EFFECT OF PLANTING TIMES AND ORGANIC NUTRIENT SOURCES ON GROWTH AND YIELD OF BRUSSELS SPROUTS

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EFFECT OF PLANTING TIMES AND ORGANIC NUTRIENT SOURCES ON GROWTH AND YIELD OF BRUSSELS SPROUTS

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CERTIFICATE

*This is to certify that the thesis entitled **"EFFECT OF PLANTING TIMES AND ORGANIC NUTRIENT SOURCES ON GROWTH AND YIELD OF BRUSSELS SPROUTS"** submitted to the Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE,** embodies the result of a piece of bona fide research work carried out by **KAZI NOWRIN,** Registration No. **13-05532**, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

Dated: …………….
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So verily, with hardship [will be] ease. Verily, with hardship [will be] ease.

(Quran 94: 5-6)

DEDICATED TO

MY BELOVED PARENTS

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ABSTRACT

An experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2018 to April, 2019 to evaluate the effect of planting times and organic nutrient sources on growth and yield of Brussels sprouts. The experiment consisted of two factors: Factor A: Planting times (three levels) as - T_1: 05 November; T_2: 20 November and T_3: 05 December and Factor B: Organic nutrients sources (four levels) as – N_0: Control (no manure); N_1: Cowdung @ 15 t/ha; N_2: Mushroom spent compost @ 7.5 t/ha and N_3: Vermicompost @ 5 t/ha. The experiment was outlined in Randomized Complete Block Design with three replications. Significant variation was found with the treatments. In case of planting time, maximum number of marketable buds (21.89/plant) and marketable yield (8.70 t/ha) were recorded from T_1 and minimum number of marketable buds (17.22/plant) and marketable yield (5.76 t/ha) were recorded from T_3. For organic nutrient sources, maximum number of marketable buds (22.59/plant) and marketable yield (8.82 t/ha) were recorded from N_3 and minimum number of marketable buds (14.30/plant) and marketable yield (4.69 t/ha) was recorded from N_0. For combined effect, the highest marketable yield (10.92 t/ha) was recorded from T_1N_3 and the lowest marketable yield (4.07 t/ha) was recorded from T_3N_0. Economic analysis revealed that T_1N_3 gave the maximum benefit cost ratio (2.59). So it can be concluded that, planting at 05 November with vermicompost @ 5 t/ha provided the best result for growth and yield of Brussels sprouts.

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ABBREVIATIONS AND ACRONYMS

Abbreviation	Full Word
@	At the rate of
AEZ	Agro-Ecological Zone
Agric.	Agricultural
Anon.	Anonymous
cm	Centimeter
CV	Coefficient of variation
cv.	Cultivar
DAT	Days After Transplanting
°C	Degree Celsius
et.al.	And others
Expt.	Experiment
g	Gram
ha	Hectare (10000 meter square)
Hort.	Horticulture
i.e.	That is
J.	Journal
kg	kilogram
LSD	Least Significance difference
ppm	parts per million
Res.	Research
Sci.	Science
t	Ton
Tk.	Taka
UK	United Kingdom
Viz.	Namely

CHAPTER I

INTRODUCTION

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INTRODUCTION

Brussels sprout (*Brassica oleracea* L. var. *gemmifera*) is a cool season vegetable crop that is grown for its green edible 'buds or sprouts' (small heads that resemble miniature cabbages). Locally in many countries it is known as 'Baby Cabbage'. The botanical family to which Brussels sprout belongs is the 'Brassicaceae' (formerly Cruciferae), also known as the 'Mustard family or cabbage family'. The "sprouts" are produced in the leaf axils, starting at the base of stem and working upward (Kumar *et al.,* 2014).

The Brussels sprouts is native to Belgium (hence the name "Brussels" sprouts). Like broccoli, it is ancestors first grew wild in Low Countries of Europe. It was believed to have been cultivated in Italy during Roman times and possibly in Belgium during 1200s. Later on it is introduced to the US during 1800s (Anon, 2012).

In terms of nutrition, Brussels sprout is as important as other Brassicaceae vegetables. It is rich in vitamins and minerals. It contains good amounts of vitamin A and C, folic acid and dietary fibre. Moreover, it contains sulforaphane, which has anticancer properties. Likewise, other Brassicas, Brussels sprout is also a good source of indole-3-carbinol, which boosts DNA repair in cells and appears to block growth of cancer cells (Kumar *et al.*, 2014).

It is quite relevant to add that the production of a crop is influenced by many factors such as quality of seed, proper management practices including time of planting, plant spacing, soil fertility management, intercultural operations etc. Planting time is an important factor for yield of crop. In Bangladesh, temperature remains fairly high up to mid-October, which gradually comes down to about 20°C on an average in mid-December. This cool period extends up to mid-February and the temperature rises sharply thereafter (Shapla, 2013). Brussels sprout is a cool season crop and thrives best in a cool humid climate. It grows best when exposed to an average daily temperature between 17 and 23°C. However, it gives maximum yield potential at temperature range of 15–18°C (Anon, 2013). Besides, it can be grown successfully on a wide range of soils, however, it performs best in well-drained loamy soil rich in organic matter (Kumar *et al.,* 2014). For this reason, the vegetable can be grown in our country.

Furthermore, fertilizer management is one of the important factors that contributes in the production and yield of any crops. Adequate supply of nutrients plays a significant role to increase the yield. In tropical to subtropical regions, the soils are seriously impoverished in plant nutrients due to intensive weathering and leaching. Besides, overuse of chemical fertilizers causes negative impact on crop cultivation (Solaiman *et. al.*, 2014). So, Maintenance of soil fertility through the use of nutrients is important, about 50% of the world's crop production being attributed to organic fertilizer use (Pradhan, 1992). Organic matter is known as 'storehouse of plant nutrients' and 'life force of a soil'. A good agricultural soil should have around 2.0% organic matter, but in Bangladesh most of the soils have less than 1.5% organic matter and some soils have even less than 1% organic matter (BARC, 2012). Nutrients are applied to the soil through organic and inorganic means. Indiscriminate use of inorganic fertilizer is believed to cause deterioration of soil texture and structure, and hinders microbial activity, pollutes ground water and finally decreases soil fertility and production. On the other hand, the use of organic manures improves soil texture, structure, humus, colour, aeration, water holding capacity and microbial activity of soil. All these, in return, increase production and reduce environmental pollution (Pare *et al*., 2000). Besides, organic fertilization important for providing plant with their nutritional requirements without having undesirable impact on the environment. Organically grown crops are believed to be healthier and contain more minerals and vitamins than that of the inorganically grown vegetables (Worthington, 2001).

Application of organic fertilizer increases the populations of micro-organisms in the soil that helps the soil to release various nutrients. These micro-organisms also produce plant growth regulators that are important for plant growth and photosynthetic activity (Levy and Taylor, 2003).

Brussels sprout is a new vegetable in Bangladesh. Therefore, our target was to work with this crop to add a new vegetable in our crop list as it is alike to other brassica crops along with their cultural practices. Besides, due to climatic changes, new crop should be added in the list and cultural managements to be practiced for better growing. If production of Brussels sprout can be started in Bangladesh, it will be available in local market for the consumers in our country as well as farmers can easily get economic benefit by local market production along with export in international market.

Considering the above facts and present situation, the main objectives of the current study were to:

1) Find out a suitable time of planting for the maximum growth and yield of Brussels sprouts under the weather condition of Bangladesh.
2) Evaluate the effect of different optimum kinds and rates of organic manures on growth and yield of Brussels sprouts.
3) To investigate the combined effect of planting times and organic nutrient sources on the growth and yield of Brussels sprouts.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The Brussels sprouts is grown in many countries including India, China, Netherlands, Germany, United Kingdoms, United States, Mexico, Canada, etc. But it is one of the vegetable species that have recently come to be recognized in our country. Besides, Consumer interest for organic fruits and vegetables are rising from last several consecutive decades. Growth and yield of Brussels sprouts have been studied in various parts of the world, but no study has been done yet before on this crop under the agro-ecological condition of Bangladesh. However, available related information on other brassica crops portioning to this study has been reviewed in the following headings according to year in a descending order.

2.1 Effect of planting time on the growth and yield of Brussels sprouts

Lina (2015) conducted an experiment at the Horticultural Research Farm, of Sher-e Bangla Agricultural University, Dhaka to study the effect of planting time (05 November, 20 November and 05 December) and gibberellic acid (0ppm, 75 ppm, 95 ppm and 115 ppm) on the growth and yield of cabbage. Due to different planting time, the highest thickness of head (13.3 cm) and the highest marketable yield (49.1 t/ha) was obtained from planting on 20 November and the lowest thickness of head (12.5 cm) and the lowest marketable yield (45.9 t/ha) was obtained from planting at 05 December. For GA_3, the highest thickness of head (14.2 cm) and the highest marketable yield (54.7 t/ha) was found from 95 ppm. For combined effect, the highest thickness of head (14.5 cm) and the highest marketable yield (59.4 t/ha) was found from planting at 20 November and gibberellic acid at 95 ppm.

Khatun *et al.* (2012) conducted an experiment at the Horticultural Research Farm, of Sher-e Bangla Agricultural University, Dhaka to study the effect of different transplanting dates (October 5, October 25, November 14 and December 4) on the growth and yield of broccoli. Different transplanting dates showed significant influence on the yield and yield contributing characters of broccoli. Weight of curd/plant (319.11g), curd yield/plot (7.83 kg) and curd yield/ha (13.04 ton) were decreased with delay in transplanting. The highest curd yield/ha was obtained from the 25th October transplanting while the lowest from the 4th December transplanting.

Kurtar (2006) conducted an experiment to determine the effect of planting times on some vegetable characters and yield components in Brussels sprouts. Planting dates were 18 July and 03 August. Total yield per plant was found 307.9 and 308.5 g plant^{-1} for first and second planting times, respectively. Thermal time needed from planting to bud initiation was 1100-1300°C day^{-1}, thermal time needed from bud initiation to harvest was 390-460°C day^{-1}. The time from planting to bud initiation and from bud initiation to harvest were measured 119 day and 67 day in First Planting Time (FPT) and 105 day and 74 day in Second Planting Time (SPT), respectively.

Natasa (2005) conducted an experiment in the Zeta plain, Municipality of Podgorica on the influence of planting dates on growth rate of and the yield Brussels sprouts. The planting dates were 10th of April, 10th of May, 10th of June, 10th of July. The growth rate of Brussels sprouts was analyzed through monitoring the height of the plant in the field, the height and mass of the stalk and the number and mass of leaves. The results show that planting at a later date accelerates the vegetative mass yield when compared to earlier planting dates, but it also stops earlier (taken from the number of days that passed from the planting date), which results in lower height of the plant, less leaves and hence lower yield. The yield ranged from 13.36 to 20.92 t/ha, where differences in yield when compared to planting dates. The highest yield was achieved in the first and the lowest in the last planting date.

Emam (2005) conducted consequently two field experiments to investigate the effect of two transplanting dates i.e., 22 August and 23 September and two within plant spacing 40, 60 cm for the second transplanting dates in 2000/2001 and 2001/2002 seasons, on vegetative growth, head quality and yield of broccoli (cv. Landmark) under the conditions of Kalyobeyia governorate. The results revealed that early planting increased plant height, number of leaves/plant and main stem diameter. On the contrary, the late transplanting on 23rd September increased head weight and diameter as well as total yield significantly.

Ahmed and Wajid (2004) carried out an experiment in Rawalakot, Pakistan to investigate the effect of sowing dates on growth and yield of broccoli cv. Green mountains. Seeds were sown in well prepared seedbeds on 20 April, 5 May, 20 May and June 2002. Seedlings were transplanted when 3-4 leaves were developed after 30 days. Sowing on 5 May produced more (18.48) and longer (47.31) leaves, taller (30.79 cm) plants, heads of greater diameter (14.97 cm) and weight (200.65 g), higher number of secondary heads (16.0) and yield per plant (15.50 kg) compared to other sowing dates. Sowing on 5 May is recommended for general cultivation of broccoli under temperate areas.

Singh (2001) conducted an experiment during the rabi seasons at Dhaulakuan, Himachal Pradesh, India to examine the plant height and head yield of broccoli planted at weekly intervals from 20 October to 22 December. The highest average values for plant height (41.75 cm) and head yield (99.05 q/ha) were recorded when the crop was transplanted on 27 October. Transplanting beyond 10 November significantly reduced both parameters.

