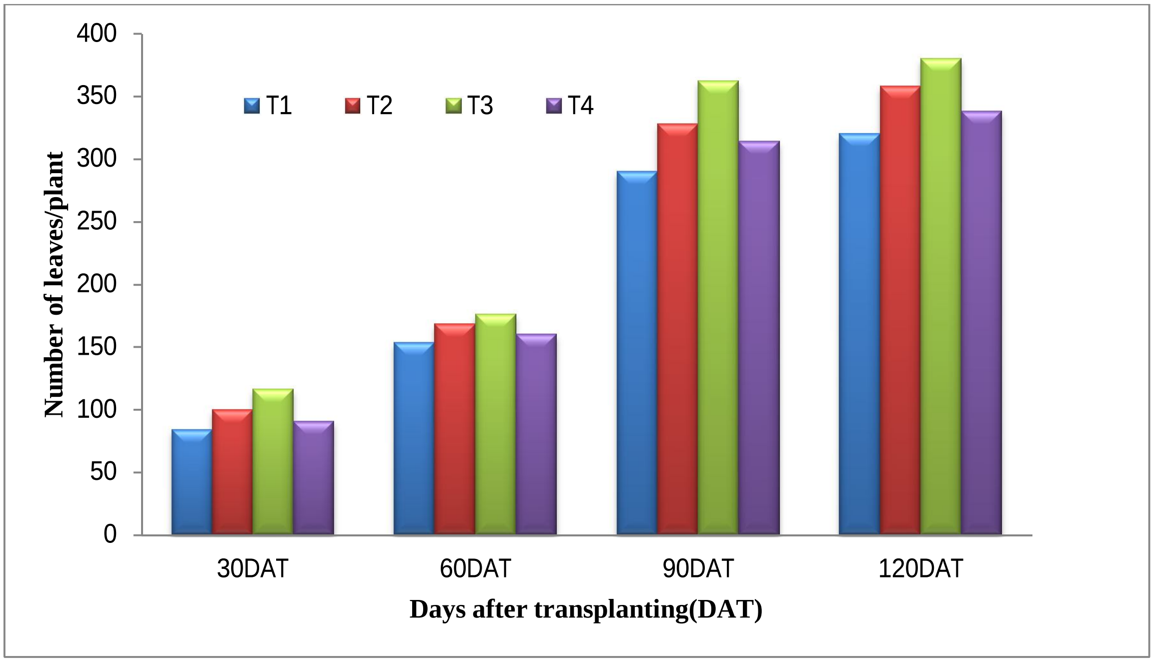
M_0: control
M_1: vermicompost @ 3 t/ha
M_2: Bio-fertilizer @ 370 kg/ha

4.3 Number of Leaves/plant

Number of leaves/plant of mint at 30, 60, 90, 120 DAT (Days after transplanting) showed statistically significant differences due to different transplanting date (Figure 5 and Appendix xii). At 30, 60, 90, 120 DAT the highest number of leaves/plant (116.00, 176.00, 362.00 and 380.00, respectively) was recorded from T_3 (Transplanting date at 15 December) whereas the lowest number of leaves/ plant (84.00, 153.00, 290.00 and 320.00 respectively) was found from T_1 (Transplanting date at 15 November). Maximum leaves number /plant were occurred due to the optimum rainfall and temperature during T_3 Where in case of T_1 and T_2 passed with a cold weather during vegetative growth and early stage of plant and in case of T_4, the growth was stunned as the less number of new leaves due to heavy rainfall and harmful weed. Telci *et al.* (2011) reported that locations with warmer climate have higher fresh herbage yield.

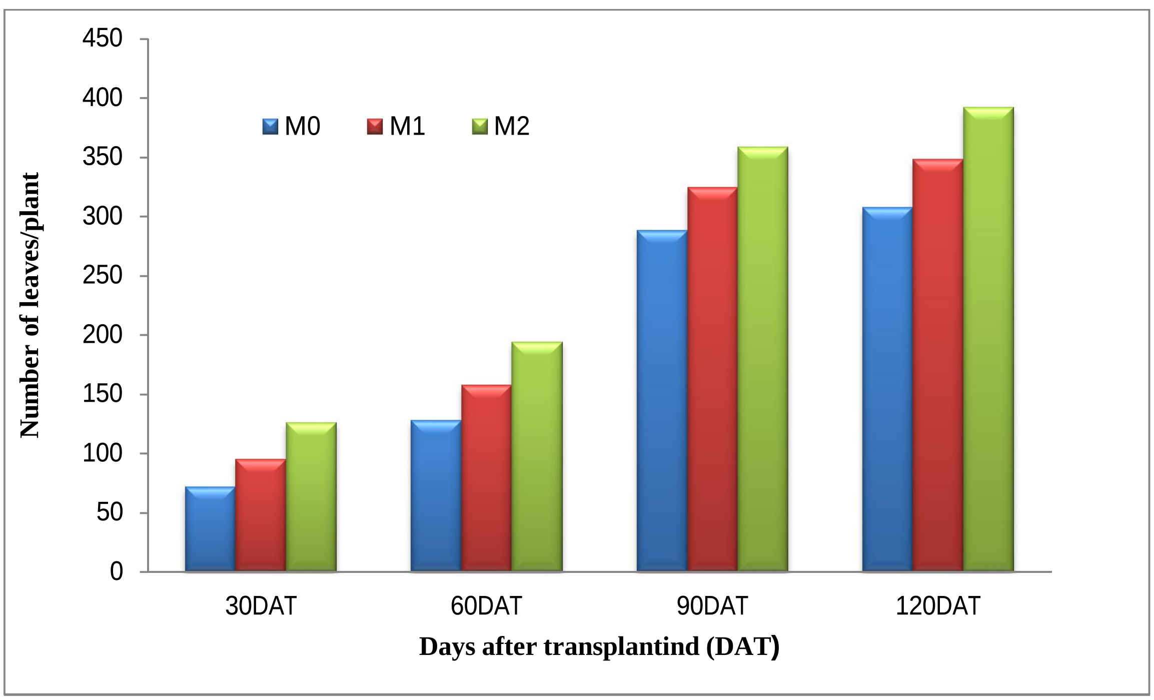
In terms of number of leaves/ plant of mint at 30, 60, 90, 120 DAT showed statistically significant differences due to different organic manures (Figure 6 and Appendix xii). At 30, 60, 90, 120 DAT the highest number of leaves/ plant (123.00, 194.17, 358.50 and 391.50 respectively) was recorded from M_2 (Bio-fertilizer @ 370kg/ha) which was statistically different (95.17, 157.50, 324.00 and 348.00, respectively) from M_1 (Vermicompost @ 3 t/ha), while the lowest number of leaves/ plant (72.00, 128.00, 288.00 and 307.50, respectively) was recorded from M_0 (0 kg /ha i.e., control). Due to the presence of readily available nitrogen which is a very important constituent of protoplasm and it exerts favourable effect on chlorophyll content of leaves which might have increased the photosynthates/ carbohydrate, amino acids etc., from which the phytohormones such as auxins, gibberellins, cytokinins and ethylene have been synthesized resulting in increased number of leaves/plant (Maynord and David, 1987).

Interaction effect of different transplanting date and organic manure showed statistically significant variation in terms of number of leaves/plant of mint at 30, 60, 90, 120 DAT (Table 4). At 30, 60, 90, 120 DAT, the height number of leaves/ plant (144, 216, 414 and 444, respectively) was observed from T_3M_2 (Transplanting date at 15 December with bio-fertilizer @ 370 kg/ha) and the lowest number of leaves/plant (60, 120, 270 and 294, respectively) was found from T_1M_0 (Transplanting date at 15 November with 0 kg Manure/ha i.e., control) treatment combination. Vermicompost contains less amount of nitrogen compared to bio-fertilizer as stated earlier. So, the supremacy of the bio-fertilizer coupled with the optimum transplanting date over the vermicompost in producing the highest number of leaves/plant is quite expected.



T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December and T_4:Transplanting date at 30 December

Figure 5: Effect of transplanting date on number of leaves of mint



M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha

Figure 6: Effect of organic manure on number of leaves of mint

Table 4. Interaction effect of organic manure and transplanting date on number of leaves/plant at different days after transplanting (DAT) of mint

Treatments	No. of leaves/plant at different days after transplanting (DAT) of			
	30	**60**	**90**	**120**
T_1M_0	60 e	120 e	270 h	294 g
T_1M_1	84 c-e	134 de	294 e-g	324 ef
T_1M_2	108 a-d	152 cd	306 ef	342 de
T_2M_0	72de	128 e	288 f-h	312 fg
T_2M_1	96 b-e	168 bc	330 cd	360 cd
T_2M_2	132 ab	208.67 a	366 b	402 b
T_3M_0	84 c-e	136 de	112 de	324 ef
T_3M_1	120 a-c	176 b	360 b	372 c
T_3M_2	144 a	216 a	414 a	444 a
T_4M_0	72 de	128 e	282 gh	300 g
T_4M_1	80.67 de	152 cd	312 de	336 e
T_4M_2	120 a-c	128 e	348 bc	378 c
Tukey HSD (0.05)	5.14	6.5	5.14	5.09

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

T_1: Transplanting date at 15 November
T_2: Transplanting date at 30 November
T3: Transplanting date at 15 December
T_4: Transplanting date at 30 December

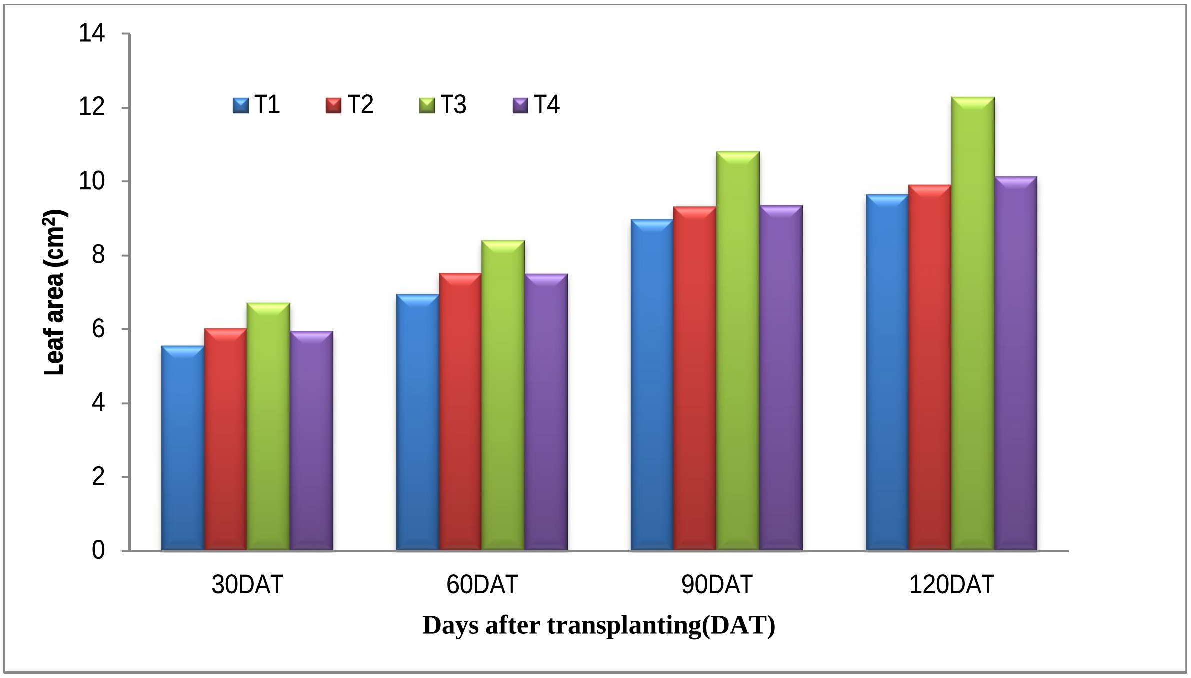
M_0: control
M_1: vermicompost @ 3 t/ha
M_2: Bio-fertilizer @ 370 kg/ha

4.4 Leaf area (cm^2)

Leaf area (cm^2) of mint at 30, 60, 90, 120 DAT (Days after transplanting) showed statistically significant differences due to different transplanting date (Figure 7 and Appendix xiii). At 30, 60, 90, 120 DAT the highest leaf area (6.70, 8.39, 10.80 and 12.27 cm^2, respectively) was recorded from T_3 (Transplanting date at 15 December) and whereas the lowest leaf area (5.54, 6.93, 8.95 and 9.63 cm^2, respectively) was found from T_1 (Transplanting date at 15 November). Leaf growth was influenced by optimum rainfall and availability of nutrients to the plant and so T_3 having the highest leaf area. Again, the heavy rainfall was caused growing of harmful and quick growth weeds that hindered the leaf growth of T_4.

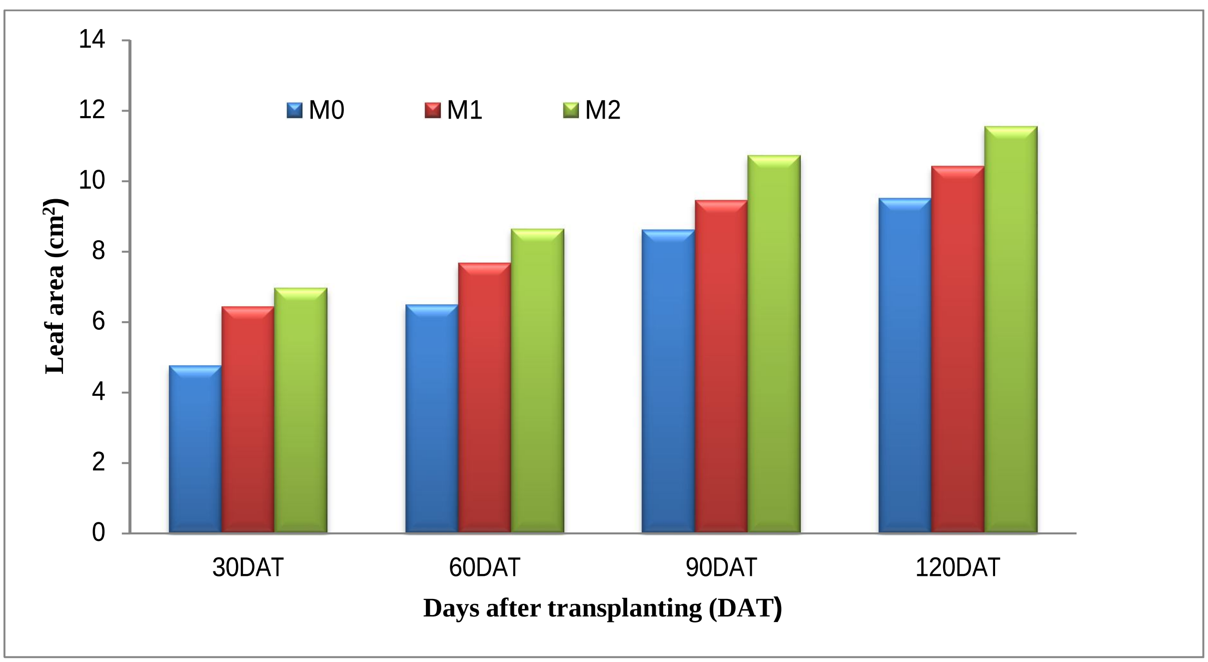
In terms of leaf area of mint at 30, 60, 90, 120 DAT showed statistically significant differences due to different organic manures (Figure 8 and Appendix xiii). At 30, 60, 90, 120 DAT the highest leaf area (6.96, 8.63, 10.72 and 11.54 cm^2, respectively) was recorded from M_2 (Bio-fertilizer @ 370kg/ha) which was statistically different (6.42, 7.66, 9.45 and 10.40 $cm^{2,}$ respectively) from M_1 (Vermicompost @ 3 t/ha), while the shortest leaf area (4.75, 6.48, 8.61 and 9.50 cm^2, respectively) was recorded from M_0 (0 kg /ha i.e., control). The specialty of bio-fertilizer over vermicompost in producing longer leaf area was probably due to the higher amount of nitrogen present in bio-fertilizer. This could be due to production of greater number of photosynthetically active leaves because of adequate N which might have led to higher metabolic activity resulting in higher production of carbohydrates and phytohormones. These might have enhanced the growth and leaf area in plants. Similar responses of increased leaf area to nitrogen application have been reported by Geetha and Madhavan Nair (1993) in *Coleus parviflorus,* Taleb and Hassan (1997) in *Coleus blumeii* and Ghosh and Pal (2002) in *Kaempferia galanga*.

Interaction effect of different transplanting date and organic manure showed statistically significant variation in terms of number of leaves/plant of mint at 30, 60, 90, 120 DAT (Table 5). At 30, 60, 90, 120 DAT, the highest leaf area (7.98, 9.50, 12.54 and 13.96 cm^2, respectively) was recorded from T_3M_2 (Transplanting date at 15 December with bio-fertilizer @ 370 kg/ha) and the shortest leaf area (4.54, 5.81, 8.28 and 9.00 cm^2, respectively) was found from T_1M_0 (Transplanting date at 15 November with 0 kg Manure/ha i.e., control) treatment combination. Bio-fertilizer contains high amount of nitrogen compared to vermicompost. So, the supremacy of the bio-fertilizer coupled with the optimum transplanting date over the vermicompost in producing height leaf area/ plant is quite expected.



T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December and T_4:Transplanting date at 30 December

Figure 7: Effect of transplanting date on of mint leaf area



M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha

Figure 8: Effect of organic manure on of mint leaf area

Table 5. Interaction effect of organic manure and transplanting date on leaf area (cm^2) at different days after transplanting (DAT) of mint

Treatments	Leaf area (cm^2)/plant at different days after transplanting (DAT) of			
	30	**60**	**90**	**120**
T_1M_0	4.54 e	5.81 f	8.28 e	9.00 fg
T_1M_1	5.75 cd	7.26 c-e	8.96 de	9.54 e-g
T_1M_2	6.33 bc	7.82 b-d	9.62 cd	10.34 c-e
T_2M_0	4.60 e	6.03 ef	8.40 e	8.97 g
T_2M_1	6.60 bc	7.70 b-d	9.00 de	9.83 d-g
T_2M_2	6.82 b	8.79 ab	10.53 bc	10.91 c
T_3M_0	5.34 de	7.48 cd	9.20 de	10.66 cd
T_3M_1	6.78 b	8.20 bc	10.66 b	12.20 b
T_3M_2	7.98 a	9.5 a	12.54 a	13.96 a
T_4M_0	4.54 e	6.60 d-f	8.58 e	9.37 e-g
T_4M_1	6.57 bc	7.48 cd	9.20 de	10.02 c-f
T_4M_2	6.71 bc	8.40 a-c	10.22 bc	10.96 c
Tukey HSD (0.05)	0.98	1.27	1.01	1.04

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

T_1: Transplanting date at 15 November
T_2: Transplanting date at 30 November
T3: Transplanting date at 15 December
T_4: Transplanting date at 30 December

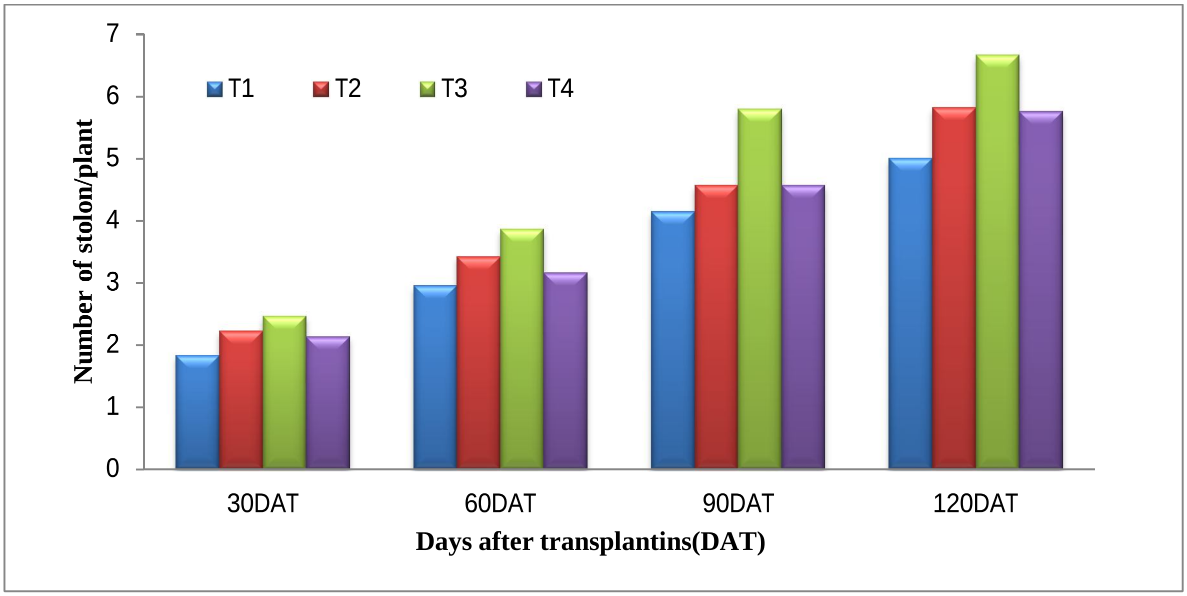
M_0: control
M_1: vermicompost @ 3 t/ha
M_2: Bio-fertilizer @ 370 kg/ha

4.5 Number of stolon/plant

Number of stolon/plant of mint at 30, 60, 90, 120 DAT (Days after transplanting) showed statistically significant differences due to different transplanting date (Figure 9 and Appendix xiv). At 30, 60, 90, 120 DAT the highest number of stolon/ plant (2.46, 3.86, 5.80 and 6.66, respectively) was recorded from T_3 (Transplanting date at 15 December) whereas the lowest number of stolon/ plant (1.83, 2.95, 4.15 and 5.00, respectively) was found from T_1 (Transplanting date at 15 November).The maximum vegetative growth of plant was occurred due to the optimum rainfall during T_3. In case of T_4, the growth was delayed as the less number of stolon due to heavy rainfall and harmful weed.

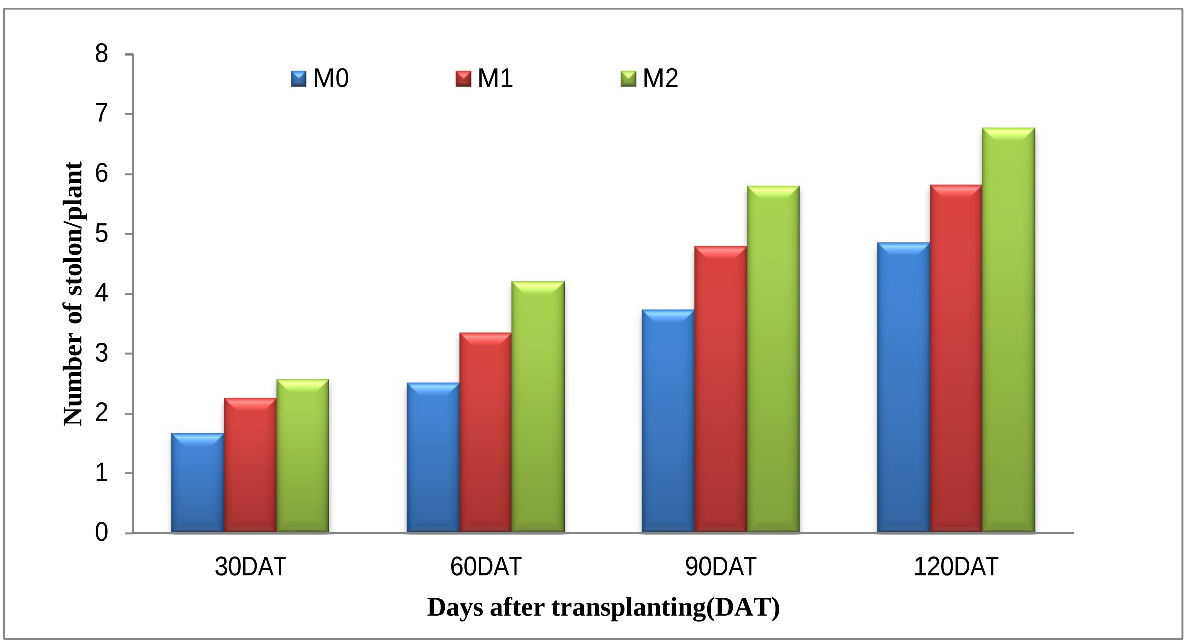
In terms of number of stolon/ plant of mint at 30, 60, 90, 120 DAT showed statistically significant differences due to different organic manures (Figure 10 and Appendix xiv). At 30, 60, 90, 120 DAT the highest number of stolon/ plant (2.56, 4.20, 5.79 and 6.76 respectively) was recorded from M_2 (Bio-fertilizer @ 370kg/ha) which was statistically different (2.25, 3.34, 4.78 and 5.81, respectively) from M_1 (Vermicompost @ 3 t/ha), while the lowest number of stolon (1.66, 2.51, 3.73 and 4.85 respectively) was recorded from M_0 (0 kg /ha i.e., control). Bio-fertilizer contains high amount of nitrogen, phosphorus and potassium than vermicompost as stated earlier in table 1. Zheljazkov *et al.* (2010) found that the application of N and P improved the productivity of *M. piperita*, increasing both the dry biomass production.