Darnata *et al.* (2000) conducted an experiment in Italy on two cultivars of broccoli with three sowing dates (August 27, October 20 and November 6). They reported that sowing time markedly influenced the yield, yield components and time of harvest. They also observing that when sowing was delayed by 36 days, yield decreased by 36% in the first year and 66% in the second.

Sari *et al.* (2000) conducted an experiment at Turkey on two cultivars of broccoli with five different sowing dates (June 15, July 1 & 15 and August 2 & 16) during 1994 and 1995. They observed that in both the years, sowing dates significantly affected the total yield and the highest yield was obtained from the June 15 sowing (1065.11 g/plant). The main head weight and diameters for the early sowing dates were higher than the others.

Dellacecca *et al*. (1996) examined in Italy the effect of three planting dates (August 20, September 24 and October 25), four topping regimes (none, topping at planting, 15 or 30 days later) on four broccoli cultivars. They reported that topping at planting and particularly in August result in the best and earliest yield of inflorescence with a relatively high weight, good firmness and small stem diameter.

Babik and Rumpel (1994) conducted an experiment in Poland to evaluate the effect of three sowing times (1-beginning of April, 2-middle of April and 3-beginning of May) and three harvesting times (from the middle of October in one month intervals) on yield and quality of Brussels sprouts cultivars of various earliness. Earliest sowing as compared to the latest one increased the processing yield of mid-late cultivars up to 80 percent. A four or eight weeks delay in harvest time of mid-late cultivars did not increase the number of overgrown sprouts (with diameter above 30 mm), what in consequence would lead to decrease of processing yield. This positive effect of early sowing was not observed in yield of early cultivars, where delay in harvest time led to decrease of processing yield due to a greater number of overgrown sprouts. The results showed that in conditions of Poland mid-late cultivars produced high processing yield when sown for transplants in the beginning of April.

Moel (1992) conducted an experiment in the Netherlands to evaluate the effect of planting dates (May 30 and July 30) on broccoli cultivar Roxie. He reported that small head size (375 g) and high percentage of first class heads were obtained from the early planted trial. He suggested that it might be due to the association of high temperature during harvest. With the later planting, the average head weight was 572g. The harvest period was from 15 October to 5 November. The total yield amounting to 15t/ha of which 89% was graded as class 1.

Bracy and Contantin (1991) reported from Louisiana, USA that the transplanting date significantly affected the yield of broccoli. Three broccoli cultivars were planted on 11 different dates during the autumn and spring season of 1985-1987. The highest yields and head weights were obtained for transplanting during spring or early autumn. Transplanting during late October and November produced lower head weights. They also suggested that the best harvesting time of broccoli heads reached 3-4 inches in diameter (0.30 to 0.44 lb/head) and florets were mature but not open.

Begum *et al.* (1990) in their experiment observed significant variation in vegetative growth and head yield while transplanting of 30 days old broccoli seedling at an interval of 15 days from Septembers 14 to December 13. Planting during October 14 to November 13 resulted in increased vegetative growth and larger curd than earlier under the environmental condition of Bangladesh.

Sterrett *et al.* (1990) carried out an experiment to evaluate the potentiality of sprouting broccoli with thirteen cultivars at East Virginia, USA and reported that the yield of some broccoli cultivars exceeded the target from the first sowing date (August 10) but it was below the target for the other two sowing dates (August 19 to September 10).

Diputado and Nichols (1989) conducted a field experiment in New Zealand on four cultivars of broccoli with six different sowing dates (September 18, November 19, January 17, March 21, and July 21). The heat unit concept was applied to relate temperature differences over the different sowing dates with time to head initiation, time to head maturity and rate of head growth. The time to head initiation appeared to be dependent on a heat unit summation above a base temperature of 10°C while the rate of head growth was related best to a heat summation above 30°C. They reported that the head and total dry weight (DW) production varied with sowing dates and with cultivars.

Ahmed and Abdullah (1986) reported that the time of planting significantly influenced the head yield and other characters of broccoli. Among the five planting dates (September 15, October 1 & 15 and November 1 & 15) the earlier planting produced taller plants and took more number of days for flower bud initiation. The highest yield was obtained from the crop planted on October 15 followed by November 1, while September 15 planting produced the lowest yield.

Bravo *et al.* (1986) conducted an experiment to evaluate the performance of some Brussels sprouts (Brassica olerecea var. gemmifera) cultivars planted on different dates at two localities in the central area of Chile. In that experiment four cultivars namely Jade Cross F1, Isla and Emerald Ball transplanted in one locality on 15 February yielded 20.46, 14.89 and 17.09 t/ha, respectively, whereas the same hybrid and cultivars transplanted on 15 March yielded 11.41, 12.57 and 13.33 t/ha, respectively. One month delay in planting resulted in reduced yield for all the hybrid and cultivars. No commercial yields were obtained from plants transplanted on 15 April. The cultivars Valiant, Camelot, Merlon and Lunet transplanted on 25 January in another location yielded 11.8, 11.82, 12.85 and 11.84 t/ha, respectively. The same cultivars transplanted on 17 February yielded 11.49, 9.85, 12.16 and 11.69 t/ha and transplanted on 10 March yielded 4.06, 4.15, 3.54 and 4.13 t/ha, respectively.

The period from transplanting to harvest was shorter with the later planting dates. For all the cultivars and hybrids late planting reduced the yield significantly in the weather condition of Chile.

2.1 Effect of organic nutrient sources on the growth and yield of Brussels sprouts

Omar (2017) conducted an experiment during 2014-2015 at Bakrajo Agricultural Research Station, Bakrajo, Sulaimani, Iraq to investigate the effect of different organic manures (cow manure 10 and 20 t/ha, sheep10 and 20 t/ha and chicken 4 and 8 t/ha) on the yield and quality of two Brussels sprouts hybrid “Topline F1” and “Attwood F1”. The results showed that “Topline F1” increased plant height, leaf weight, leaf area, bud size, yield. plant^{-1}, yield/ha and Ascorbic acid. “Attwood F1” took shorter time to harvest days. The highest yield/plant, yield/ha and bud number obtained from cow manure 20 t/ha, highest plant height and bud fresh weight obtained from sheep manure 20 t/ha, while the highest leaf number, leaf weight, leaf area and bud size recorded for chicken manure 8 t/ha. NPK gave highest protein and nitrate content values. The highest ascorbic acid obtained from the control treatment. Shorter period to harvest was recorded for cow and sheep manure 20t/ha.

Akter (2014) conducted an experiment on at the Horticultural Research Farm, of Sher-e Bangla Agricultural University, Dhaka to study the effect of different levels of vermicompost (no manure, 3.6 t/ha, 7.2 t/ha and 10.8 t/ha) on the growth and yield of three different cabbage varieties (Atlas 70, Autumn Queen and Profit). In case of varieties, Autumn Queen gave the highest (39.17 t/ha) yield and the lowest (36.84 t/ha) from Atlas 70. For vermicompost levels, 10.8 t/ha gave the highest (64.78 t/ha) yield and lowest (14.79 t/ha) from no manure. For interaction effect, Autumn Queen variety with 10.8 t/ha gave the highest (71.80 t/ha) yield and lowest from Atlas 70 with no manure.

Islam (2013) conducted an experiment at the Horticultural Research Farm, of Sher-e Bangla Agricultural University, Dhaka to study the effect of different organic manure (No manure, Cowdung 25 t/ha and spent mushroom compost 17 t/ha) and mulching (No mulching, black polythene, water hyacinth and rice straw) on broccoli. The highest stem length of curd, crown length, diameter and weight of primary curd/plant, number and weight of secondary curds/plant and yield (16.99 t/ha) were obtained from Spent mushroom compost. In case of mulching, the highest stem length of curd, crown length, diameter and weight of primary curd/plant, number and weight of secondary curds/plant and yield (14.58 t/ha) were obtained from water hyacinth mulching. Their combined effect showed that the highest curd yield (18.28 t/ha) was obtained from 17 t/ha spent mushroom compost with water hyacinth mulch.

Pour *et al.* (2013) conducted an experiment to evaluate the possible effects of different concentrations of vermicompost on the growth and physiology of cabbage seedling (*Brassica oleracea* var. *capitata*). Vermicompost were used at five different levels (0, 10%, 20%, 40% and 80%). The seeds were planted in five different prepared soil mixtures with vermicompost and grouped in five different treatment groups including control (C), vermicompost of 10% (V10), vermicompost of 20% (V20), vermicompost of 40% (V40) and vermicompost of 80% (V80). The utilization of different levels of vermicompost had significantly enhancing effects on the Zn and auxin contents in leaf tissues. The results indicated that there were significantly positive correlations between the Zn and auxin contents. The applied vermicompost affected the leaf characteristics including the number of produced leaves, leaf area, fresh and dry mass. These findings indicated that the effects of vermicompost on plant growth and development not only were nutritional but also hormonal and biochemical and the utilization of high levels of vermicompost, especially at seedling stage, neither is not only economic but also may have adverse effects on the plant growth and development.

Shapla (2013) an experiment at the Horticultural Research Farm, of Sher-e Bangla Agricultural University, Dhaka to study the effect of different planting time (13 November, 23 November and 03 December) and organic manure (no manure application, cowdung at 15 t/ha, poultry manure at 12 t/ha and vermicompost at 13 t/ha) on broccoli. In planting time, the highest weight of primary curd per plant (427.8 g) and highest yield (10.6 t/ha) was recorded from 23 November and the lowest (404.2 g) and (9.91 t/ha) from 03 December. For organic manure, the highest weight of primary curd per plant (484.7 g) and highest yield (12.0 t/ha) was recorded from poultry manure at 12 t/ha and while the lowest (253.9 g) and (6.45 t/ha) from no manure. Therefore, the combined interaction showed that the highest weight of primary curd per plant (532.3 g) and highest yield (13.4 t/ha) was obtained from the planting time 23 November and poultry manure at 12 t/ha.

Theunissen *et al.*, (2010) reported vermicompost contains plant nutrients including N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B, the uptake of which has a positive effect on plant nutrition, photosynthesis, the chlorophyll content of the leaves and improves the nutrient content of the different plant components (roots, shoots and the fruits). The high percentage of humic acids in vermicompost contributes to plant health, as it promotes the synthesis of phenolic compounds such as anthocyanins and flavonoids which may improve the plant quality and act as a deterrent to pests and diseases.

Maurya *et al.* (2008) A field experiment was conducted in Pantnagar, Uttaranchal, India, during 2005-06 and 2006-07 to study the effects of the following treatments on broccoli (cv. Fiesta): recommended fertilizers (RF; 120:60:60 kg NPK/ha), farmyard manure (FYM) at 20 t/ha, FYM at 10 t/ha + 50% FR, neem cake at 5 quintal/ha, neem cake at 2.5 quintal/ha + 50% RF, vermicompost at 5 t/ha, vermicompost at 2.5 t/ha + 50% RF, poultry manure at 5 t/ha, and poultry manure at 2.5 t/ha + 50% RF. In 2005-06, poultry manure + 50% RF and FYM + 50% RF resulted in the greatest plant height. In 2006-07, poultry manure + 50% RF, vermicompost + 50% RF, RF and poultry manure gave the tallest plants. The number of fully opened leaves in both years was highest for poultry manure + 50% RF. Leaf length was greatest for poultry manure + 50% RF and vermicompost + 50% RF. The greatest leaf weight per plant was recorded for poultry manure + 50% RF, FYM + 50% RF and vermicompost + 50% RF in 2005-06, and for poultry manure + 50% RF, RF, FYM + 50% RF and vermicompost + 50% RF in 200607. Poultry manure + 50% RF, FYM + 50% RF and vermicompost + 50% RF registered the greatest head weight in 2005-06, whereas poultry manure + 50% RF was superior for this trait in 2006-07. The highest yields were obtained with poultry manure + 50% RF.

Peksen *et al.* (2008) conducted an investigation to study the effect of chemical composition of seedling media prepared by spent mushroom compost on seedling growth and development of kale and broccoli. Spent mushroom compost (SMC), which was kept for 18 months in open field, conventional seedling medium (CSM) consisting of a mixture of decomposed farmyard manure, sand and garden soil at a rate of 2:1:1, commercial peat (P), SMC+CSM (1:1, v/v) and SMC+P (1:1, v/v) were used. Seeds of broccoli (Brassica oleracea L. var. italica L. cv. Greenpeace F1) and kale (Brassica oleraceae L. var. acephale D.C. cv. Temel) were used. Some chemical and physical properties of different seedling media prepared by SMC were compared and their effects on days to emergence (DE), emergence percentage (EP), seedling height (SH), mean leaf area per seedling (LA) and total dry weight of seedling (DW) were determined. Correlation analyses were done to determine the relationships between chemical constituents of the seedling media and DE, EP, SH, LA and DW. The results exposed that SMC+P or SMC could be used as seedling media for both kale and broccoli.