Interaction effect of different transplanting date and organic manure showed statistically significant variation in terms of number of stolon/plant of mint at 30, 60, 90, 120 DAT (Table 6). At 30, 60, 90, 120 DAT, the highest number of stolon/ plant (2.66, 4.80, 6.93 and 7.66, respectively) was recorded from T_3M_2 (Transplanting date at 15 December with bio-fertilizer @ 370 kg/ha) and the lowest number of stolon/plant (1.33, 2.13, 3.26 and 4.13, respectively) was found from T_1M_0 (Transplanting date at 15 November with 0 kg Manure/ha i.e., control) treatment combination. Vermicompost contains less amount of nitrogen compared to bio-fertilizer. So, the supremacy of the bio-fertilizer coupled with the optimum transplanting date over the vermicompost in producing height number of leaves/ plant is quite expected.



T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December and T_4:Transplanting date at 30 December

Figure 9: Effect of transplanting date on number of stolon/plant of mint



M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha

Figure 10: Effect of organic manure on number of stolon/plant of mint

Table 6. Interaction effect of organic manure and transplanting date on number of stolon/plant at different days after transplanting (DAT) of mint

Treatments	No. of stolon/plant at different days after transplanting (DAT) of			
	30	**60**	**90**	**120**
T_1M_0	1.33 d	2.13 g	3.26 e	4.13 e
T_1M_1	1.83 b-d	2.93 ef	4.13 c-e	4.93 d
T_1M_2	2.33 a-c	3.80 b-d	5.06 bc	5.93 c
T_2M_0	1.66 cd	2.66 e-g	3.60 de	4.80 d
T_2M_1	2.33 a-c	3.33 c-e	4.53 cd	5.86 c
T_2M_2	2.66 ab	4.26 ab	5.60 b	6.80 b
T_3M_0	2.00 a-d	2.86 ef	4.53 cd	5.66 c
T_3M_1	2.66 ab	3.93 bc	5.93 b	6.66 b
T_3M_2	2.73 a	4.8 a	6.93 a	7.66 a
T_4M_0	1.66 cd	2.40fg	3.53 e	4.80 d
T_4M_1	2.13 a-d	3.16 de	4.53 cd	5.80 c
T_4M_2	2.60 ab	3.93 bc	5.56 b	6.66 b
Tukey HSD (0.05)	0.84	0.69	0.99	0.61

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

T_1: Transplanting date at 15 November
T_2: Transplanting date at 30 November
T3: Transplanting date at 15 December
T_4: Transplanting date at 30 December

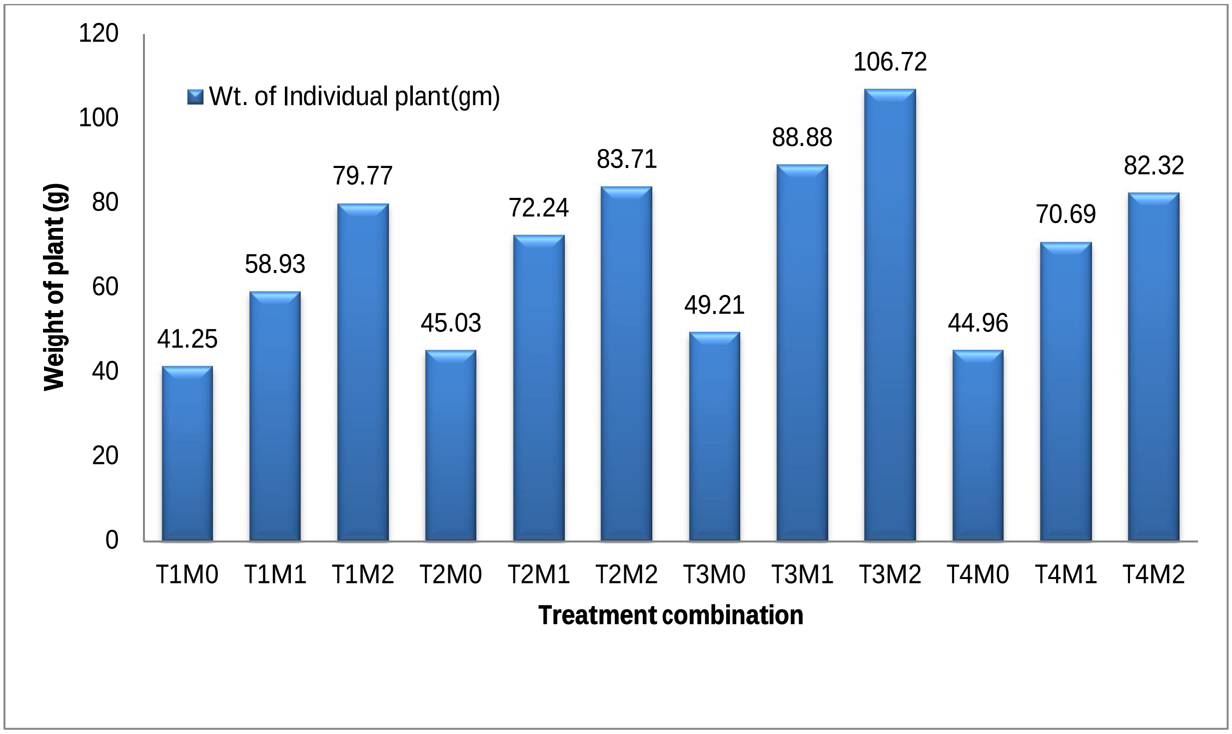
M_0: control
M_1: vermicompost @ 3 t/ha
M_2: Bio-fertilizer @ 370 kg/ha

4.6 Weight of individual plant

Weight of individual plant of mint showed significant differences with Different transplanting date (Table 7). The highest weight of individual plant (81.60g) was recorded from T_3 which was followed by (66.99 g) T_2 that is statistically similar to (65.99 g) T_4, while the lowest weight (58.98 g) was observed from T_1. Sharma (2012) reported that a climate with adequate and regular rainfall and good sunshine during its growing period ensures a good yield of mint.

Significant variation was recorded for weight of individual plant of mint showed due to different organic manure (Table 7). The highest weight of individual plant (88.13 g) was recorded from M_2 (bio-fertilizer @ 370 kg/ha) which was followed (72.68 g) by M_1 (vermicompost@3 t/ha), whereas the lowest weight (153.88 g) was found from M_0 (control).

Interaction effect of different transplanting date and organic manure showed statistically significant differences in terms of weight of individual plant of mint (Figure 11). The highest weight of individual plant (106.72 g) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer@370 kg/ha) and the lowest weight (41.25 g) was found from T_1M_0 (transplanting at 15 November with control) treatment combination. Nitrogen, being a constituent of protoplasm and its favourable effect on chlorophyll content of leaves might have resulted in increased synthesis of carbohydrates (Tisdale *et al.* 1985) and fresh weight increased.



T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December , T_4:Transplanting date at 30 December and M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha

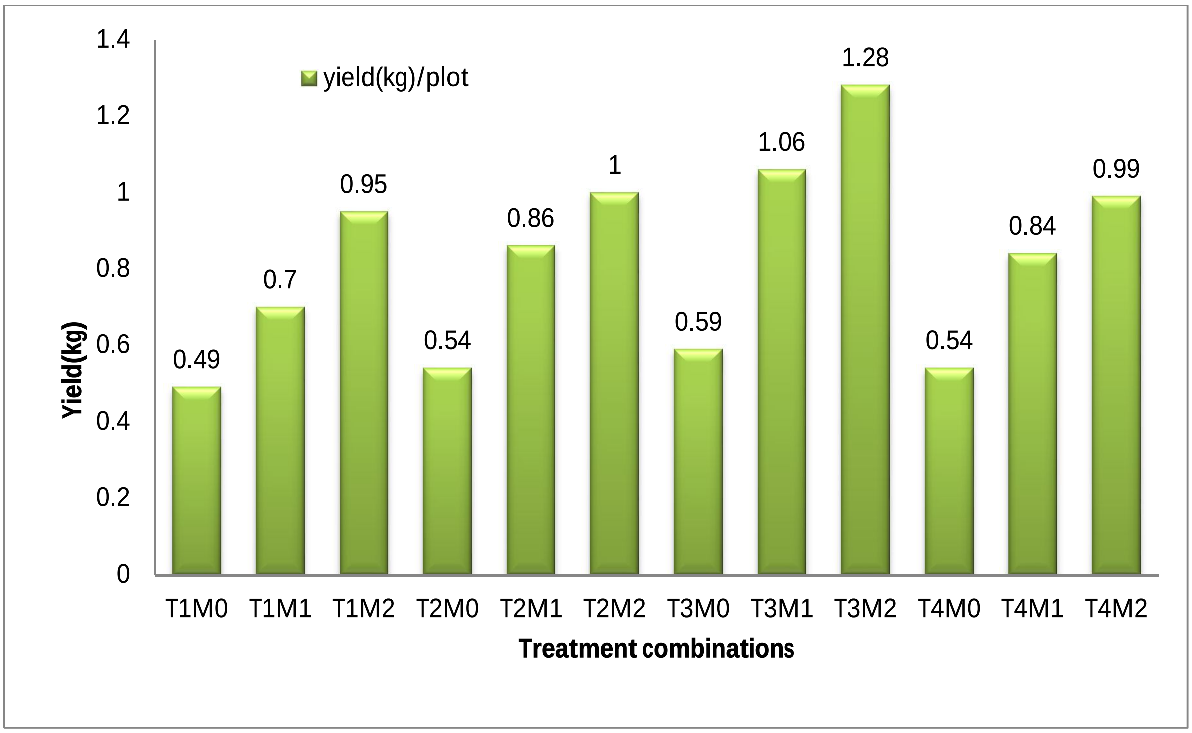
Figure 11. Interaction effect of transplanting date and organic manure on individual weight of mint

4.7 Fresh herbage yield/plot

Fresh herbage yield/plot of mint showed significant differences in response to different transplanting date (Table 7). The highest yield/plot (0.97 kg) was found from T_3 which was followed by (0.80 kg) T_2 and T_4 (0.79 kg) while the lowest yield/plot (0.71 kg) was observed from T_1.

Significant variation was recorded for Yield/plot of mint showed due to different organic manure (Table 7). The highest yield/plot (1.05 kg) was recorded from M_2 (bio-fertilizer@ 370 kg/ha) which was followed by (0.87 kg) M_1 (vermicompost @ 3 t/ha), whereas the lowest weight (0.54 kg) was found from M_0 (control).

Interaction effect of different transplanting date and organic manure showed significant differences in terms of yield/plot of mint under the present trial (Figure 12). The highest yield/plot (1.28 kg) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer @370 kg/ha) and the lowest weight (0.49 kg) was found from T_1M_0 (transplanting at 15 November with control i.e. 0 kg/ha) treatment combination. Arafa *et al*. (2017) reported that bio-fertilizers on *Mentha* plant produced higher fresh herb g/plant and t/ha.



T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December, T_4:Transplanting date at 30 December and M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha

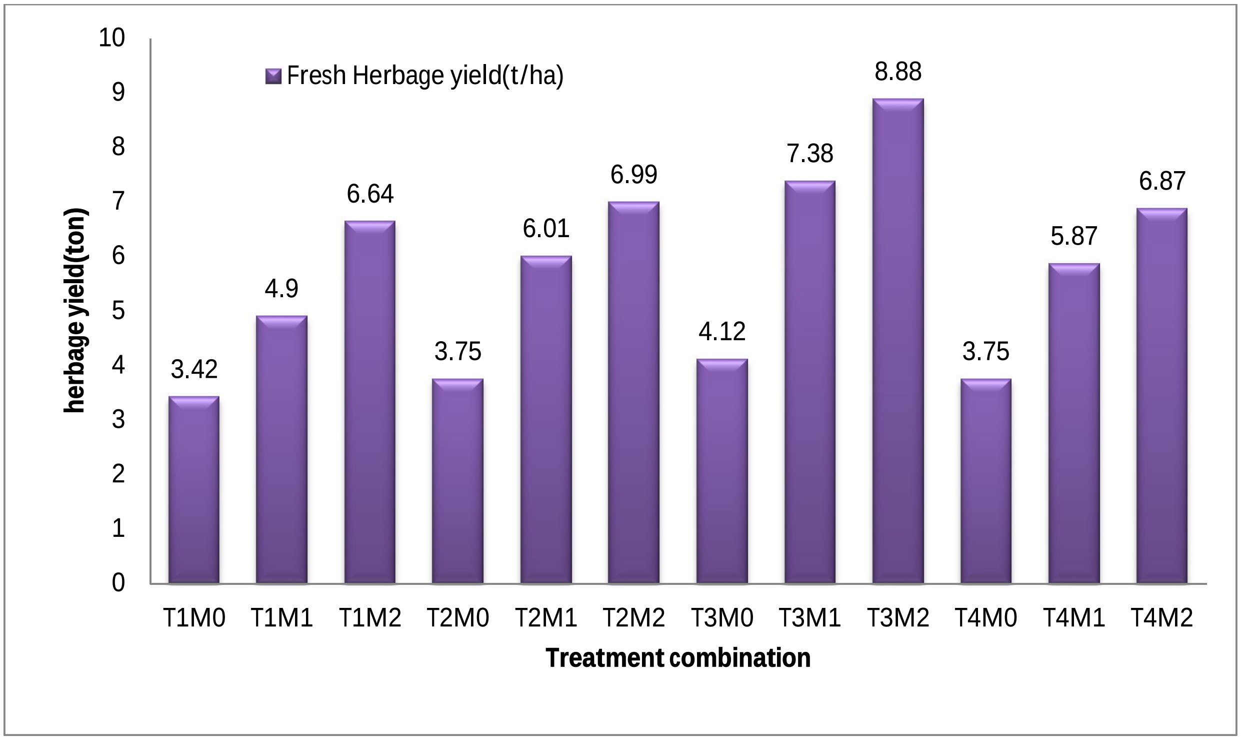
Figure 12: Interaction effect of transplanting date and organic manure on fresh herbage yield (kg)/plot of mint

4.8 Fresh herbage yield (ton) /hectare

Fresh herbage yield/hectare of mint showed significant differences in response to different transplanting date (Table 7). The highest fresh herbage yield/hectare (6.79 t) was found from T_3 which was followed by T_2 (5.88 t) and T_4 (5.50 t), while the lowest fresh herbage yield/hectare (4.99 t) was observed from T_1.

Significant variation was recorded for fresh herbage yield /hectare of mint showed due to different organic manure (Table 7). The highest fresh herbage yield /hectare (7.34 t) was recorded from M_2 (bio-fertilizer@370 kg/ha) which was followed (6.04 t) by M_1 (vermicompost @3 t/ha), whereas the lowest herbage yield (t) /ha (3.76 t) was found from M_0 (control).

Interaction effect of different transplanting date and organic manure showed significant differences in terms of fresh herbage yield/hectare of mint under the present trial (Figure 13). The highest herbage yield (t) /ha (8.88 t) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer @370 kg/ha) and the lowest weight (3.42 t) was found from T_1M_0 (transplanting at 15 November with control i.e.0 kg/ha) treatment combination. Arafa *et al*. (2017) reported that bio-fertilizers on *Mentha* plant produced higher fresh herb g/plant and ton/ha.



T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December , T_4:Transplanting date at 30 December and M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha

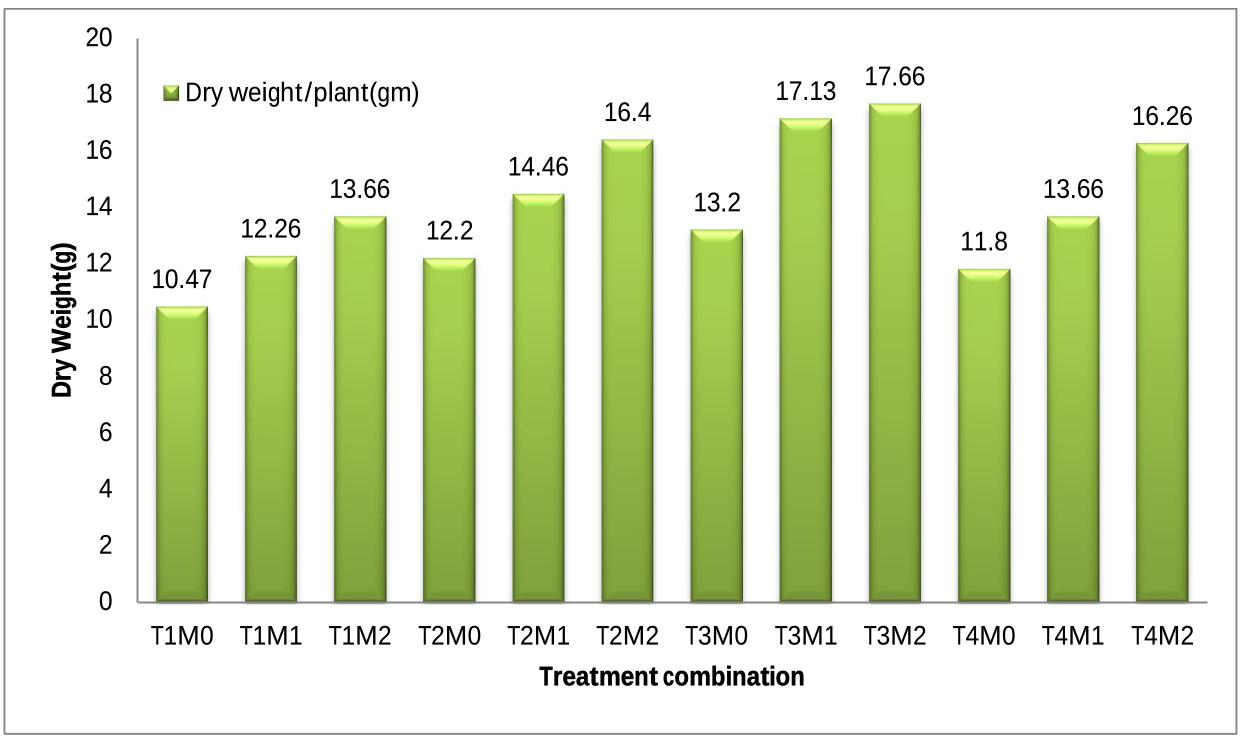
Figure 13: Interaction effect of transplanting date and organic manure on fresh herbage yield (t)/ha of mint

4.9 Dry weight of individual plant

Dry weight of individual plant of mint showed significant differences in response to different transplanting date (Table 7). The highest dry weight of individual plant (16.66 g) was found from T_3 which was followed by T_2 (14.35 g) and T_4 (13.91 g), while the lowest dry weight of individual plant (12.13 g) was observed from T_1.

Significant variation was recorded for dry weight of individual plant of mint showed due to different organic manure (Table 7). The highest dry weight of individual plant (16.50 g) was recorded from M_2 (bio-fertilizer@ 370 kg/ha) which was followed (14.38 g) by M_1 (vermicompost @ 3 t/ha), whereas the lowest dry weight was (11.91 g) found from M_0 (control).

Interaction effect of different transplanting date and organic manure showed significant differences in terms of dry weight of individual plant of mint under the present trial (Figure 14). The highest dry weight of individual plant (17.66 g) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer @370 kg/ha) and the lowest dry weight (10.47 g) was found from T_1M_0 (transplanting at 15 November with control) treatment combination. T_3M_2 produces highest dry weight due to increased leaf area, cholorophyll content as Raghava (2003) also reported that higher dry weight production may be due to increased leaf area, chlorophyll content, thereby increased photosynthetic efficiency and higher carbohydrate assimilation.



T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December , T_4:Transplanting date at 30 December and M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha

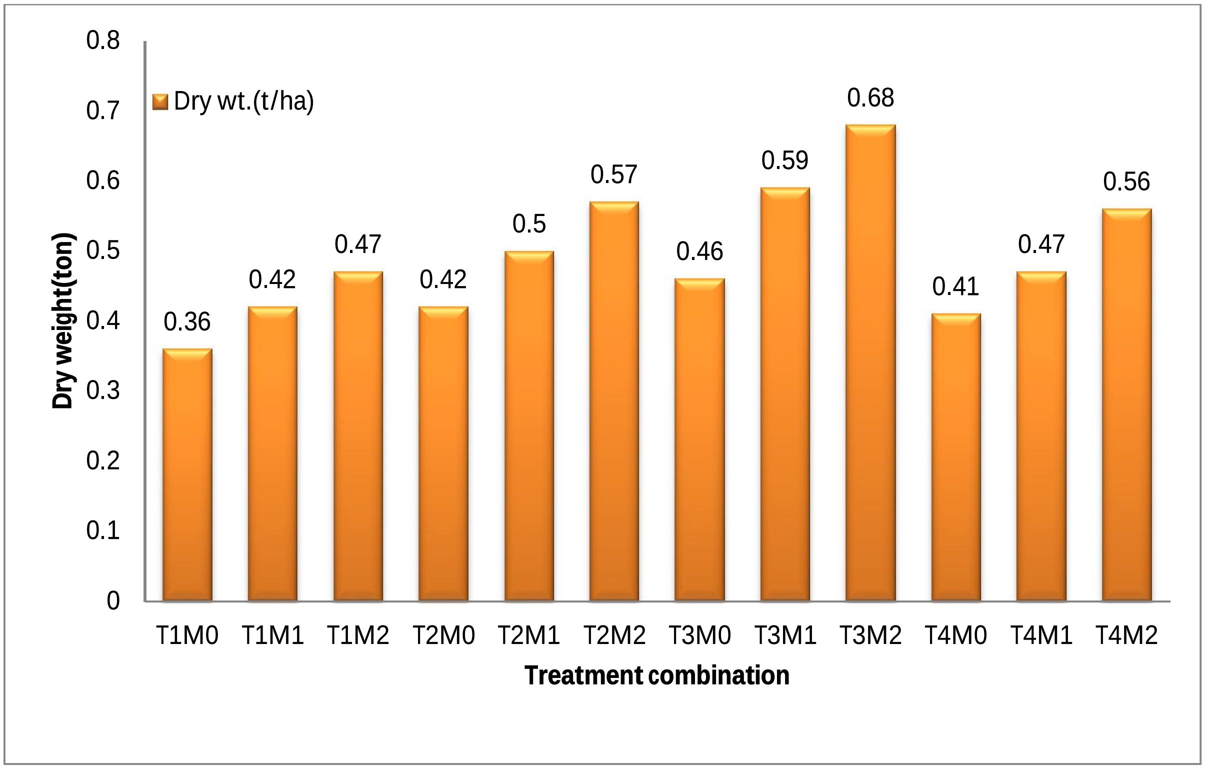
Figure 14: Interaction effect of transplanting date and organic manure on dry weight (g)/plant of mint

4.10 Dry weight/hectare

Dry weight/hectare of mint varied significantly in response to different transplanting date (Table 7). The highest dry weight/hectare of mint (0.57 t) was found from T_3 which was followed by T_2 (0.49 t) and T_4 (0.48 t), while the lowest dry weight/hectare (0.42 t) was observed from T_1.

Significant variation was recorded for dry weight/hectare of mint showed due to different organic manure (Table 7). The highest dry weight/hectare (0.57 t) was recorded from M_2 (bio-fertilizer@ 370 kg/ha) which was followed (0.49 t) by M_1 (vermicompost @ 3 t/ha), whereas the lowest dry weight/hectare (0.41t) was found from M_0 (control).

Interaction effect of different transplanting date and organic manure showed significant differences in terms of dry weight/hectare of mint under the present trial (Figure 15). The highest dry weight/hectare (0.68 t) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer @ 370 kg/ha) and the lowest dry weight/hectare (0.36 t) was found from T_1M_0 (transplanting at 15 November with control) treatment combination. Mahmoodabad *et al.* (2014) reported that organic manure showed the highest plant dry weights over the control treatment. As suggested by Krishnamoorthy and Ravikumar (1973), higher production of dry matter by the plant could be due to the fact that organic manures have high amounts of humus, which facilitate N-fixation by microbes, regulate the nitrogen supply to the plants and also helps in the production of plant growth promoters. Application of organic nutrients induced better utilization of water and nutrients for plant growth and development and also improved photosynthetic efficiency of individual plants, thereby resulting in increased yields.