Abou *et al.* (2006) conducted two successive field experiments at El-Kassasein, Ismailia Governorate, Egypt to study the response of vegetative growth and yield of some broccoli varieties to apply organic manures (Cattle and poultry manures) compared with mineral fertilization. The highest vegetative growth parameters (plant height, and leaf number) were recorded by plants which were supplied with 100% cattle manure. However, the highest total yield and quality of broccoli were recorded by adding poultry manure in the two seasons. Organic fertilizers improve soil structure, thereby allowing root development into deeper soil layers.

Ahlawat *et al.* (2006) conducted a field experiment to study the effects of spent mushroom substrate (SMS) recomposed by different methods and mixed with arable soil on the vegetative growth, yield and quality attributes of cauliflower (*Brassica oleracea* var. *botrytis*) were studied. Mixing of anaerobically recomposed SMS at 2.5 kg/m + chemical fertilizers (N, P and K at 12.5, 7.5 and 6.5 g/m^2, respectively) significantly enhanced vegetative growth during curd harvesting, gross and net yields, and quality attributes, and reduced the incidence of black rot disease and larval infestation. The mortality of plants during seedling transplanting was also lower under anaerobic SMS treatments. Thus, the use of anaerobically recomposed SMS with chemical fertilizers for cauliflower cultivation was found to be a better option of SMS disposal and raising high quality vegetable crops.

Chaudhary *et al*. (2003) conducted a field experiment in Orissa, India starting from 1999 to investigate the use of vermicompost in cabbage cv. S-22 and tomato cv. Golden Acre production. Vermicompost was prepared using Gliricidia leaves and *Eisenia fetida* and was applied at 100 and 200 g/plant with or without farmyard manure (FYM), at 250 and 500 g/plant. The treatment received VC at 200 g/plant + FYM at 250 g/plant was the best for obtaining sustainable yields in both crops.

Parthasarthi and Ranganathan (2002) reported that vermicomposting is a bio-oxidation and stabilization process of organic material that involves the joint action of earthworms and microorganisms. The earthworms are the agents which help for turning, fragmentation and aeration. It also raises N_2 fixation by both nodular and free living N_2 fixing bacteria and thus increase plant growth. Vermicompost has been proved as one of the cheapest source of nitrogen and other essential elements for better nodule formation and yield particularly in legumes. Such plants can meet their N needs through both biological nitrogen fixation (symbiosis) and native nitrogen in the soil.

Hochmuth *et al.* (1993) conducted an experiment to investigate the response of cabbage yields, head quality and leaf nutrient status to poultry manure fertilization. They reported that the marketable yield of cauliflower responded quadratically to increasing rates of poultry manure, with the maximum yield (24.4 t/ha) being obtained by 18.8 t/ha. The results showed that manuring efficiency was initially higher with commercial fertilizer than the poultry manure alone, since lower amounts of total nutrients were applied using commercial fertilizer.

Subhan (1988) carried out an experiment on cabbage cv. Gloria Osena and applied 15, 20, 25 or 30 t/ha of cattle manure, composted maize straw or composted rice straw. He observed that application of organic manure increased head diameter at 60 days after planting and the average number of leaves/plant and reduced the number of days to crop maturity. Application of 25 or 30 t cattle manure/ha gave the largest cabbage and the highest yield/plot.

Omori *et al.* (1972) reported that application of 10 t/acre of fresh cattle manure increased the yield of pimento, eggplant and Chinese cabbage but reduced the yield of cucumber and tomato compared with normal (rate unspecified) application. Fresh chicken manure at the rate of 5-10 t/acre could be used for pimento, eggplant and Chinese cabbage without deleterious effect.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter illustrates information concerning methodology that was used in the execution of the experiment. It comprises a short description of experimental site, climatic condition, materials used for the experiment, treatments, data collection, procedure, and statistical analysis.

3.1 Experimental site

The experiment was conducted at Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka during the period from October 2018-April 2019 to study the effect of different planting time and organic nutrient sources on the growth and yield of Brussels sprouts.

3.2 Geographical Location

The location of the experimental site is in 24.09°N latitude and 90.26°E longitudes. The altitude of the location was 8 m from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207 which has been showen in the Appendix I.

3.3 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 5.6 and 0.78%, respectively and the the soil composed of 27% sand, 43% silt, 30% clay. Details descriptions of the characteristics of soil are presented in Appendix III.

3.4 Climatic condition

Experimental site was located in the subtropical monsoon climatic zone, set aparted by heavy rainfall during the months from April to September (Kharif season) and scant of rainfall during the rest of the year (Rabi season). Plenty of sunshine and moderately low temperature prevails during October to March (Rabi season) which is generally preferred for vegetable cultivation. Details of the meteorological data during the period of the experiment was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka-1212 and presented in Appendix II.

3.5 Planting materials

The test crop used in the experiment was Brussels sprouts variety "Groninger". Seeds were collected from De Ree UK Ltd, Bolton, England. Before sowing in the seedbed a germination test was performed (Plate 1 a). Seeds were sown in a seed tray on 20 September 2018. Within 3 to 4 days after showing the emergence of the seedlings took place.

3.6 Treatments of the experiment

The two factorial experiment was conducted to evaluate the effect of different planting times and organic nutrient sources on growth and yield of Brussels sprouts. Factors are follows:

Factor A: Planting time (three levels) as

i. T_1: 05 November, 2018
ii. T_2: 20 November, 2018
iii. T_3: 05 December, 2018

Factor B: Organic nutrient sources (four levels) as

i. N_0: Control i.e. no manure
ii. N_1: Cowdung @ 15 t/ha
iii. N_2: Mushroom spent compost @ 7.5 t/ha
iv. N_3: Vermicompost @ 5 t/ha

[The rate of organic nutrient sources are based on the nitrogen percentage of the manures mentioned in Table-1]

There were 12 (3 × 4) treatments combination such as T_1N_0, T_1N_1, T_1N_2, T_1N_3, T_2N_0, T_2N_1, T_2N_2, T_2N_3, T_3N_0, T_3 N_1, T_3N_2 and T_3N_3.

3.7 Seedbed preparation and raising of seedlings

The seedlings of Brussels sprouts were raised at Horticulture Farm, of Sher-e-Bangla Agricultural University (SAU), Dhaka, under special care in one seed bed of 3 m × 1 m size. Soil of the seed bed was ploughed, prepared well and clods were broken into small pieces and converted into loose, friable to obtain good tilth. All weeds, stubbles and dead roots of the previous crops were removed carefully. Seedbeds were dried in the sun to prevent the damping of disease. Seed were sown in each seed bed on 5th October, 20th October and 5th November, 2018 to get seedlings of 30 days old at the time of transplanting. After sowing, the seeds were covered fine layer of soil followed by light watering by water can. Thereafter the beds were covered with dry straw to maintain required temperature and moisture. The cover of dry straw was removed immediately after emergence of seed sprout. Seeds were completely germinated within 5-6 days after sowing. Shading was given by polythene over the seedbed to protect the young seedlings from scorching sunlight and rainfall. No chemical fertilizers were applied for rising of seedlings. Weeding, mulching and irrigation were done from time to time to provide a favorable environment for good growth and raising quality seedlings.

3.8 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 135.85 m^2 with length 20.90 m and width 6.50 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 1.5 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 Figure 1.

3.9 Preparation of the main field

The selected plot of the experiment was opened in the 2nd week of October 2018 with a power tiller, and left exposed to the sun for a week. Subsequently cross ploughing was done five times with a country plough followed by laddering to make the land suitable for transplanting the seedlings. All weeds, stubbles and residues were eliminated from the field. Finally, a good tilth was achieved. The experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in Figure 1. The soil was treated with insecticides (cinocarb 3G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

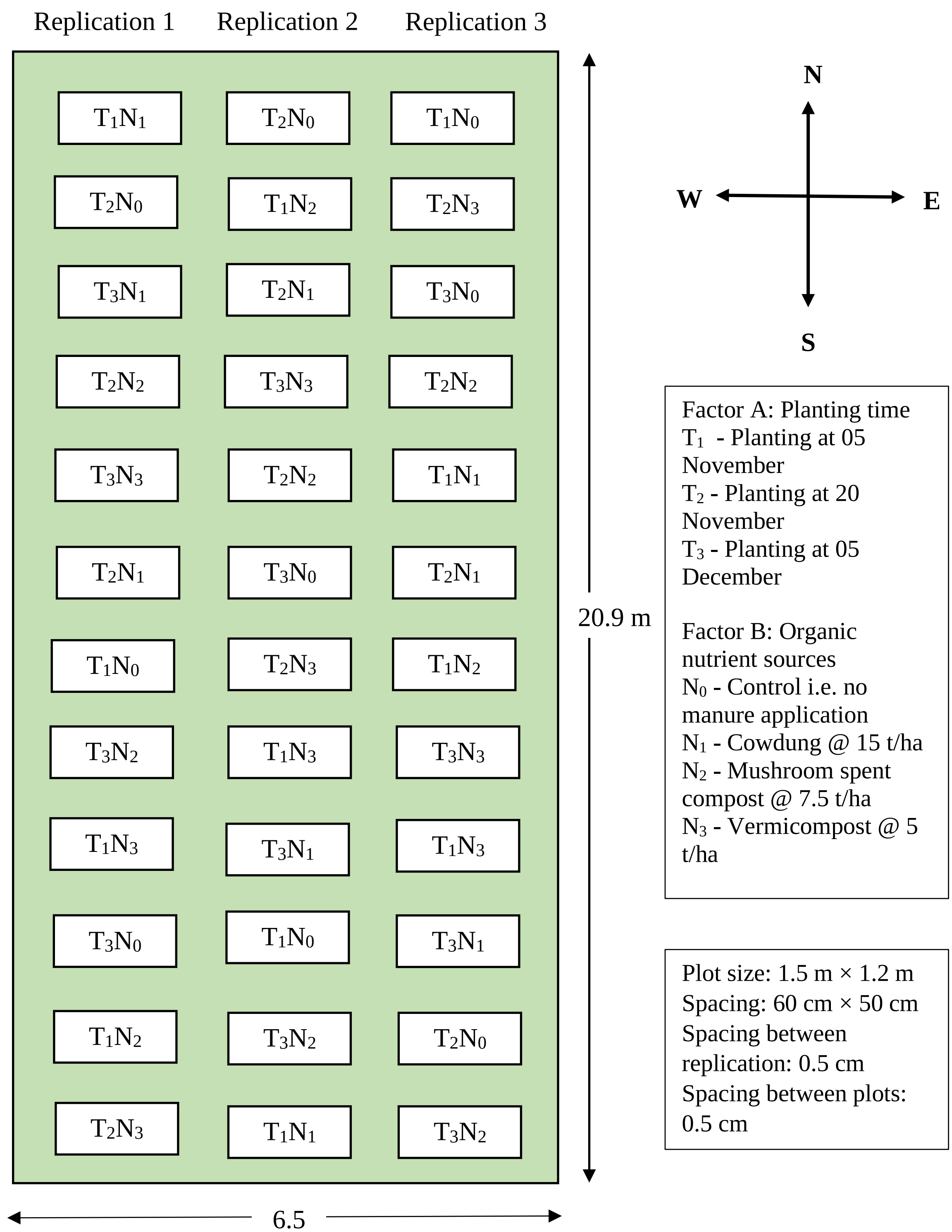


Fig 1. Layout of experiment

3.10 Application of manure

The entire amount of cowdung, vermicompost and spent mushroom compost (SMC) were applied as per treatment as a basal dose during final land preparation. No inorganic fertilizers were applied in the experimental field.

- Cowdung @ 2700 g/plot
- Mushroom spent compost @ 1350 g/plot
- Vermicompost @ 900 g/plot

3.11 Composition of nutrients

The composition of cowdung, mushroom spent compost and vermicompost is shown as tabular form in Table 1.

Table 1. Composition of cowdung, mushroom spent compost and vermicompost.

Manures	Nutrients (%)		
	N	P	K
Cowdung	0.62	0.49	0.60
Mushroom spent compost	1.28	0.65	1.4
Vermicompost	1.85	1.58	2.20

Source: Soil Resource Development Institute (SRDI), 2018

3.12 Transplanting of seedlings

Healthy and uniform seedlings of 30 days old seedlings were transplanting in the experimental plots on 05 November, 20 November and 05 December, 2018 as per treatment of planting time. The seedlings were uprooted carefully from the seed bed to avoid damage to the root system. To minimize the damage to the roots of seedlings, the seed beds were watered on hour before uprooting the seedlings. Transplanting was done in the afternoon. The seedlings were watered immediately after transplanting. Seedlings were sown in the plot with maintaining distance between row to row and plant to plant was 60 cm and 50 cm, respectively. The young transplants were shaded by banana leaf sheath during day time to protect them from scorching sunshine up to 7 days until they were set in the soil. They (transplants) were kept open at night to allow them receiving dew. A number of seedlings were also planted in the border in the experimental plots for gap filling.