T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December , T_4:Transplanting date at 30 December and M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha

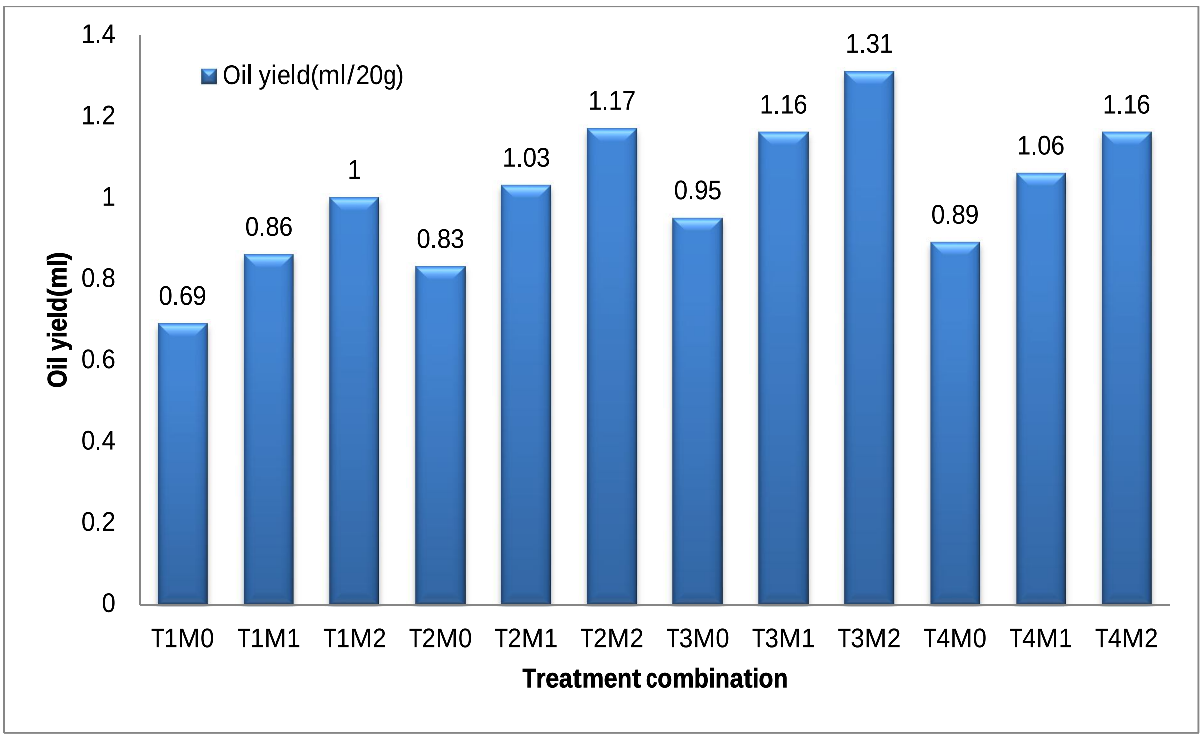
Figure 15: Interaction effect of transplanting date and organic manure on dry weight (t)/ha of mint

4.11 Essential oil yield (ml)

Essential oil yield (ml)/20 g of dry mint varied significantly due to different transplanting date (Table 7). The highest oil yield (ml)/20 g of dry mint (1.14 ml) was found from T_3 which was followed by T_2 (1.01 ml) and T_4 (1.04 ml) T_4, while the lowest oil yield (0.85 ml) was observed from T_1.

Significant variation was recorded for oil yield (ml)/20 g of dry mint showed due to different organic manure (Table 7). The highest oil yield (ml)/20 g of dry mint (1.16 ml) was recorded from M_2 (bio-fertilizer@ 370 kg/ha) which was followed (1.03 ml) by M_1 (vermicompost @ 3 t/ha), whereas the lowest oil yield (0.84 ml) was found from M_0 (control). Scavroni *et al.* (2005) also reported that oil production in mint plants increased when plants were grown with biosolid.

Interaction effect of different transplanting date and organic manure showed significant differences in terms of oil yield (ml)/ 20g of dry mint (Figure 16). The highest oil yield (1.31 ml) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer @370 kg/ha) and the lowest weight (0.69 ml) was found from T_1M_0 (transplanting at 15 November with control) treatment combination. Bio-fertilizers gave better results for all studied traits as the oil percentage and yield per plant which was also supported by Gharib *et al.* (2008)



T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December , T_4:Transplanting date at 30 December and M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha

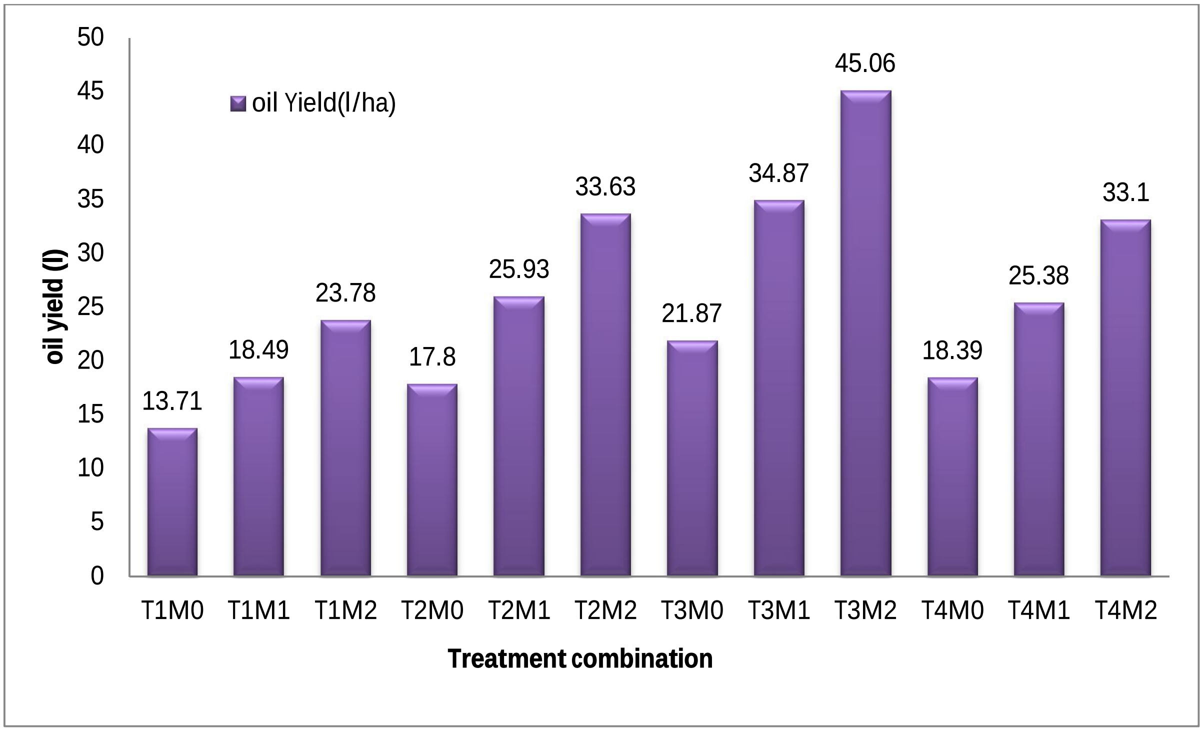
Figure 16: Interaction effect of transplanting date and organic manure on oil yield (ml)/20 g of dry mint

4.12 Oil yield (liter/hectare)

Oil yield/hectare of mint showed significant differences in response to different transplanting date (Table 7). The highest oil yield/hectare (33.93 L) was found from T_3 which was followed by (25.78 L) T_2 and (25.62 L) T_4, while the lowest oil yield/hectare (18.33 L) was observed from T_1. Ozel and Ozguven (2002) also supported that highest essential oil yield and menthol content of mint obtained from autumn transplantation.

Significant variation was recorded for oil yield/hectare of mint showed due to different organic manure (Table 7). The highest oil yield/hectare (33.89 L) was recorded from M_2 (bio-fertilizer@ 370 kg/ha) which was followed (26.17 L) by M_1 (vermicompost @3 t/ha), whereas the lowest oil yield/hectare (17.69 L) was found from M_0 (control).

Interaction effect of different transplanting date and organic manure showed significant differences in terms of oil yield/hectare of mint (Figure 17). The highest oil yield/hectare (45.06 L) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer @370 kg/ha) and the lowest oil yield/hectare (13.71 L) was found from T_1M_0 (transplanting at 15 November with control) treatment combination.



T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December , T_4:Transplanting date at 30 December and M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha

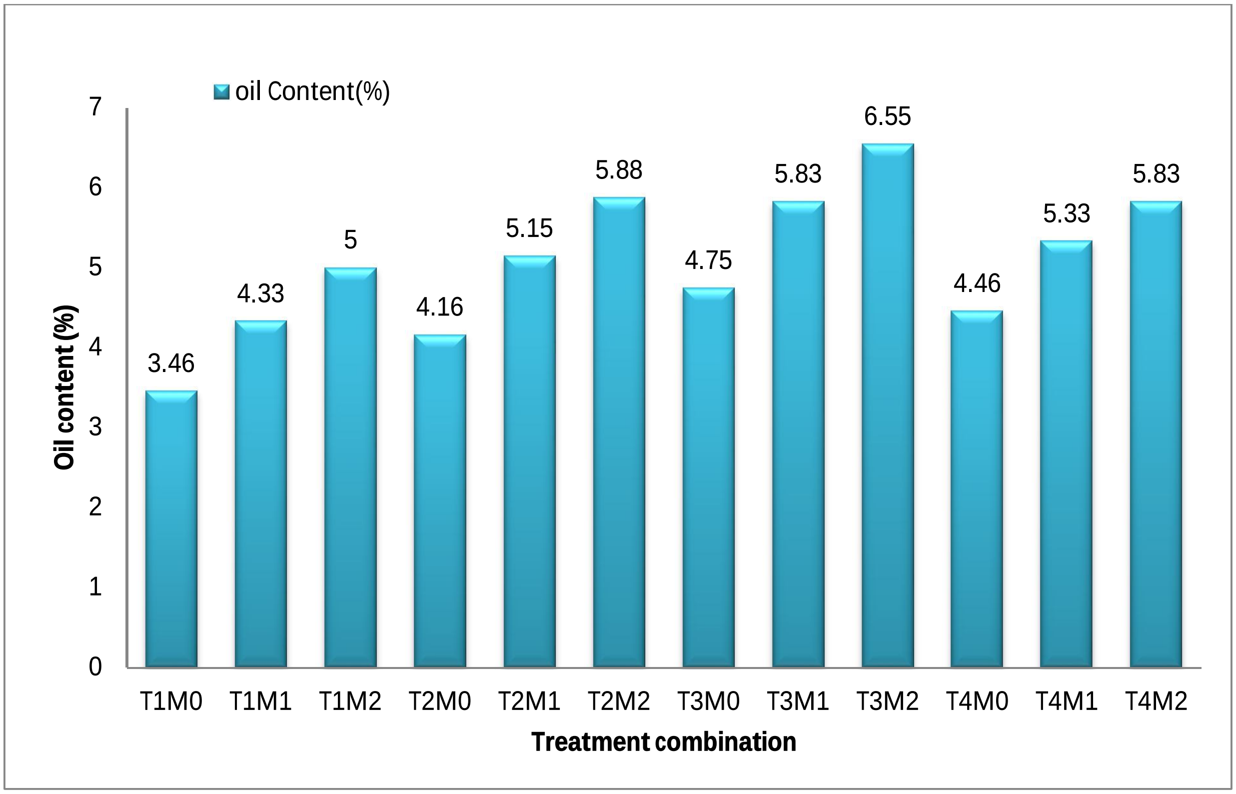
Figure 17: Interaction effect of transplanting date and organic manure on oil yield (liter)/hectare of mint

4.13 Essential Oil content

Essential Oil content of mint showed significant differences in response to different transplanting date (Table 7). The highest oil content (5.71%) was found from T_3 which was followed by (5.21%) T_4 and (5.06%) T_3, while the lowest oil content (4.26%) was observed from T_1. Salim *et al*. (2015) reported that the highest oil content obtained from summer due to that the season conditions activate the physiological process, which lead to oil gland formation and collection of oil in oil glands. The difference in oil content was due to climatic factors such as temperature, rainfall and light.

In terms of oil content of mint showed significant differences due to different organic manures (Table 7). The highest oil content (5.81%) was recorded from M_2 (bio-fertilizer@ 370 kg/ha) which was followed (5.16%) by M_1 (vermicompost @3 t/ha), whereas the lowest oil content (4.20%) was found from M_0 (control).