3.13 Intercultural operations

After raising seedlings, various intercultural operations such as gap filling, weeding, earthing up, irrigation pest and disease control etc. were accomplished for better growth and development of the Brussels sprouts seedlings.

3.13.1 Gap filling

The transplanted seedlings in the experimental plot were kept under careful observation. Very few seedlings were damaged after transplanting and such seedling were replaced by new seedlings from the same stock. Planted earlier on the border of the experimental plots same as planting time treatment. Those seedlings were transplanted with a big mass of soil with roots to minimize transplanting stock. Replacement was done with healthy seedling having a boll of earth which was also planted on the same date by the side of the unit plot. The transplants were given shading and watering for 7 days for their proper establishment.

3.13.2 Weeding

Hand weeding was done after the establishment of the seedlings as and when necessary.

a

b

c

d

Plate 1. Pictorial presentation of germination test, treatment, seedbed and experimental field. (a) Germination test, (b) A pile of mushroom spent compost, (c) Seedlings in the seedbed, (d) Experimental field

3.13.3 Earthing up

Earthing up was done at 20 and 40 days after transplanting on both sides of rows by taking the soil from the space between the rows by a small spade.

3.13.4 Staking

When the plants were well established, staking was done to each plants using bamboo sticks with rope to keep the plants erect. As the plants grew up within a few days of staking, other cultural operations were carried out.

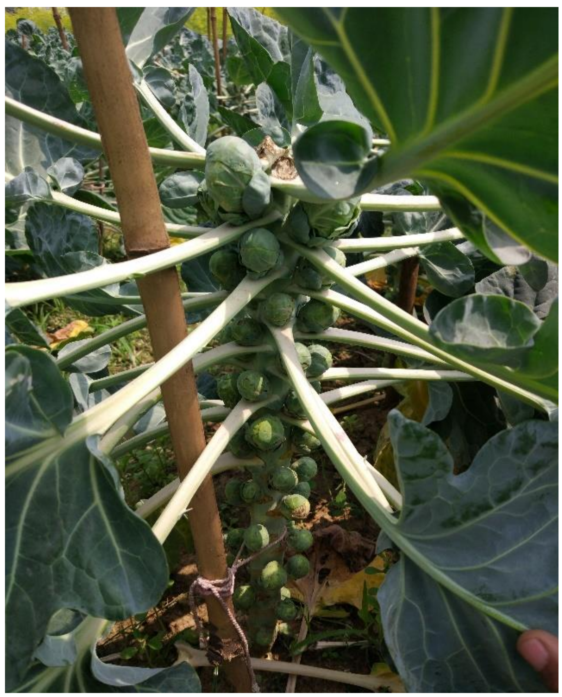
3.13.5 Irrigation

Light watering was given by a watering cane at every morning and afternoon. Following transplanting and it was continued for a week for rapid and well establishment of the transplanted seedlings.

3.13.6 Topping

Topping is done by removing the apical meristem to arrest apical dominance. As the sprouts of Brussels sprouts are axillary buds, removing the apical meristem causes the axillary buds to expand. Topping as an important operation followed in this crop. The fully grown plants are pinched-off from growing point (Kumar *et al*., 2014). In this experiment, all the plants of different planting time were topped at 90 DAT (Plate 2 b).

a **b**



c

Plate 2. Pictorial presentation of different methodological work (a) Initiation of bud, (b) A plant few days after topping (c) A topped plant with mature bud

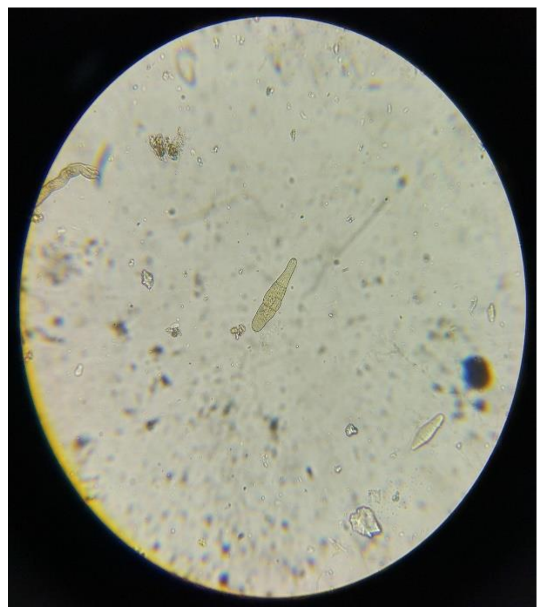
3.13.7 Pest and disease control

Pest and disease control is a very critical factor during the period of establishment of seeding in the field. In spite of Cirocarb 3G applications during final land preparation, few young plants were damaged due to the infestation of mole cricket and cut worm. It was controlled both mechanically and spraying Darsban 29 EC @ 3%. During the growth stage of the plants, alternaria leaf spot was identified from the experiment field. Infested leaf samples were collected and observed under the microscope in the plant pathology laboratory of Sher-e-Bangla Agricultural University. Both *Alternaria brassicae* and *Alternaria brassicicola* were identified under microscope (Plate 3 c & d respectively). The symptoms of the disease are yellow, dark brown to black circular leaf spots with target like, concentric rings. Individual spots coalesce into large necrotic areas and result in leaf drop. To control the disease no pesticides were applied, older leaves from the lower portions were trimmed which ensures better sun and clean cultivation. At the time of bud maturation diamond back caterpillar infestation was noticed. To control the infestation, Voliam Flexi 300 SC was applied @ 0.5ml/L.

3.14 Harvesting

Generally, the buds mature from the below part of the plant. But due to topping operation in the experiment, the bud started to mature from the upper part. Following the visual appraisal of ripeness, the buds were picked and the yield achieved was measured. Hand picking of the buds were done. Throughout the harvesting period around two or three picking were required for a single plant. Delayed picking can result in a deterioration of quality by discoloration of outer leaves, over large loose sprouts, outer leaves of the sprout parting from the buttons or appearance of internal browning.

a **b**



c **d**

Plate 3. Pictorial presentation of insect and disease found in the experimental field, (a) Diamondback caterpillar, (b) An infested leaf of Brussels sprouts by Alternaria leaf spot, (c) Microscopic view of *Alternaria brassicae* & (d) *Alternaria brassicicola*

3.15 Data collection

Four plants were randomly selected from each unit plot. Data were collected in respect of the following parameters to assess plant growth; yield attributes and yields as affected by different treatments of the experiment. Data on plant height, number of leaves were collected at 40, 55, 70 and 85 days after transplanting (DAT). All other yield contributing characters and yield parameters were recorded during harvest and after harvest.

3.15.1 Plant height

Plant height was measured from selected plants in centimeter from the ground level to the tip of the longest leaf and mean value was calculated. Plant height was also recorded at 15 days interval starting from 40 days after Transplanting (DAT) up to 85 days to observe the growth rate of plants.

3.15.2 Number of leaves per plant

Number of leaves was manually counted from selected plants and each leaf was counted from bottom to top up to fully opened leaves maintaining 15 days interval starting from 40 days after Transplanting (DAT) up to 85 days and their average was computed as average number of leaves per plant.

3.15.3 Days from transplanting to bud initiation

Each plant of the experiment plot was kept under close observation for recording the data on days from transplanting to first visible curd. Total number of days from the date of transplanting to the first visible curd was recorded

3.15.4 Length of stem

The length of stem was taken from the ground level to the top of plant during harvesting. A meter scale used to measure the length of stem and was expressed centimeter (cm).

3.15.5 Diameter of stem

The diameter of the stem was measured at the base of the stem. It was recorded by slide calipers and expressed in centimeter (cm).

3.15.6 Length of root

The length of root was considered from the base of the tip of the root. It was measured in centimeter (cm) with a meter scale after harvesting.

3.15.7 Leaf area

Leaf area was measured from leaf length and leaf breadth. Mature leaves from 20 cm above the ground level were used for this purpose and expressed in cm^2. Then the mean was calculated.

3.15.8 Fresh weight of leaves per plant

The fresh weight of leaves per plant was recorded from the average of selected plants in gram (g) with a beam balance at harvest.

3.15.9 Dry matter content of leaf

At first 100 gm leaves of selected plant was collected, cut into pieces and was dried under sunshine for a few days and then dried in an oven at 70°C for 72 hours before taking dry weight till it was constant. The dry weight was recorded in gram (g) with a beam balance.

3.15.10 Fresh weight of stem per plant

The fresh weight of stem was recorded after removing the leaves and root from the average of selected plants in gram (g) with a beam balance.

3.15.11 Dry matter content of stem

100 gm stem of selected plant was collected, cut into pieces and was dried under sunshine for a few days and then dried in an oven at 70°C for 72 hours before taking dry weight till it was constant. The dry weight was recorded in gram (g) with a beam balance.

3.15.12 Dry matter content of bud

Sample of 100 g bud was taken, cut into pieces and was dried under direct sunshine for 3 days and then was dried in an oven at 70°C for 72 hours before taking the dry weight till it was constant. The dry weight was recorded in gram (g) with a beam balance.

3.15.13 Length and diameter of marketable bud

Bud length and diameter were measured by using slide calipers and expressed in centimeter (cm), then the average was computed.

3.15.14 Weight of a single marketable bud

Total bud weight of each selected plant was measured with a beam balance and the weight was divided by the total no of buds. The bud weight was expressed in gram (g).

3.15.15 Number of marketable buds per plant

Number of buds from selected plants were counted and then the average was computed and expressed as the average number of buds per plant. Buds that were loose, open or less than 2cm in diameter were not counted as marketable bud.

3.15.16 Marketable yield/plant

Yield per plant was calculated in gram (g) by a balance from the total weight of fruits per selected plants which was harvested at different periods and was recorded.

3.15.17 Marketable yield/ha

The marketable yield per hectare was measured by converting marketable yield per plot into yield per hectare and was expressed in ton.

3.16 Statistical analysis

The data obtained for different characters were statistically analyzed by using Statistix 10 computer package programme to find out the significance of the difference for planting time and organic manure on yield and yield contributing characters of Brussels sprouts. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. Difference between treatments was assessed by Least Significant Difference (LSD) test at 0.05% level of significance (Gomez and Gomez, 1984).

3.17 Economic analysis

The cost of production was analyzed in order to find out the most economic combination different level of planting time and organic nutrient sources. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @ 14% in simple rate. As Brussels sprouts are not available in our market, the market price were fixed in comparison to India's market price. Analyses were done according to the procedure of Alam *et al.* (1989). The benefit cost ratio (BCR) was calculated as follows:

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

A **b**

c

Plate 4. Pictorial presentation of marketable and unmarketable buds (a) Loose & open unmarketable buds (b) Marketable buds after harvest (c) Different sizes of buds

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to observe the effect of planting time and organic manure on growth and yield of Brussels sprouts under the soil and agro climatic condition of Sher-e-Bangla Agricultural University (SAU), Dhaka. Data on different growth and yield parameter were recorded. The analyses of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix IV-X. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Plant height

Different levels of planting time showed significant variation on the plant height of Brussels sprouts at 40, 55, 70 and 85 days after transplanting (Fig. 2). At 40, 55, 70 and 85 DAT the tallest plant (41.40, 47.75, 54.40 and 59.90 cm, respectively) was recorded from T_1 (planting at 05 November). The shortest plant (39.81 and 45.75 cm) at 40 and 55 DAT was found from T_3 (planting at 05 December) which was statistically similar to (39.92 and 45.79 cm respectively) T_2 (20 November). But at 70 and 85 DAT the shortest plant (51.71 and 57.88 cm) was recorded from T_2 (planting at 20 November) whereas at 70DAT the shortest plant height was statistically similar to (52.58 cm) T_3 (planting at 05 December). Data revealed that different transplanting time produced different height of plant and the tallest plant was found from early date of planting. Ahmed and Abdullah (1986) reported that the earlier planting produced taller plants in broccoli.

Different organic manure showed significant differences on plant height of Brussels sprouts at 40, 55, 70 and 85 DAT (Fig. 3). At 40 DAT the tallest plant (42.17cm) was found from N_3 (vermicompost @ 5 t/ha) which was statistically identical (42 cm) to N_2 (mushroom spent compost @ 7.5 t/ha). At 55 DAT the tallest plant (49.17 cm) was recorded from N_2 (mushroom spent compost @ 7.5 t/ha) which was statistically identical to (49.03 cm) N_3 (vermicompost @ 5 t/ha). At 70 and 85 DAT the tallest plant (46.50 and 63.39 cm) was found from N_3 (vermicompost @ 5 t/ha) which was statistically identical (55.61 and 62.58 cm) to N_2 (mushroom spent compost @ 7.5 t/ha). And the shortest plant (36.14, 40.47, 46.08 and 51 cm) at 40, 55, 70 and 85 DAT was recorded from N_0 (control i.e. no manure). Study referred that application of lower amount of vermicompost than the other treatment can increase the plant height. Brown, 1995; Arancon *et al*., 2004 also found taller plant from vermicompost treatment. They reported that microbes like fungi, bacteria, yeasts, actinomycetes, algae etc. are capable of producing auxins, gibberellins etc. in appreciable quantity during vermicomposting which affects plant growth appreciably.

Combined effect of different planting time and organic manure showed significant differences on plant height of Brussels sprouts at 40, 55, 70 and 85 DAT (Table 2). At 40 DAT the tallest plant (43.17 cm) was recorded from T_1N_3 and the shortest plant (35.42 cm) was found in T_3N_0 which was statistically identical to T_2N_0 (35.67 cm) and T_1N_0 (37.33 cm). At 55 DAT the tallest plant (50.67 cm) was found in T_1N_2 and the shortest plant (39.50 cm) was recorded from T_3N_0. At 70 DAT the tallest plant (57.17 cm) was found in T_1N_2 which was statistically identical with T_1N_3 (56.83 cm), T_3N_3 (56.75 cm), T_1N_1 (56.08 cm) and T_2N_3 (55.92 cm). The shortest plant at 70 DAT was found in T_2N_0 (45.25 cm) which was statistically identical with T_3N_0 (45.50 cm) and T_1N_0 (47.50 cm). At 85 DAT the tallest plant was recorded for T_3N_3 (63.83 cm) which was statistically identical with T_1N_3 (63.75 cm) and the shortest plant was found in T_2N_0 (50.58 cm) which was statistically identical to T_1N_0 (51.17 cm) and T_3N_0 (51.25 cm).

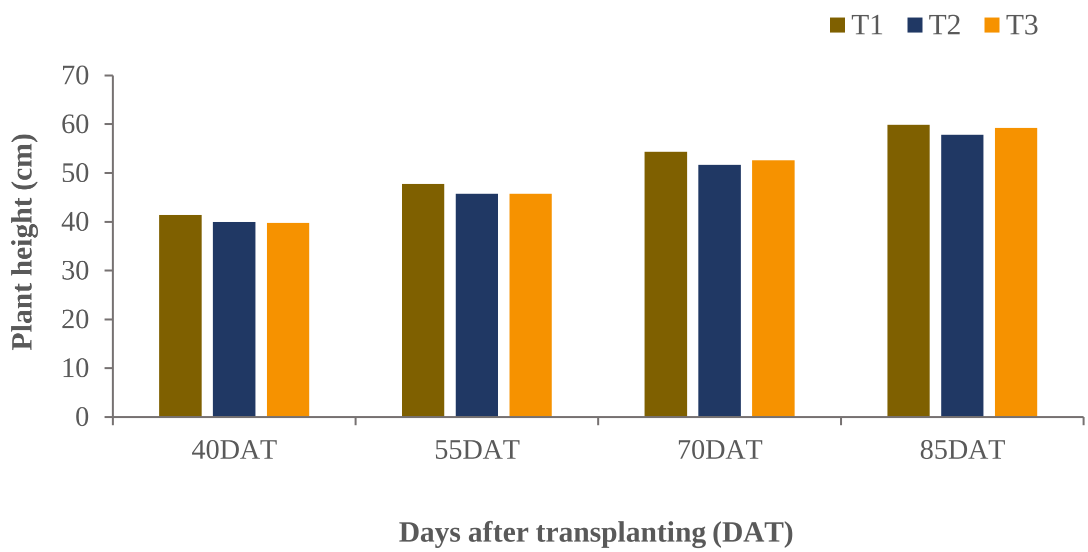


Fig. 2. Effect of planting time on plant height at different days after transplanting of Brussels sprouts; i.e. T_1: Planting at 5 November, T_2: Planting 20 November, T_3: Planting 5 December.

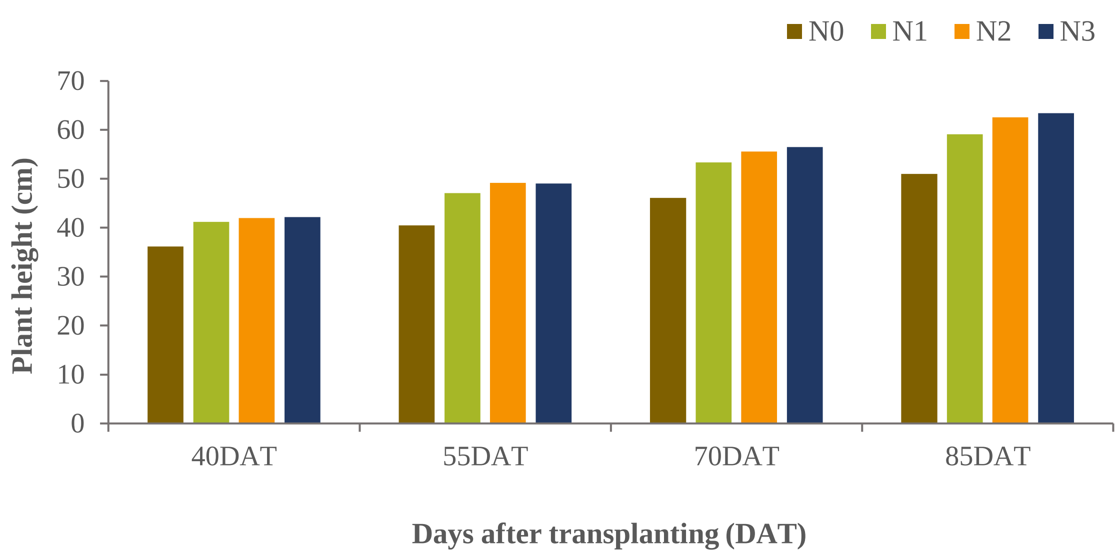


Fig. 3. Effect of different organic nutrient sources on plant height at different days after transplanting of Brussels sprouts; i.e. N_0: Control (no manure application), N_1: Cowdung @ 15 t/ha, N_2: Mushroom spent compost @ 7.5 t/ha, N_3: Vermicompost @ 5 t/ha.

Table 2. Combined effect of planting time and organic nutrient sources on plant height at different days after transplanting (DAT) of Brussels sprouts.

Treatments	Plant height (cm)			
	40 DAT	55 DAT	70 DAT	85 DAT
T_1N_0	37.33 c	42.00 d	47.50 d	51.17 e
T_1N_1	42.08 ab	49.08 ab	56.08 a	61.08 bc
T_1N_2	43.00 ab	50.67 a	57.17 a	63.58 ab
T_1N_3	43.17 a	49.25 ab	56.83 a	63.75 a
T_2N_0	35.67 c	39.92 de	45.25 d	50.58 e
T_2N_1	40.33 b	45.17 c	50.92 c	56.67 d
T_2N_2	41.92 ab	49.08 ab	54.75 ab	61.67 abc
T_2N_3	41.75 ab	49.00 ab	55.92 a	62.58 ab
T_3N_0	35.42 c	39.50 e	45.50 d	51.25 e
T_3N_1	41.17 ab	46.92 bc	53.17 bc	59.50 c
T_3N_2	41.08 ab	47.75 b	54.92 ab	62.50 ab
T_3N_3	41.58 ab	48.83 ab	56.75 a	63.83 a
$LSD_{(0.05)}$	2.74	2.42	2.60	2.60
CV (%)	4.00	3.08	2.90	2.61

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

Here,

T_1: Planting 5 November

T_2: Planting 20 November

T_3: Planting 5 December

N_0: Control (no manure application)

N_1: Cowdung @ 15 t/ha

N_2: Mushroom spent compost @ 7.5 t/ha

N_3: Vermicompost @ 5 t/ha

4.2 Number of leaves per plant

The leaves formed by the plant of Brussels sprouts are important since, in addition to an assimilation area, they are also a place for possible forming of sprouts (Natasa, 2005). Number of leaves per plant of Brussels sprouts at 40, 55, 70 and 85 DAT (Days after transplanting) showed statistically significant differences due to different transplanting time (Fig. 4). At 40, 55, 70 and 85 DAT the highest number of leaves/plant (14.21, 24.92, 31.46 and 36.88, respectively) was recorded from T_1 (planting at 05 November) whereas the lowest number of leaves per plant (13.75, 23.08, 28.92 and 34.31, respectively) was found from T_3 (planting at 05 December) which was statistically identical (14.04, 23.17, 29.08 and 34.90, respectively) to T_2 (planting at 20 November). Khan *et al*. (2015) observed that sowing dates significantly influenced various growth characteristics of cabbage. Singh *et al*. (2015) recorded the highest number of leaves per plant from early planted plants. Emam (2005) also observed that early planting increased number of leaves/plant of broccoli.

Leaves are important vegetative organ, as it assists plant in photosynthesis, transpiration and respiration process. Different nutrients have appreciated effect on the number of leaves per plant at different DAT. Higher leaf number indicates wholesome growth and development. In terms of different organic nutrient sources, number of leaves per plant of Brussels sprouts at 40, 55, 70 and 85 DAT showed statistically significant differences (Fig. 5). At 40, 55, 70 and 85 DAT the highest number of leaves per plant (15.08, 25.61, 32.64 and 38.67, respectively) was found for N_3 (vermicompost @ 5 t/ha). In case of 70 DAT highest leaf number per plant from N_3 (vermicompost @ 5 t/ha) treatment was statistically different from all other treatments but at 40, 55 and 85 DAT it was statistically identical (14.69, 25.39, 37.50) to N_2 (mushroom spent compost @ 7.5 t/ha). The lowest number of leaves per plant (11.94, 19.94, 25.33 and 30.31) was found at 40, 55, 70 and 85 DAT for

N_0 (control i.e. no manure). Due to available nutrient in vermicompost, plants grown with this treatment produce higher number of leaves. Result was supported by Jahan *et al.* (2014) who mentioned that application of vermicompost performed the best response on leaf number of cauliflower.

Combined effect of different planting time and organic nutrient sources showed significant variation on number of leaves per plant of Brussels sprouts at 40, 55, 70 and 85 DAT (Table 3). At 40, 55 and 70 DAT highest number of leaves per plant (15.08, 26.58, and 33.75) was recorded from T_1N_3 combination it was statistically identical to (14.92, 26.67 and 33.67 cm) T_1N_2. At 85 DAT both T_1N_3 and T_1N_2 showed the highest number of leaves per plant (39.58). At 40, 55 and 70 DAT the lowest number of leaves per plant (11.67, 18.75 and 25.25) was found from T_2N_0. At 85 DAT the lowest number of leaves per plant (29.25) was found from T_3N_0 which was statistically identical with T_2N_0 (30.50).

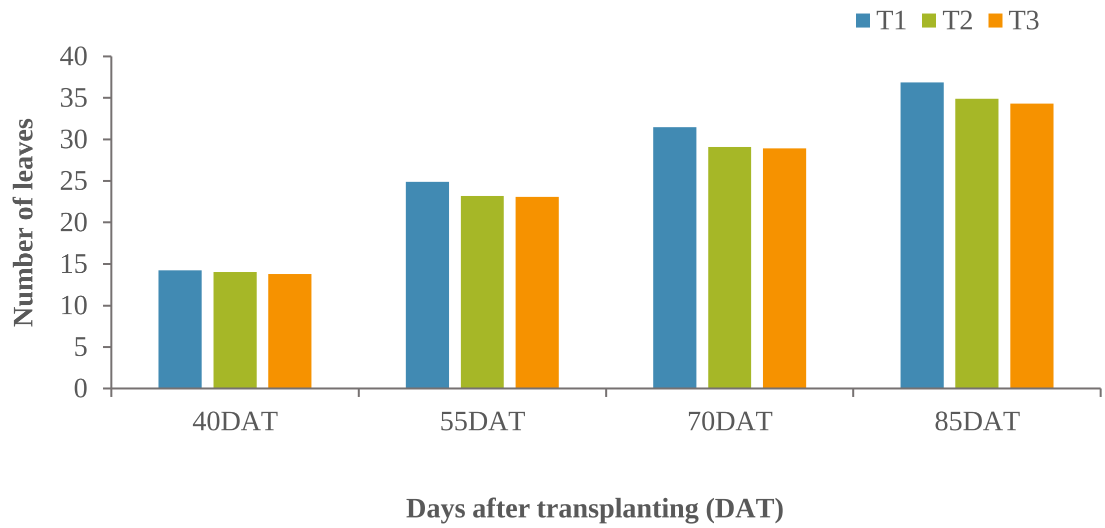


Fig. 4. Effect of planting time on number of leaves per plant of Brussels sprouts at different days after transplanting; i.e. T_1: Planting 5 November, T_2: Planting 20 November, T_3: Planting 5 December.