Interaction effect of different transplanting date and organic manure showed significant differences in terms of oil content of mint under the present trial (Figure 18). The highest oil content (6.55%) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer @370 kg/ha) and the lowest oil content (3.46%) was found from T_1M_0 (transplanting at 15 November with control) treatment combination. Bio-fertilizer is supplied the major nutrients as N, P and K to the plant on long term basis which enhanced plant height, leaf number and leaf area/plant, fresh and dry weight (g) as well as oil yield and essential oil content which was also supported by Arafa *et al*. (2017) ; Ordookhani *et al.* (2011); Kumar and Sood, (2010).



T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December, T_4:Transplanting date at 30 December and M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha

Figure 18: Interaction effect of transplanting date and organic manure on essential oil content of mint

Table 7: Effect of Transplanting date and organic manure on yield and yield contributing characters of mint at different days transplanting (DAT)

Treatments	Wt. of Individual plant (gm)	Yield (kg)/plot	Fresh Herbage yield (t/ha)	Dry weight/plant (g)	Dry wt. (t/ha)	Oil yield (ml/20 g)	Oil Content (%)	Oil Yield (l/ha)
Different Transplanting date								
T_1	0.58.98 c	0.71 c	4.99 c	12.13 c	0.42 c	0.85 c	4.26 c	18.33 c
T_2	66.99 b	0.80 b	5.58 b	14.35 b	0.49 b	1.01 b	5.06 b	25.78 b
T_3	81.60 a	0.97 a	6.79 a	16.66 a	0.57 a	1.14 a	5.71 a	33.93 a
T_4	65.99 b	0.79 b	5.50 b	13.91 b	0.48 b	1.04 b	5.21 b	25.62 b
Tukey HSD(0.05)	2.76	0.03	0.23	1.06	0.03	0.06	0.33	3.59
Level of Significance	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Different Organic Manure								
M_0	45.11 c	0.54 c	3.76 c	11.91 c	0.41 c	0.84 c	4.20 c	17.69 c
M_1	72.68 b	0.87 b	6.04 b	14.38 b	0.49 b	1.03 b	5.16 b	26.17 b
M_2	88.13 a	1.05 a	7.34 a	16.50 a	0.57 a	1.16 a	5.81 a	33.89 a
Tukey HSD(0.05)	2.16	0.02	0.18	0.83	0.02	0.05	0.26	2.81
Level of Significance	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
CV(%)	3.08	3.19	3.19	5.69	5.78	5.01	10.58	5.01

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

T_1: Transplanting date at 15 November
T_2: Transplanting date at 30 November
T3: Transplanting date at 15 December
T_4: Transplanting date at 30 December

M_0: control
M_1: vermicompost @ 3 t/ha
M_2: Bio-fertilizer @ 370 kg/ha

4.14 Economic analysis

Input costs for land preparation, organic manure, and manpower required for all the operations from raising of cutting to harvesting of mint were recorded as per plot and converted into cost/hectare (Appendix XVI). Price of mint was considered as per present market rate basis. The economic analysis presented under the following headings-

4.14.1 Gross return

The combination of different transplanting date and organic manure showed different value in terms of gross return (Table 8). The highest gross return (BDT 13,32,000/ha) was obtained from the treatment combination of T_3M_2 and the second highest gross return (BDT 11,07,000/ha) was found in T_3M_1. The lowest gross return (BDT 5,13000/ha) was obtained from T_1M_0 treatment combination.

4.14.2 Net return

In case of net return, different transplanting date and organic manure showed different levels of net return under the present trial (Table 8.). The highest net return (BDT 11,05,679/ha) was found from the treatment combination T_3M_2 and the second highest net return (BDT 8,22179/ha) was obtained from the combination T_2M_2. The lowest (BDT 3,07,970/ha) net return was obtained T_1M_0.

4.14.3 Benefit cost ratio

In the different transplanting date and organic manure manure, the highest benefit cost ratio (5.89) was obtained from the combination of T_3M_2 and the second highest benefit cost ratio (4.63) was estimated from the combination of T_2M_2. The lowest benefit cost ratio (2.50) was obtained from T_1M_0 (Table 8). From economic point of view, it is apparent from the above results that the combination of T_3M_2 was better than rest of the combination in mint cultivation.

Table 8. Cost and return of mint cultivation as influenced by different level of vermicompost and bio-fertilizer

Treatments	Cost of production (Tk./ha)	Yield of fresh harbage of mint (t/ha)	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
T_1M_0	205030	3.42	513000	307970	2.50
T_1M_1	288505	4.90	735000	446495	2.55
T_1M_2	226321	6.64	996000	769679	4.40
T_2M_0	205030	3.75	562500	357470	2.74
T_2M_1	288505	6.01	901500	612995	3.12
T_2M_2	226321	6.99	1048500	822179	4.63
T_3M_0	205030	4.12	618000	412970	3.01
T_3M_1	288505	7.38	1107000	818495	3.84
T_3M_2	226321	8.88	1332000	1105679	5.89
T_4M_0	205030	3.75	562500	357470	2.74
T_4M_1	288505	5.87	880500	591995	3.05
T_4M_2	226321	6.87	1030500	804179	4.55

Price of fresh herbage of mint @ Tk. 150/kg

T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December , T_4:Transplanting date at 30 December and M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha

Chapter V
Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out in the Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2017 to April 2018 to find out the effect of transplanting date and organic manure on growth and yield of herbage and essential oil content of mint. The experiment consisted of two factors; Factor A: Transplanting date (4 levels) as- T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T_3: Transplanting date at 15 December, T_4: Transplanting date at 30 December and Factor B: Organic Manure (3 levels) as- M_0: 0 kg manure/ha (control), M_1: Vermicompost @ 3 t/ha, M_2: Bio-fertilizer @ 370kg/ha. The two factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded for different growth and yield parameters and significant variation was recorded for different treatment. The collected data were statistically analyzed for evaluation of the treatment effect.

Significant variations were observed due to Plant height of mint at 30, 60, 90, 120 DAT the tallest plant (15.13, 18.80, 22.9 and 20.46 cm, respectively) was recorded from T_3 (Transplanting date at 15 December) and the shortest plant (12.93, 16.20, 19.84 and 16.93 cm, respectively) was found from T_1 (Transplanting date at 15 November); The height number of branches/plant (9.97, 22.55, 67.66 and 92.66 respectively) was found from T_3 whereas the lowest branch no./plant (7.26, 15.33, 46.00 and 71.00 respectively) was found from T_1; the highest number of leaves/ plant (116.00, 176.00, 362.00 and 380.00 respectively) was recorded from T_3 and the lowest number of leaves/ plant (84, 153, 290 and 320 respectively) was found from T_1; the highest leaf area (6.70, 8.39, 10.80 and 12.27 cm_2, respectively) was recorded from T_3 and whereas the lowest leaf area (5.54, 6.93, 8.95 and 9.63 cm2, respectively) was found from T_1;

the highest number of stolon/ plant (2.46, 3.86, 5.80 and 6.66 , respectively) was recorded from T_3 (Transplanting date at 15 December) whereas the lowest number of stolon/ plant (1.83, 2.95, 4.15 and 5.00 , respectively) was found from T_1 (Transplanting date at 15 November). The highest weight of individual plant (81.60 g) was found from T_3 while the lowest weight (58.98 g) was observed from T_1. The highest yield/plot (0.97 kg) was found from T_3 while the lowest yield/plot (0.71 kg) was observed from T_1. The highest fresh herbage yield /hectare (6.79 t) was found from T_3 while the lowest fresh herbage yield/hectare (4.99 t) was observed from T_1. The highest dry weight of individual plant (16.66 g) was found from T_3 which was followed by T_2 (14.35 g) while the lowest dry weight of individual plant (12.13 g) was observed from T_1. The highest dry weight/hectare of mint (0.57 t) was found from T_3 while the lowest dry weight/hectare (0.42 t) was observed from T_1. The highest oil yield (1.14 ml) /20 g of dry mint were found from T_3 while the lowest oil yield (0.85 ml) was observed from T_1. The highest oil yield/ha (33.93 L) was found from T_3 while the lowest oil yield/hectare (18.33 L) was observed from T_1. The highest oil content (5.71%) was found from T_3 while the lowest oil content (4.26%) was observed from T_1.

In terms of plant height of mint at 30, 60, 90, 120 DAT where the tallest plant (15.40, 19.65, 23.95 and 21.00 cm, respectively) was observed from M_2 (Bio-fertilizer @ 370 kg/ha) which was statistically different (14.30, 17.95, 21.83 and 19.20 cm, respectively) from M_1 (Vermicompost @ 3 t/ha), while the shortest plant (12.41, 15.11, 18.46 and 16.06 cm, respectively) was recorded from M_0 (control). The highest branch no./plant (10.76, 24.21, 72.65 and 97.65 respectively) was observed from M_2 (Bio-fertilizer @ 370 kg/ha) which was statistically different (8.30, 18.68, 56.05 and 81.05, respectively) from M_1 (Vermicompost @ 3 t/ha), while the lowest branch no./plant (6.322, 13.53, 40.60 and 65.60, respectively) was recorded from M_0 (0 kg /ha i.e., control). The highest number of leaves/ plant (123.00, 194.17, 358.50 and 391.50, respectively) was observed from M_2 (Bio-fertilizer @ 370kg/ha) which was statistically different (95.17, 157.50, 324.00 and 348.00, respectively) from M_1 (Vermicompost @ 3 t/ha), while the shortest plant (72.00, 128.00, 288.00 and 307.50, respectively) was recorded from M_0 (0 kg /ha i.e., control). Highest leaf area (6.96, 8.63, 10.72 and 11.54 cm^2, respectively) was observed from M_2 (Bio-fertilizer @ 370 kg/ha) which was statistically different (6.42, 7.66, 9.45 and 10.40 cm^2, respectively) from M_1 (Vermicompost @ 3 t/ha), while the shortest leaf area (4.75, 6.48, 8.61 and 9.50 cm^2, respectively) was recorded from M_0 (0 kg /ha i.e. control). The highest number of stolon/ plant (2.56, 4.20, 5.79 and 6.76, respectively) was recorded from M_2 (Bio-fertilizer @ 370 kg/ha) which was statistically different (2.25, 3.34, 4.78 and 5.81, respectively) from M_1 (Vermicompost @ 3 t/ha), while the lowest number of stolon (1.66, 2.51, 3.73 and 4.85, respectively) was recorded from M_0. The highest weight of individual plant (88.13 g) was recorded from M_2 (bio-fertilizer @370kg/ha) which was followed (72.68 g) by M_1 (vermicompost@3 t/ha), whereas the lowest weight (153.88 g) was found from M_0 (control). The highest yield/plot (1.05 kg) was recorded from M_2 (bio-fertilizer@ 370 kg/ha) which was followed by (0.87 kg) M_1 (vermicompost @3 t/ha), whereas the lowest weight (0.54 kg) was found from M_0 (control). The highest fresh herbage yield /hectare (7.34 t) was recorded from M_2 (bio-fertilizer@370 kg/ha) which was followed (6.04 t) by M_1 (vermicompost @3 t/ha), whereas the lowest herbage yield (t) /hectare (3.76 t) was found from M_0 (control). The highest dry weight of individual plant (16.50 g) was recorded from M_2 (bio-fertilizer@ 370 kg/ha) which was followed (14.38 g) by M_1 (vermicompost @3 t/ha), whereas the lowest dry weight was (11.9 g) found from M_0 (control). The highest dry weight/hectare (0.57 t) was recorded from M_2 (bio-fertilizer@ 370 kg/ha) which was followed (0.49 t) by M_1 (vermicompost @3 t/ha), whereas the lowest dry weight/hectare (0.41 t) was found from M_0 (control). The highest oil yield (ml)/20 g of dry mint (1.16 ml) was recorded from M_2 (bio-fertilizer@ 370 kg/ha) which was followed (1.03 ml) by M_1 (vermicompost @3 t/ha), whereas the lowest oil yield (0.84 ml) was found from M_0 (control). The highest oil yield/hectare (5.81 L) was recorded from M_2

(bio-fertilizer@ 370 kg/ha) which was followed (5.16 L) by M_1 (vermicompost @3 t/ha), whereas the lowest oil yield/hectare (4.20 L) was found from M_0 (control). The highest oil content (5.81%) was recorded from M_2 (bio-fertilizer@ 370 kg/ha) which was followed (5.16%) by M_1 (vermicompost @3 t/ha), whereas the lowest oil content (4.20%) was found from M_0 (control).