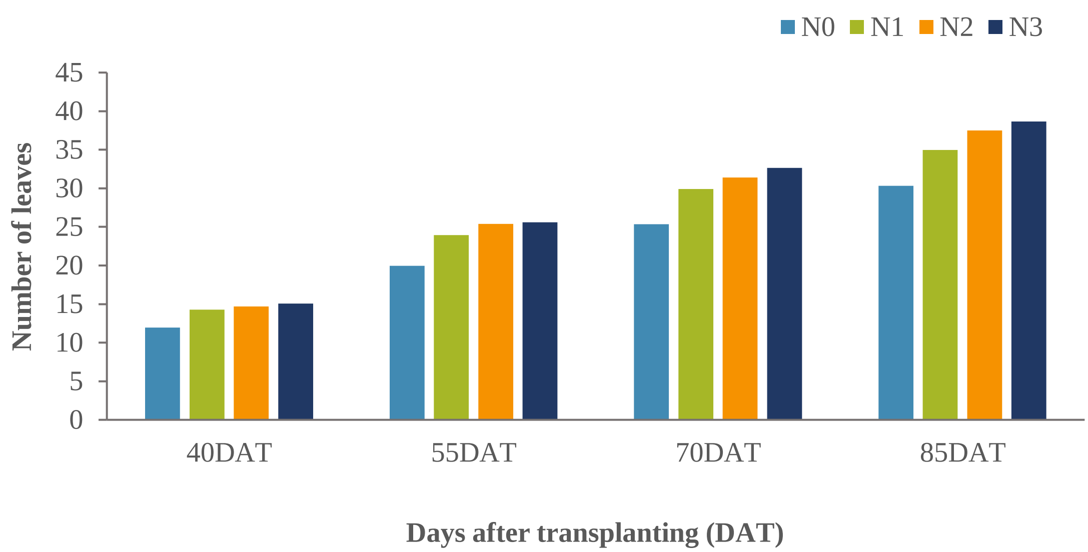


Fig. 5. Effect of different organic nutrient sources on number of leaves per plant of Brussels sprouts at different days after transplanting; i.e. N_0: Control (no manure application), N_1: Cowdung @ 15 t/ha, N_2: mushroom spent compost @ 7.5 t/ha, N_3: Vermicompost @ 5 t/ha.

Table 3. Combined effect of planting time and organic nutrient sources on number of leaves per plant at different days after transplanting (DAT) of Brussels sprouts.

Treatments	No. leaves			
	40 DAT	**55 DAT**	**70 DAT**	**85 DAT**
T_1N_0	12.17 c	21.00 e	26.25 e	31.17 ef
T_1N_1	14.67 ab	25.42 ab	32.17 ab	37.17 ab
T_1N_2	14.92 a	26.67 a	33.67 a	39.58 a
T_1N_3	15.08 a	26.58 a	33.75 a	39.58 a
T_2N_0	11.67 c	18.75 f	25.25 e	30.50 f
T_2N_1	14.42 ab	23.33 cd	28.58 d	34.25 cd
T_2N_2	14.83 a	25.17 a-c	30.58 b-d	36.67 bc
T_2N_3	15.25 a	25.42 ab	31.92 a-c	38.17 ab
T_3N_0	12.00 c	20.08 ef	24.50 e	29.25 f
T_3N_1	13.75 b	23.08 d	29.00 d	33.50 de
T_3N_2	14.33 ab	24.33 b-d	29.92 cd	36.25 bc
T_3N_3	14.92 a	24.83 a-d	32.25 ab	38.25 ab
$LSD_{(0.05)}$	1.05	1.84	2.05	2.68
CV (%)	4.42	4.58	4.05	4.48

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

Here,

T_1: Planting 5 November

T_2: Planting 20 November

T_3: Planting 5 December

N_0: Control (no manure application)

N_1: Cowdung @ 15 t/ha

N_2: Mushroom spent compost @ 7.5 t/ha

N_3: Vermicompost @ 5 t/ha

4.3 Days from transplanting to bud initiation

Different levels of planting time showed significant variation on the days from transplanting to bud initiation of Brussels sprouts (Fig. 6). Longest period was required for bud initiation (70.69 days) in T_3 (planting at 05 December) whereas the shortest period (67.20 days) was in T_1 (planting at 05 November). Lina (2015) also reported that with delayed planting bud initiation is delayed.

Significant variation was recorded for days to bud formation of Brussels sprouts due to different organic nutrient sources (Fig. 7). The minimum period (68.3 days) required for bud initiation was showed by N_1 (cowdung @ 15 t/ha), it was statistically identical to (68.63 days) N_3 (vermicompost @ 5 t/ha) and (68.89 days) N_2 (mushroom spent compost @ 7.5 t/ha). The maximum time (70.48 days) required for bud initiation was for N_0 (control i.e. no manure). Therefore, the bud initiation was earlier than that of the control treatment. These findings are in agreement with the observation of Subhan (1988) who reported that application of manure reduced the number of days for cabbage head formation as well as maturity.

Combined effect of planting time and different organic nutrient sources showed significant differences for days to bud initiation of Brussels sprouts (Table 6). The lowest period (66.45 days) required for bud initiation was for T_1N_1 which was statistically identical to T_1N_2 (66.67 days) and T_1N_3 (66.78 days). The highest period (72 days) required for bud initiation was recorded from T_3N_0.

4.4 Length of stem

The stalk height of Brussels sprouts has a direct effect on number of leaves formed and hence the number of sprouts and yield (Natasa, 2005). Length of stem varied significantly for different planting time of Brussels sprouts (Table 4). The highest length of stem (37.90 cm) was recorded from T_1 (planting at 05 November) while the lowest (35.77 cm) was recorded from T_2 (planting at 20 November). Emam (2005) also observed the highest length of stem from early planting in broccoli.

Different organic nutrient sources showed significant variation on the stem length of Brussels sprouts (Table 5). The highest length of stem (41.56 cm) was found from N_3 (vermicompost @ 5 t/ha) which was statistically similar to (40.61 cm) N_2 (mushroom spent compost @ 7.5 t/ha). The lowest length of stem (28.31 cm) was recorded from N_0 (control i.e. no manure). Akter (2014) also reported highest length of stem from vermicompost treated treatment over the control in cabbage.

Significant influence was found on stem length due to the combined effect of planting time and organic nutrient sources (Table 6). Result showed that the highest length of stem (42.42 cm) was obtained from T_3N_3 which was statistically identical to (42.17cm) T_1N_3, (41.08 cm) T_1N_2 and (40.50 cm) T_3N_2. The lowest length of stem (27.83 cm) was obtained from T_2N_0 which was statistically identical to (27.83 cm) T_2N_0.

4.5 Diameter of stem

Planting time showed significant variation on stem diameter of Brussels sprouts (Table 4). Highest diameter of stem (2.67 cm) was recorded T_3 (planting at 05 December) which was statistically identical to (2.65 cm) T_1 (planting at 05 November) whereas the lowest diameter of stem (2.53 cm) was recorded from T_2 (planting at 20 November).

Effect of different organic nutrient sources showed significant variation on the stem diameter of Brussels sprouts (Table 5). The highest diameter of stem (2.71 cm) was recorded from N_3 (vermicompost @ 5 t/ha) which was statistically identical to (2.65 cm) N_2 (mushroom spent compost @ 7.5 t/ha) and the lowest diameter of stem (2.51 cm) was recorded from N_0 (control i.e. no manure).

Combined effect of planting time and organic nutrient sources was significant on the stem diameter of Brussels sprouts (Table 6). The highest stem diameter (2.77 cm) was found from T_3N_3 and the lowest stem diameter (2.45 cm) was found from T_2N_0.

4.6 Length of root

Length of root was not significantly influenced by planting time (Table 4). But the highest length of root (31.63 cm) was found from T_3 (planting at 05 December) and the lowest length of root (29.90 cm) was found from T_1 (planting at 05 November). The trend of the present results was agreed to that of Khatun *et al.* (2012).

Different organic nutrient sources showed significant variation on the length of root of Brussels sprouts (Table 5). The highest root length (33.94 cm) was recorded from N_1 (Cowdung @ 15 t/ha) which was statistically similar to (31.61 cm) N_2 (mushroom spent compost @ 7.5 t/ha) and (31.06 cm) N_3 (vermicompost @ 5 t/ha). The lowest root length (27.42 cm) was recorded from N_0 (control i.e. no manure). Trevisan *et al.* (2010) reported that humic substances in organic matter enhance root growth and elongation due to the production of auxin or auxin-like components. Moreover, it was demonstrated that organic matter has a positive effect on soil physical properties by increasing soil porosity that is favourable to root growth and function (Passioura, 2002). Probably for this reason root length is reduced in the treatment where no manure was applied.

Combined effect of planting time and organic nutrient sources showed statistically significant inequality among the root length of Brussels sprouts (Table 6). The highest root length (36.42 cm) was recorded for T_3N_1 and the lowest root length (26.58 cm) was recorded for T_1N_0.

Table 4. Effect of planting time on days to bud initiation, length of stem, diameter of stem and length of root of Brussels sprouts.

Treatments	Days to bud initiation	Length of stem (cm)	Diameter of stem (cm)	Length of root (cm)
T_1	67.20 c	37.90 a	2.65 a	29.90 a
T_2	69.33 b	35.77 b	2.53 b	31.50 a
T_3	70.69 a	36.98 ab	2.67 a	31.63 a
$LSD_{(0.05)}$	0.77	1.67	0.12	2.81
CV (%)	1.32	5.34	5.25	10.71

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

Here, T_1: Planting at 5 November, T_2: Planting at 20 November, T_3: Planting at 5 December

Table 5. Effect of different organic nutrient sources on days to bud initiation, length of stem, diameter of stem and length of root of Brussels sprouts.

Treatments	Days to bud initiation	Length of stem (cm)	Diameter of stem (cm)	Length of root (cm)
N_0	70.48 a	28.31 c	2.51 b	27.42 b
N_1	68.30 b	37.06 b	2.61 ab	33.94 a
N_2	68.89 b	40.61 a	2.65 a	31.61 a
N_3	68.63 b	41.56 a	2.71 a	31.06 a
$LSD_{(0.05)}$	0.89	1.93	0.13	3.25
CV (%)	1.32	5.34	5.25	10.71

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

Here, N_0: Control (no manure application), N_1: Cowdung @ 15 t/ha, N_2: Mushroom spent compost @ 7.5 t/ha, N_3: Vermicompost @ 5 t/ha.

Table 6. Combined effect of planting time and organic nutrient sources on days to bud initiation, length of stem, diameter of stem and length of root of Brussels sprouts.

Treatments	Days to bud initiation	Length of stem (cm)	Diameter of stem (cm)	Length of root (cm)
T_1N_0	68.89 cd	29.08 d	2.52 b-d	26.58 d
T_1N_1	66.45 e	39.25 ab	2.67 a-d	32.17 a-d
T_1N_2	66.67 e	41.08 a	2.68 a-c	30.67 b-d
T_1N_3	66.78 e	42.17 a	2.73 a-c	30.17 b-d
T_2N_0	70.56 ab	27.83 d	2.45 d	28.00 b-d
T_2N_1	68.67 d	34.92 c	2.53 b-d	33.25 a-c
T_2N_2	69.33 b-d	40.25 ab	2.52 cd	33.33 ab
T_2N_3	68.78 d	40.08 ab	2.62 a-d	31.42 a-d
T_3N_0	72.00 a	28.00 d	2.55 a-d	27.67 cd
T_3N_1	69.78 b-d	37.00 bc	2.62 a-d	36.42 a
T_3N_2	70.67 ab	40.50 a	2.75 a-d	30.83 a-d
T_3N_3	70.33 bc	42.42 a	2.77 a	31.58 a-d
$LSD_{(0.05)}$	1.54	3.33	0.23	5.62
CV (%)	1.32	5.34	5.25	10.71

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

Here,

T_1: Planting 5 November

T_2: Planting 20 November

T_3: Planting 5 December

N_0: Control (no manure application)

N_1: Cowdung @ 15 t/ha

N_2: Mushroom spent compost @ 7.5 t/ha

N_3: Vermicompost @ 5 t/ha

4.7 Leaf area

Different planting time did not show significant variation on the leaf area of Brussels sprouts (Table 7). But the maximum leaf area (650.71cm^2) was found from T_1 (planting at 05 November) and the minimum leaf area (638.99 cm^2) was found from T_3 (planting at 05 December).

Significant variation was recorded for leaf area of Brussels sprouts due to different organic nutrient sources (Table 8). The maximum leaf area (704.35 cm^2) was recorded N_3 (vermicompost @ 5 t/ha) and the minimum leaf area (573.76 cm^2) was recorded from N_0 (control i.e. no manure). Azarmi *et al*. (2008) reported that application of vermicompost at rate of 15, 10 and 5 t/ha increase leaf area about 43, 35 and 18%, respectively in comparison to control.

Combined effect of planting time and organic nutrient sources showed significant inequality among the leaf area of Brussels sprouts (Table 9). The maximum leaf area (730.58 cm^2) was found from T_3N_3 and the minimum leaf area (567.67 cm^2) was recorded from T_2N_0 which was statistically identical to (569.42 cm^2) T_3N_0 and (584.21 cm^2) T_1N_0.

4.8 Fresh weight of leaves per plant

In some countries leaves of the top rosette after topping operation and leaves from the stalk are consumed due to their high nutritive value. As the use of leaves in human consumption is not common, they can be used as forage, together with the stalk (Natasa, 2005). Different planting time showed significant variation on the fresh weight of leaves per plant of Brussels sprouts (Table 7). The highest fresh weight of leaves (530.65 g) was recorded from T_1 (planting at 05 November) and the lowest fresh weight of leaves (446.37 g) was recorded from T_3 (planting at 05 December). Emam (2005) and Shapla (2013) reported similar findings in broccoli.

Significant variation was recorded for the fresh weight of leaves of Brussels sprouts due to different organic nutrient sources (Table 8). The highest fresh weight of leaves per plant (657.41 g) was recorded from N_3 (vermicompost @ 5 t/ha) and the lowest fresh weight of leaves (312.88 g) was recorded from N_0 (control i.e. no manure). Abd *et al*. (2019) reported vermicompost has positive effect on the fresh weight of leaves in lettuce.

Combined effect of planting time and organic nutrient sources showed significant influence on the fresh weight of leaves per plant of Brussels sprouts (Table 9). The highest fresh weight of leaves per plant (721.5 g) was recorded from T_1N_3 and the lowest fresh weight of leaf (292.65 g) was recorded from T_3N_0.

4.9 Dry matter content of leaf

Significant variation was recorded for dry matter content of leaf of Brussels sprouts due to different planting time (Table 7). The highest dry matter content of leaf (17.50 %) was recorded from T_1 (planting at 05 November) and the lowest dry matter content of leaf (14.94 %) was recorded from T_3 (planting at 05 December). Shapla (2013) reported that dry weight of leaf is reduced with delayed planting in broccoli.

Dry matter content of leaf of Brussels sprouts showed statistically significant inequality among different organic nutrient sources (Table 8). The highest dry matter content of leaf (17.03 %) was recorded from N_3 (vermicompost @ 5 t/ha) which was statistically similar to (16.38 %) N_2 (mushroom spent compost @ 7.5 t/ha) and (16.23 %) N_1 (cowdung @ 15 t/ha) and the lowest dry matter content of leaf (14.86 %) was recorded from N_0 (control i.e. no manure). Abd *et al*. (2019) reported higher dry weight of leaf with increasing dose of vermicompost over the control.

Table 7. Effect of planting time on leaf area, fresh weight of leaf/plant and dry matter content of leaf of Brussels sprouts.

Treatments	Leaf area (cm^2)	Fresh weight of leaves /plant (g)	Dry matter content of leaf (%)
T_1	650.71 a	530.65 a	17.50 a
T_2	647.78 a	479.49 ab	15.93 b
T_3	638.99 a	446.37 b	14.94 c
$LSD_{(0.05)}$	39.63	60.56	0.76
CV (%)	7.25	14.73	5.58

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

Here, T_1: Planting at 5 November, T_2: Planting at 20 November, T_3: Planting at 5 December

Table 8. Effect of different organic nutrient sources on leaf area, fresh weight of leaf/plant and dry matter content of leaf of Brussels sprouts.

Treatments	Leaf area (cm^2)	Fresh weight of leaf/plant (g)	Dry matter content of leaf (%)
N_0	573.76 c	312.88 c	14.86 b
N_1	641.31 b	454.98 b	16.23 a
N_2	663.89 ab	516.74 b	16.38 a
N_3	704.35 a	657.41 a	17.03 a
$LSD_{(0.05)}$	45.76	69.93	0.88
CV (%)	7.25	14.73	5.58

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

Here, N_0: Control (no manure application), N_1: Cowdung @ 15 t/ha, N_2: mushroom spent compost @ 7.5 t/ha, N_3: Vermicompost @ 5 t/ha.

Table 9. Combined effect of planting time and organic nutrient sources leaf area, fresh weight of leaf/plant and dry matter content of leaf of Brussels sprouts.

Treatments	Leaf area (cm^2)	Fresh weight of leaves /plant (g)	Dry matter content of leaf (%)
T_1N_0	584.21 d	299.68 gh	15.54 c-e
T_1N_1	672.63 a-c	517.98 c-e	17.53 ab
T_1N_2	665.48 a-c	583.42 c	17.92 ab
T_1N_3	680.54 a-c	721.5 a	18.99 a
T_2N_0	567.67 d	346.32 f-h	14.83 de
T_2N_1	635.5 b-d	431.16 d-f	16.40 bc
T_2N_2	686.02 a-c	596.55 bc	15.93 cd
T_2N_3	701.92 ab	543.93 cd	16.57 bc
T_3N_0	569.42 d	292.65 h	14.20 e
T_3N_1	615.79 cd	415.79 e-g	14.75 de
T_3N_2	640.17 b-d	370.25 f-h	15.28 c-e
T_3N_3	730.58 a	706.79 ab	15.53 c-e
$LSD_{(0.05)}$	79.26	121.11	1.52
CV (%)	7.25	14.73	5.58

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

Here,

T_1: Planting 5 November

T_2: Planting 20 November

T_3: Planting 5 December

N_0: Control (no manure application)

N_1: Cowdung @ 15 t/ha

N_2: Mushroom spent compost @ 7.5 t/ha

N_3: Vermicompost @ 5 t/ha

Combined effect of planting time and organic nutrient sources showed significant variation on the dry matter content of leaf of Brussels sprouts (Table 9). The highest dry matter content of leaf (18.99 %) was recorded from T_1N_3 and the lowest dry matter content of leaf (14.20 %) was recorded from T_3N_0.

4.10 Fresh weight of stem per plant

Different planting time did not show any significant variation on the fresh weight of stem per plant of Brussels sprouts (Table 10). But result showed that the highest fresh weight of stem per plant (209.87 g) was found from T_1 (planting at 05 November) and the lowest fresh weight of stem per plant (planting at 193.75 g) was obtained from T_2 (20 November).

Fresh weight of stem per plant of Brussels sprouts showed significant variation for different organic nutrient sources (Table 11). The highest fresh weight of stem per plant (219.22 g) was found from N_3 (vermicompost @ 5 t/ha) which was statistically identical (213.50 g) to N_2 (mushroom spent compost @ 7.5 t/ha) and the lowest fresh weight of stem per plant (184.00 g) was found from N_0 (control i.e. no manure).

Combined effect of planting time and organic nutrient sources showed significant variation on the fresh weight of stem per plant of Brussels sprouts (Table 12). The highest fresh weight of stem per plant (239.67 g) was obtained from T_3N_3 and the lowest fresh weight of stem per plant (169.67 g) was found from T_2N_0.

4.11 Dry matter content of stem

Dry matter content of stem was not significantly affected by different planting time (Table 10). But the highest dry matter content of stem (23.68%) was recorded from

T_3 (planting at 05 December) and the lowest dry matter content of (22.32%) was recorded from T_2 (planting at 20 November).

Different organic nutrient sources showed significant effect on the dry matter content of stem (Table 11). The highest dry matter content of stem (24.39%) was found from N_3 (vermicompost @ 5 t/ha) which was statistically identical to (23.50%) N_1 (cowdung @ 15 t/ha) and the lowest dry matter content of stem (21.08%) was found from N_0 (control i.e. no manure). Azarmi *et al*. (2008) reported that shoot dry weight increased significantly with raising vermicompost rate.

Combined effect of planting time and organic nutrient sources showed significant variation on the dry matter content of stem of Brussels sprouts (Table 12). The highest dry matter content of stem (25.49%) was found from T_3N_3 and the lowest dry matter content of stem (19.57%) was found from T_2N_0.

4.12 Dry matter content of bud

Dry matter content of bud was significantly affected by different planting time (Table 10). The highest dry matter content of bud (12.73%) was recorded from T_3 (planting at 05 December) and the lowest dry matter content of bud (11.82%) was recorded from T_2 (planting at 20 November). Diputado and Nichols (1989) reported that the head dry weight production varied with sowing dates in broccoli.

Different organic nutrient sources showed significant variation on the dry matter content of bud (Table 11). The highest dry matter content of bud (12.80%) was recorded from N_1 (cowdung @ 15 t/ha) which was statistically similar to (12.77%) N_3 (vermicompost @ 5 t/ha) and (12.17%) N_2 (mushroom spent compost @ 7.5 t/ha). The lowest dry matter content of bud (11.19%) was recorded from N_0 (control i.e. no manure).

Table 10. Effect of planting time on fresh weight of stem/plant, dry matter content of stem and dry matter content of bud of Brussels sprouts.

Treatments	Fresh weight of stem per plant (g)	Dry matter content of stem (%)	Dry matter content of bud (%)
T_1	209.87 a	22.65 a	12.16 ab
T_2	193.75 a	22.32 a	11.82 b
T_3	209.63 a	23.68 a	12.73 a
$LSD_{(0.05)}$	21.07	1.96	0.75
CV (%)	12.18	10.12	7.28

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

Here, T_1: Planting at 5 November, T_2: Planting at 20 November, T_3: Planting at 5 December

Table 11. Effect of different organic nutrient sources on fresh weight of stem/plant, dry matter content of stem and dry matter content of bud of Brussels sprouts.

Treatments	Fresh weight of stem per plant (g)	Dry matter content of stem (%)	Dry matter content of bud (%)
N_0	184.00 b	21.08 b	11.19 b
N_1	200.94 ab	23.50 a	12.80 a
N_2	213.50 a	22.57 ab	12.17 a
N_3	219.22 a	24.39 a	12.77 a
$LSD_{(0.05)}$	24.33	2.26	0.87
CV (%)	12.18	10.12	7.28

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

Here, N_0: Control (no manure application), N_1: Cowdung @ 15 t/ha, N_2: mushroom spent compost @ 7.5 t/ha, N_3: Vermicompost @ 5 t/ha.

Table 12. Combined effect of planting time and organic nutrient sources on fresh weight of stem/plant, dry matter content of stem and dry matter content of bud of Brussels sprouts.

Treatments	Fresh weight of stem per plant (g)	Dry matter content of stem (%)	Dry matter content of bud (%)
T_1N_0	189.00 bc	20.66 bc	10.64 d
T_1N_1	220.50 ab	24.13 ab	12.86 ab
T_1N_2	223.67 ab	22.73 a-c	11.97 b-d
T_1N_3	206.33 a-c	23.06 a-c	13.16 ab
T_2N_0	169.67 c	19.57 c	11.15 cd
T_2N_1	192.50 bc	22.79 a-c	11.89 b-d
T_2N_2	201.17 a-c	22.32 a-c	12.01 b-d
T_2N_3	211.67 a-c	24.60 a	12.21 a-c
T_3N_0	193.33 bc	22.99 a-c	11.79 b-d
T_3N_1	189.83 bc	23.58 ab	13.66 a
T_3N_2	215.67 ab	22.66 a-c	12.54 a-c
T_3N_3	239.67 a	25.49 a	12.95 ab
$LSD_{(0.05)}$	42.15	3.92	1.51
CV (%)	12.18	10.12	7.28

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

Here,

T_1: Planting 5 November

T_2: Planting 20 November

T_3: Planting 5 December

N_0: Control (no manure application)

N_1: Cowdung @ 15 t/ha

N_2: Mushroom spent compost @ 7.5 t/ha

N_3: Vermicompost @ 5 t/ha

Combined effect of planting time and organic nutrient sources showed significant variation on the dry matter content of bud (Table 12). The highest dry matter content of bud (13.66%) was recorded from T_3N_1 and the lowest dry matter content of bud (10.64%) was recorded from T_1N_0.