Interaction effect of different transplanting date and organic manure showed statistically significant variation in terms of plant height of mint at 30, 60, 90, 120 DAT . At 30, 60, 90, 120 DAT, the tallest plant (16.80, 21.20, 25.80 and 23.20 cm, respectively) was observed from T_3M_2 (Transplanting date at 15 December with bio-fertilizer @ 370 kg/ha) and the shortest plant (11.60, 14.00, 17.20 and 14.80 cm, respectively) was found from T_1M_0 (Transplanting date at 15 November with 0 kg Manure/ha i.e., control) treatment combination. The highest branch number/plant (12.26, 27.53, 82.60 and 107.60, respectively) was observed from T_3M_2 (Transplanting date at 15 December with bio-fertilizer @ 370kg/ha) and the shortest plant (5.20, 10.20, 30.60 and 55.60 respectively) was found from T_1M_0 (Transplanting date at 15 November with 0 kg Manure/ha i.e., control) treatment combination. The height number of leaves/ plant (144, 216, 414 and 444, respectively) was observed from T_3M_2 (Transplanting date at 15 December with bio-fertilizer @ 370kg/ha) and the lowest number of leaves/plant (60, 120, 270 and 294, respectively) was found from T_1M_0 (Transplanting date at 15 November with 0 kg Manure/ha i.e., control) treatment combination. The highest leaf area (7.98, 9.50, 12.54 and 13.96 cm2, respectively) was observed from T_3M_2 (Transplanting date at 15 December with bio-fertilizer @ 370 kg/ha) and the shortest leaf area (4.54, 5.81, 8.28 and 9.00 cm^2, respectively) was found from T_1M_0 (Transplanting date at 15 November with 0 kg Manure/ha i.e., control) treatment combination. The highest number of stolon/ plant (2.66, 4.80, 6.93 and 7.66, respectively) was recorded from T_3M_2 (Transplanting date at 15 December with bio-fertilizer @ 370 kg/ha) and the lowest number of stolon/plant (1.33, 2.13, 3.26 and 4.13, respectively) was found from T_1M_0 (Transplanting date at 15 November with 0 kg/ha). The highest weight of individual plant (106.72 g) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer@370 kg/ha) and the lowest weight (41.25 g) was found from T_1M_0 (transplanting at 15 November with control) treatment combination. Interaction effect of different transplanting date and organic manure showed significant differences in terms of yield/plot of mint under the present trial. The highest yield/plot (1.28 kg) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer @370 kg/ha) and the lowest weight (0.49 kg) was found from T_1M_0 (transplanting at 15 November with control i.e. 0 kg/ha) treatment combination. The highest herbage yield (t) /hectare (8.88 t) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer @ 370 kg/ha) and the lowest weight (3.42 t) was found from T_1M_0 (transplanting at 15 November with control i.e.0 kg/ha) treatment combination. The highest dry weight of individual plant (17.66 g) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer @370 kg/ha) and the lowest dry weight (10.47 g) was found from T_1M_0 (transplanting at 15 November with control) treatment combination. The highest dry weight/hectare (0.68 t) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer @370 kg/ha) and the lowest dry weight/hectare (0.36 t) was found from T_1M_0 (transplanting at 15 November with control) treatment combination. The highest oil yield (1.31ml) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer @370 kg/ha) and the lowest weight (0.69 ml) was found from T_1M_0 (transplanting at 15 November with control) treatment combination. The highest oil yield/hectare (45.06 L) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer @370 kg/ha) and the lowest oil yield/hectare (13.71 L) was found from T_1M_0 (transplanting at 15 November with control) treatment combination. The highest oil content (6.55%) was observed from T_3M_2 (transplanting at 15 December with bio-fertilizer @370 kg/ha) and the lowest oil content (3.46%) was found from T_1M_0 (transplanting at 15 November with control) treatment combination.

The combination of different transplanting date and organic manure, the highest gross return (BDT 13,32,000/ha) was obtained from the treatment combination of T_3M_2 and the lowest gross return (BDT 5,13,000/ha) was obtained from T_1M_0 treatment combination. The highest net return (BDT 11,05,679/ha) was found from the treatment combination T_3M_2 and the lowest (BDT 3,07,970/ha) net return was obtained T_1M_0. The highest benefit cost ratio (5.89) was obtained from the combination of T_3M_2 and the lowest benefit cost ratio (2.50) was obtained from T_1M_0. From economic point of view, it is apparent from the above results that the combination of T_3M_2 was better than rest of the combination in mint cultivation.

Conclusion

Considering the above mentioned findings, it can be concluded that the transplanting date at 15 December with bio-fertilizer @ 370 kg/ha on mint plant most effective for vegetative growth and as well as quantitative yield of its essential oil. To maintain good soil and keep the environment sound, it would be the best to advise growers for the application of bio-fertilizer as organic nutrient source for commercial production of mint. However, further studies with different transplanting date, various sources of organic manure, their higher levels, and longer period of study could be explored before drawing valid conclusions.

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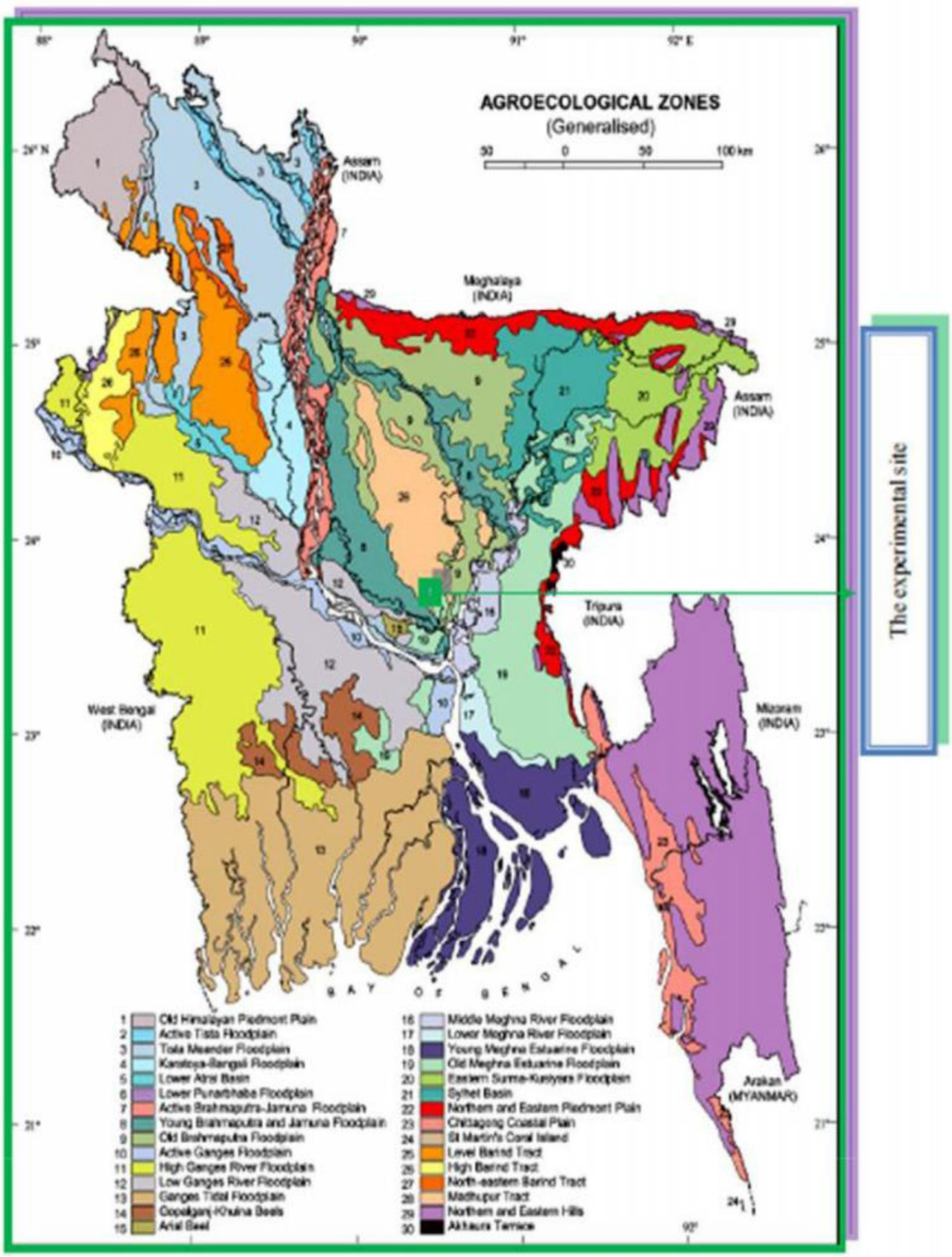
Appendices

APPENDICES

Appendix I. Map showing the experimental site



Appendix II. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2017 to April 2018

Month	Air temperature (ºC)		Relative humidity (%)	Total Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
November, 2017	25.8	16.0	76	00	6.8
December, 2017	22.6	13.4	78	05	6.6
January, 2018	24.9	12.2	64	02	5.8
February, 2018	26.7	16.9	69	30	6.7
March, 2018	27.5	19.4	81	22	6.9
April, 2018	28.8	20.8	88	26	6.9

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

Appendix III. Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

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

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	26
% Silt	43
% clay	31
Textural class	Sandy loam
pH	5.9
Catayan exchange capacity	2.64 meq 100 g/soil
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10

Appendix IV. Analysis of variance of the data on plant height of mint at different days after transplanting (DAT) as influenced by different transplanting date and organic manure

Source of Variance	Degree of Freedom	Mean Square			
		Plant Height (cm) at			
		30DAT	60DAT	90DAT	120DAT
Replication	2	0.14	0.07	0.12	0.14
Transplanting date (A)	3	7.41**	10.21**	14.43**	18.89**
Organic Manure (B)	2	27.31**	62.94**	92.02**	74.79**
Interaction (AxB)	6	0.19**	0.20*	0.23**	0.65**
Error	22	0.05	0.07	0.07	0.11

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

Appendix V. Analysis of variance of the data on number of branch /plant of mint at different days after transplanting (DAT) as influenced by different transplanting date and organic manure

Source of Variance	Degree of Freedom	Mean Square			
		Number of branch at			
		30DAT	60DAT	90DAT	120DAT
Replication	2	0.33	0.25	0.083	3.08
Transplanting date (A)	3	11.66**	42.00**	226.61**	709.61**
Organic Manure (B)	2	59.42**	204.75**	414.93**	589.25**
Interaction (AxB)	6	0.66	6.75**	16.34**	22.34**
Error	22	1.05	1.06	1.08	3.30

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

Appendix VI. Analysis of variance of the data on number of leaf /plant of mint at different days after transplanting (DAT) as influenced by different transplanting date and organic manure

Source of Variance	Degree of Freedom	Mean Square			
		No. of leaf at			
		30DAT	60DAT	90DAT	120DAT
Replication	2	30.78	19.10	3.00	3.00
Transplanting date (A)	3	1722.78**	2796.00**	8145.00**	6012.00**
Organic Manure (B)	2	8806.78**	13185.40**	14913.00**	21177.00**
Interaction (AxB)	6	118.78	433.00**	585.00**	729.00**
Error	22	157.32	63.50	39.00	39.00

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

Appendix VII. Analysis of variance of the data on leaf area of mint at different days after transplanting (DAT) as influenced by different transplanting date and organic manure

Source of Variance	Degree of Freedom	Mean Square			
		Leaf area (cm^2) at			
		30DAT	60DAT	90DAT	120DAT
Replication	2	0.15	0.23	0.19	0.18
Transplanting date (A)	3	2.09**	3.17**	6.04**	13.21**
Organic Manure (B)	2	15.90**	13.89**	13.55**	12.60**
Interaction (AxB)	6	0.26	0.24	0.61**	0.57**
Error	22	2.41	0.18	0.11	0.12

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

AppendixVIII. Analysis of variance of the data on number of stolon/plant of mint at different days after transplanting (DAT) as influenced by different transplanting date and organic manure

Source of Variance	Degree of Freedom	Mean Square No. of stolon/plant at			
		30DAT	60DAT	90DAT	120DAT
Replication	2	0.55	0.26	1.08	1.19
Transplanting date (A)	3	0.61**	1.38**	4.57**	4.17**
Organic Manure (B)	2	2.51**	8.50**	12.71**	11.02**
Interaction (AxB)	6	0.05	0.03	0.06	0.01
Error	22	0.08	0.05	0.11	0.04

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

Appendix IX. Analysis of variance of the data on yield contributing characters and yield of mint as influenced by different transplanting date and organic manure

Source of Variance	Degrees of freedom	Mean Square							
		Wt. of Individual plant(g)	yield(kg)/plot	Fresh Herbage yield(t/ha)	Dry weight/plant(g)	Dry wt.(t/ha)	Oil yield(ml/20g)	oil Content(%)	oil Yield(l/ha)
Replication	2	159.5	0.02	1.11	15.97	0.02	0.11	2.66	224.86
Transplanting date (A)	3	758.08**	0.10**	5.27**	31.33**	0.03**	0.12**	3.22**	265.83**
Organic Manure (B)	2	5698.44**	0.82**	39.58**	63.14**	0.07**	0.31**	7.80**	787.81**
Interaction (AxB)	6	98.98**	0.01**	0.65**	1.59	0.01	0.01	0.02	19.95*
Error	22	4.46	0.001	0.03	0.65	0.00	0.002	0.06	7.52

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

Appendix X. Effect of Transplanting date and organic manure on plant height of at different days transplanting (DAT) of mint

Treatments	Plant Height at different DAT			
	30DAT	60DAT	90DAT	120DAT
Different Transplanting date				
T_1	12.93 d	16.20 c	19.84 c	16.93 c
T_2	14.20 b	17.66 b	21.60 b	18.67 b
T_3	15.13 a	18.80 a	22.93 a	20.46 a
T_4	12.93 d	17.62 b	21.35 b	18.95 b
Tukey HSD(0.05)	0.29	0.34	0.34	0.42
Level of Significance	0.05	0.05	0.05	0.05
Different Organic Manure				
M_0	12.41 c	15.11 c	18.46 c	16.06 c
M_1	14.30 b	17.95 b	21.83 b	19.2 b
M_2	15.40 a	19.65 a	23.95 a	21.00 a
Tukey HSD(0.05)	0.22	0.26	0.26	0.33
Level of Significance	0.05	0.05	0.05	0.05
CV(%)	1.60	1.48	1.22	1.73

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

T_1: Transplanting date at 15 November
T_2: Transplanting date at 30 November
T3: Transplanting date at 15 December
T_4: Transplanting date at 30 December

M_0: control
M_1: vermicompost @ 3 t/ha
M_2: Bio-fertilizer @ 370 kg/ha

Appendix XI. Effect of Transplanting date and organic manure on number of branch/plant of at different days transplanting (DAT) of mint

Treatments	Number of Branches at Different DAT			
	30DAT	60DAT	90DAT	120DAT
Different Transplanting date				
T_1	7.26 b	15.33 c	46.00 c	71.00 c
T_2	8.55 b	18.93 b	56.80 b	81.80 b
T_3	9.97 a	22.55 a	67.66 a	92.66 a
T_4	8.05 b	18.42 b	55.80 b	80.26 b
Tukey HSD(0.05)	1.34	2.48	1.36	2.36
Level of Significance	0.05	0.05	0.05	0.05
Different Organic Manure				
M_0	6.32 c	13.53 c	40.60 c	65.60 c
M_1	8.30 b	18.68 b	56.05 b	81.05 b
M_2	10.76 a	24.21 a	72.65 c	97.65 a
Tukey HSD(0.05)	1.05	1.94	1.07	1.85
Level of Significance	0.05	0.05	0.05	0.05
CV(%)	12.61	5.17	1.93	1.64

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

T_1: Transplanting date at 15 November
T_2: Transplanting date at 30 November
T3: Transplanting date at 15 December
T_4: Transplanting date at 30 December

M_0: control
M_1: vermicompost @ 3 t/ha
M_2: Bio-fertilizer @ 370 kg/ha

Appendix XII.: Effect of Transplanting date and organic manure on number of leaf/plant at different days transplanting (DAT) of mint

Treatments	Number of leaf/plant at different DAT			
	30DAT	60DAT	90DAT	120DAT
Different Transplanting date		153.33 c	290.00 d	320.00 d
T_1	84.00 b	168.22 ab	328.00 b	358.00 b
T_2	100.00 ab	176.00 a	362.00 a	380.00 a
T_3	116.00 a	160.00 b	314.00 c	338.00 c
T_4	90.89 b			
Tukey HSD(0.05)	3.92	3.43	3.92	3.93
Level of Significance	0.05	0.05	0.05	0.05
Different Organic Manure				
M_0	72.00 c	128.00 c	288.00 c	307.50 c
M_1	95.17 b	157.50 b	324.00 b	348.00 b
M_2	126.00 a	194.17 a	358.50 a	391.50 a
Tukey HSD(0.05)	3.55	3.25	6.40	3.56
Level of Significance	0.05	0.05	0.05	0.05
CV(%)	12.84	4.98	1.93	1.79

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

T_1: Transplanting date at 15 November
T_2: Transplanting date at 30 November
T3: Transplanting date at 15 December
T_4: Transplanting date at 30 December

M_0: control
M_1: vermicompost @ 3 t/ha
M_2: Bio-fertilizer @ 370 kg/ha

Appendix XIII. Effect of Transplanting date and organic manure on leaf area (cm^2) at different days transplanting (DAT) of mint

Treatments	**Leaf area at different DAT**			
	30DAT	60DAT	90DAT	120DAT
Different Transplanting date				
T_1	5.54 c	6.93 b	8.95 b	9.63 c
T_2	6.01 b	7.51 b	9.31 b	9.90 bc
T_3	6.70 a	8.39 a	10.80 a	12.27 a
T_4	5.94 bc	7.49 b	9.33 b	10.12 b
Tukey HSD(0.05)	0.43	0.56	0.44	0.46
Level of Significance	0.05	0.05	0.05	0.05
Different Organic Manure				
M_0	4.75 c	6.48 c	8.61 c	9.50 c
M_1	6.42 b	7.66 b	9.45 b	10.40 b
M_2	6.96 a	8.63 a	10.72 a	11.54 a
Tukey HSD(0.05)	0.33	0.43	0.35	0.36
Level of Significance	0.05	0.05	0.05	0.05
CV(%)	5.47	5.64	3.55	3.37

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

T_1: Transplanting date at 15 November
T_2: Transplanting date at 30 November
T3: Transplanting date at 15 December
T_4: Transplanting date at 30 December

M_0: control
M_1: vermicompost @ 3 t/ha
M_2: Bio-fertilizer @ 370 kg/ha

Appendix XIV. Effect of Transplanting date and organic manure on number of stolon/plant at different days transplanting (DAT) of mint

Treatments	Number of Stolon/ plant at different DAT			
	30DAT	60DAT	90DAT	120DAT
Different Transplanting date				
T_1	1.83 b	2.95 c	4.15 b	5.00 c
T_2	2.22 a	3.42 b	4.57 b	5.82 b
T_3	2.46 a	3.86 a	5.80 a	6.66 a
T_4	2.13 ab	3.16 bc	4.57 b	5.75 b
Tukey HSD(0.05)	0.37	0.31	0.43	0.09
Level of Significance	0.05	0.05	0.05	0.05
Different Organic Manure				
M_0	1.66 c	2.51 c	3.73 c	4.85 c
M_1	2.25 b	3.34 b	4.78 b	5.81 b
M_2	2.56 a	4.2 a	5.79 a	6.76 a
Tukey HSD(0.05)	0.29	0.23	0.34	0.21
Level of Significance	0.05	0.05	0.05	0.05
CV(%)	13.18	6.97	7.03	3.57

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

T_1: Transplanting date at 15 November
T_2: Transplanting date at 30 November
T3: Transplanting date at 15 December
T_4: Transplanting date at 30 December

M_0: control
M_1: vermicompost @ 3 t/ha
M_2: Bio-fertilizer @ 370 kg/ha

Appendix XV. Interaction effect of organic manure and transplanting date on yield and yield contributing characters of mint at different days after transplanting (DAT)

Treatments	Wt. of Individual plant(g)	Yield (kg)/plot	Fresh Herbage yield(t/ha)	Dry weight/plant(g)	Dry wt.(t/ha)	Oil yield (ml/20g)	Oil Content (%)	Oil Yield(l/ha)
T_1M_0	41.25 g	0.49 g	3.42 g	10.47 f	0.36 f	0.69 g	3.46 g	13.71 f
T_1M_1	58.93 e	0.70 e	4.90 e	12.26 def	0.42 def	0.86 ef	4.33 ef	18.49 fe
T_1M_2	79.77 c	0.95 c	6.64 c	13.66 de	0.47 de	1 cde	5.00 cde	23.78 e
T_2M_0	45.03 fg	0.54 fg	3.75 fg	12.2 def	0.42 def	0.83 fg	4.16 fg	17.8 ef
T_2M_1	72.24 d	0.86 d	6.01 d	14.46 cd	0.50 cd	1.03 bcd	5.15 bcd	25.93 cde
T_2M_2	83.71 bc	1.00 bc	6.99 bc	16.4 bc	0.57 bc	1.17 ab	5.88 ab	33.63 bc
T_3M_0	49.21 f	0.59 f	4.12 f	13.2 de	0.46 de	0.95 cdef	4.75 cdef	21.87 e
T_3M_1	88.88 b	1.06 b	7.38 b	17.13 b	0.59 ab	1.16 ab	5.83 ab	34.87 b
T_3M_2	106.72 a	1.28 a	8.88 a	17.66 a	0.68 a	1.31 a	6.55 a	45.06 a
T_4M_0	44.96 fg	0.54 fg	3.75 fg	11.8 ef	0.41 ef	0.89 def	4.46 def	18.39 ef
T_4M_1	70.69 d	0.84 d	5.87 d	13.66 de	0.47 de	1.06 bc	5.33 bc	25.38 de
T_4M_2	82.32 c	0.99 bc	6.87 bc	16.26 bc	0.56 bc	1.16 ab	5.83 ab	33.1 bcd
Tukey HSD (0.05)	6.26	0.07	0.54	2.41	0.08	0.15	0.75	8.14

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

T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December , T_4:Transplanting date at 30 December and M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha.

Appendix XVI. Per hectare production cost of Mint

A. Input cost

Treatments	Labour cost	Ploughing cost	Planting material Cost	Irrigation cost	Vermiocompost	Bio-fertilizer	Sub total (A)
T_1M_0	42,000	7,500	45,000	4,000	0	0	98,500
T_1M_1	42,000	7,500	45,000	4,000	75,000	0	173,500
T_1M_2	42,000	7,500	45,000	4,000	0	16,500	115,000
T_2M_0	42,000	7,500	45,000	4,000	0	0	98,500
T_2M_1	42,000	7,500	45,000	4,000	75,000	0	173,500
T_2M_2	42,000	7,500	45,000	4,000	0	16,500	115,000
T_3M_0	42,000	7,500	45,000	4,000	0	0	98,500
T_3M_1	42,000	7,500	45,000	4,000	75,000	0	173,500
T_3M_2	42,000	7,500	45,000	4,000	0	16,500	115,000
T_4M_0	42,000	7,500	45,000	4,000	0	0	98,500
T_4M_1	42,000	7,500	45,000	4,000	75,000	0	173,500
T_4M_2	42,000	7,500	45,000	4,000	0	16,500	115,000

T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December , T_4:Transplanting date at 30 December and M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha

Appendix XVI. Per hectare production cost of mint (Cont'd)

B. Overhead cost (Tk. /ha)

Treatment Combination	Cost of lease of land (12% of value of land Tk. 15,00000/year	Miscellaneous cost (Tk. 5% of the input cost	Interest on running capital for 6 months (Tk. 12% of cost/year)	Sub total (Tk) (B)	Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)]
T_1M_0	90,000	4,925	11,605	106,530	205,030
T_1M_1	90,000	8,675	16,330	115,005	288,505
T_1M_2	90,000	5,775	12,646	111,321	226,321
T_2M_0	90,000	4,925	11,605	106,530	205,030
T_2M_1	90,000	8,675	16,330	115,005	288,505
T_2M_2	90,000	5,775	12,646	111,321	226,321
T_3M_0	90,000	4,925	11,605	106,530	205,030
T_3M_1	90,000	8,675	16,330	115,005	288,505
T_3M_2	90,000	5,775	12,646	111,321	226,321
T_4M_0	90,000	4,925	11,605	106,530	205,030
T_4M_1	90,000	8,675	16,330	115,005	288,505
T_4M_2	90,000	5,775	12,646	111,321	226,321

T_1: Transplanting date at 15 November, T_2: Transplanting date at 30 November, T3: Transplanting date at 15 December , T_4:Transplanting date at 30 December and M_0: control, M_1: vermicompost @ 3 t/ha .M_2: Bio-fertilizer @ 370 kg/ha .