4.13 Length of marketable bud

Bud length of Brussels sprouts showed statistically significant inequality among different planting time (Table 13). The maximum length of marketable bud (4.42 cm) was recorded from T_1 (planting at 05 November) while the minimum length of marketable bud (3.80 cm) was recorded from T_3 (planting at 05 December). Bravo *et al*. (1986), Kurter (2006) and Natasa (2006) also observed significant variation for bud length of Brussels sprouts due to different planting time.

Significant variation was recorded for different organic nutrient sources in terms of bud length of Brussels sprouts (Table 14). The maximum length of marketable bud (4.41 cm) was recorded from N_3 (vermicompost @ 5 t/ha) and the minimum length of marketable bud (3.74 cm) was recorded from N_0 (control i.e. no manure). Vermicompost contains most nutrients in plant available form such as nitrate, phosphate, exchangeable calcium and soluble potassium (Orozco *et al*. 1996). Probably for this reason bud length is increased in vermicompost treated treatment. Omar (2017) reported significant variation on bud size of Brussels sprouts due to different organic manure.

Combined effect of planting time and organic nutrient sources showed significant variation on the length of marketable bud of Brussels sprouts (Table 15). The maximum bud length (4.85 cm) was found from T_1N_3 and the minimum bud length (3.41 cm) was found from T_3N_0.

4.14 Diameter of marketable bud

Diameter of marketable bud showed statistically significant inequality among different planting time of Brussels sprouts (Table 13). The maximum diameter of marketable bud (2.50 cm) was recorded from T_1 (planting at 05 November) and the minimum marketable diameter of bud (2.40 cm) was recorded from T_3 (planting at 05 December). Lina (2015) and Sari *et al.* (2000) reported significant variation in head and curd diameter of cabbage and broccoli respectively due to different planting time.

Significant variation was recorded for different organic nutrient sources in terms of diameter of marketable bud of Brussels sprouts (Table 14). The maximum diameter of marketable bud (2.52 cm) was found from N_3 (vermicompost @ 5 t/ha) which was statistically similar to (2.50 cm) N_2 (mushroom spent compost @ 7.5 t/ha) and (2.45 cm) N_1 (cowdung). The minimum diameter of marketable bud (2.33 cm) was found from N_0 (control i.e. no manure). Akter (2014) reported that diameter of head increased significantly with the raising rate of vermicompost in cabbage.

Combined effect of planting time and organic nutrient sources exposed significant variation on the diameter of marketable bud of Brussels sprouts (Table 15). The maximum diameter of marketable bud (2.63 cm) was found from T_1N_2 and the minimum marketable diameter of bud (2.30 cm) was found from T_3N_0.

4.15 Weight of single marketable bud

Weight of single marketable bud of Brussels sprouts showed statistically significant inequality among different planting time (Table 13). The maximum weight of single marketable bud (11.78 g) was found from T_1 (planting at 05 November) and the minimum weight of single marketable bud (9.97 g) was found from T_3 (planting at 05 December). Kurter (2006) also observed significant variation in the weight of single marketable bud of Brussels sprouts due to different planting time. Shapla (2013) reported that curd weight is reduced in broccoli due to late planting.

Significant variation was recorded for different organic nutrient sources in terms of weight of single marketable bud of Brussels sprouts (Table 14). The maximum weight of single marketable bud (11.60 g) was found from N_3 (vermicompost @ 5 t/ha) which was statistically identical to (11.37 g) N_2 (mushroom spent compost @ 7.5 t/ha). The minimum weight of single marketable bud (9.82 g) was found from N_0 (control i.e. no manure). Islam (2013) reported higher weight of curd from the spent mushroom compost treated treatment over the control and cowdung treated treatment in case of broccoli. Vermicompost has larger populations of bacteria, fungi and actinomycetes compared with conventional composts also outstanding physico-chemical and biological properties (Nair *et al*., 1997) which may contribute to the growth and yield and resulted in higher weight of bud.

Combined effect of planting time and organic nutrient sources exposed significant influence on the weight of single marketable bud of Brussels sprouts (Table 15). The maximum weight of single marketable bud (12.79 g) was recorded from T_1N_2 which was statistically similar to (12.71 g) T_1N_3. The minimum weight of single marketable bud (9.24 g) was found from T_3N_0.

Table 13. Effect of planting time on length of marketable bud, diameter of marketable bud and weight of single marketable bud of Brussels sprouts.

Treatments	Length of marketable bud (cm)	Diameter of marketable bud (cm)	Weight of single marketable bud (g)
T_1	4.42 a	2.50 a	11.78 a
T_2	4.09 b	2.45 ab	10.85 b
T_3	3.80 c	2.40 b	9.97 c
$LSD_{(0.05)}$	0.20	0.10	0.44
CV (%)	5.90	4.69	4.81

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

Here, T_1: Planting at 5 November, T_2: Planting at 20 November, T_3: Planting at 5 December

Table 14. Effect of different organic nutrient sources on length of marketable bud, diameter of marketable bud and weight of single marketable bud of Brussels sprouts.

Treatments	Length of marketable bud (cm)	Diameter of marketable bud (cm)	Weight of single marketable bud (g)
N_0	3.74 c	2.33 b	9.82 c
N_1	4.03 b	2.45 a	10.68 b
N_2	4.22 ab	2.50 a	11.37 a
N_3	4.41 a	2.52 a	11.60 a
$LSD_{(0.05)}$	0.24	0.11	0.51
CV (%)	5.90	4.69	4.81

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

Here, N_0: Control (no manure application), N_1: Cowdung @ 15 t/ha, N_2: Mushroom spent compost @ 7.5 t/ha, N_3: Vermicompost @ 5 t/ha.

Table 15. Combined effect of planting time and organic nutrient sources on length of marketable bud, diameter of marketable bud and weight of single marketable bud of Brussels sprouts.

Treatments	Length of marketable bud (cm)	Diameter of marketable bud (cm)	Weight of single marketable bud (g)
T_1N_0	4.01 cd	2.35 cd	10.36 d
T_1N_1	4.24 bc	2.44 a-d	11.26 bc
T_1N_2	4.57 ab	2.63 a	12.79 a
T_1N_3	4.85 a	2.58 ab	12.71 a
T_2N_0	3.80 de	2.33 cd	9.85 de
T_2N_1	4.08 cd	2.46 a-d	10.64 cd
T_2N_2	4.21 bc	2.48 a-d	11.29 bc
T_2N_3	4.26 bc	2.51 a-c	11.60 b
T_3N_0	3.41 e	2.30 d	9.24 e
T_3N_1	3.78 de	2.44 a-d	10.12 de
T_3N_2	3.87 cd	2.39 a-d	10.03 de
T_3N_3	4.12 cd	2.48 a-d	10.48 cd
$LSD_{(0.05)}$	0.41	0.19	0.89
CV (%)	5.90	4.69	4.81

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

Here,

T_1: Planting 5 November

T_2: Planting 20 November

T_3: Planting 5 December

N_0: Control (no manure application)

N_1: Cowdung @ 15 t/ha

N_2: Mushroom spent compost @ 7.5 t/ha

N_3: Vermicompost @ 5 t/ha

4.16 Number of marketable buds per plant

Number of marketable buds per plant of Brussels sprouts showed statistically significant inequality among different planting time (Table 16). The maximum number of marketable buds per plant (21.89) was recorded from T_1 (planting at 05 November) and the minimum number of marketable buds per plant (17.22) was recorded from T_3 (planting at 05 December). From the result it is manifested that the number of marketable buds per plant gradually decreased with delayed planting that is T_3 treatment (planting at 05 December). In the T_3 (planting at 05 December) treatment the bud maturation time was between March to April when the mean average maximum and minimum temperature were increased (Appendix I). This probably resulted in loose, open, reduced bud size and weight and ultimately the lower number of marketable buds per plant. Kurter (2006) also reported significant effect of planting time on the number of marketable bud per plant of Brussels sprouts.

Different organic nutrient sources showed significant inequality among the number of marketable buds per plant of Brussels sprouts (Table 17). The maximum number of marketable buds per plant (22.59) was recorded from N_3 (vermicompost @ 5 t/ha) and the minimum number of marketable buds per plant (14.30) was recorded from N_0 (control i.e. no manure). These results might be attributed to that manures provide a source of all necessary macro and micro nutrients in available forms, thereby improving the physical, chemical and biological properties of the soil (Abou *et al*. 2006).

Combined effect of planting time and organic nutrient sources exposed significant variation on the number of marketable buds per plant of Brussels sprouts (Table 18). But the maximum number of marketable buds per plant (25.78) was recorded from

T_1N_3 and the minimum number of marketable buds per plant (13.22) was recorded from T_3N_0.

4.17 Marketable yield per plant

Different planting times showed significant effect on the marketable yield per plant of Brussels sprouts (Table 16). The maximum marketable yield per plant (261.15 g) was recorded from T_1 (planting at 05 November) and on the contrary minimum marketable yield per plant (172.82 g) was recorded from T_3 (planting at 05 December). Khatun *et al*. (2012) found different transplanting dates showed significant influence on the yield and yield contributing characters of broccoli. They observed that weight of curd per plant (319.11 g), were decreased with delay in transplanting.

Marketable yield per plant of Brussels sprouts showed statistically significant inequality among different organic nutrient sources (Table 17). The maximum marketable yield per plant (264.49 g) was recorded from N_3 (vermicompost @ 5 t/ha) and the minimum marketable yield per plant (140.77 g) was recorded from N_0 (control i.e. no manure). Islam (2013) reported higher yield per plant in broccoli from spent mushroom compost treated treatment over the control and cowdung treated treatment. Akter (2014) reported that with raising the vermicompost application rate the yield per plant of cabbage increased positively.

Significant variation was recorded for combined effect of planting time and organic nutrient sources in terms of marketable yield per plant of Brussels sprouts (Table 18). The maximum marketable yield per plant (327.54 g) was recorded from T_1N_3 which was statistically identical to (301.08 g) T_1N_2 and the minimum marketable yield per (122.23 g) was recorded from T_3N_0.

4.18 Marketable yield per hectare

Different planting time showed significant effect on the marketable yield per hectare of Brussels sprouts (Table 16). Maximum marketable yield per hectare (8.70 t) was recorded from T_1 (planting at 05 November) and the minimum marketable yield per hectare (5.76 t) was recorded from T_3 (planting at 05 December). Kryuchkov and Suddenko (1991) reported that late sowing reduced the head development and yield in cabbage. Hasan *et al.* (2003) revealed that cabbage cultivation is more profitable in pre-rabi period and least profitable (actually negative profitable) in the late-rabi period.

Marketable yield per hectare of Brussels sprouts showed statistically significant inequality among different organic nutrient sources (Table 17). Maximum marketable yield per hectare (8.82 t) was recorded from N_3 (vermicompost @ 5 t/ha) and the minimum marketable yield per hectare (4.69 t) was recorded from N_0 (control i.e. no manure). Vermicompost contributes in soil fertility and quality by rising microbial activity and microbial biomass levels and also prohibits annihilation of soil borne pests and diseases (Durak *et al*., 2017). Orozco *et al*., 1996 reported that vermicompost significantly ameliorate plants growth when applied even in small amounts and it is a sustainable source of some nutrients such as N, P, K and Fe and the nutrients in vermicompost are easily absorbed by plants.

Significant variation was recorded for combined effect of planting time and organic nutrient sources in terms of marketable yield per hectare of Brussels sprouts (Table 18). Maximum marketable yield per hectare (10.92 t) was recorded from T_1N_3 which was statistically similar to (10.04 t) T_1N_2 and the minimum marketable yield per hectare (4.07 t) was recorded from T_3N_0.

Table 16. Effect of planting time on number marketable of bud, marketable yield per plant and marketable yield per hectare of Brussels sprouts.

Treatments	No. of marketable buds/plant	Marketable yield/plant (g)	Marketable yield/ha (t)
T_1	21.89 a	261.15 a	8.70 a
T_2	19.11 b	209.45 b	6.98 b
T_3	17.22 c	172.82 c	5.76 c
$LSD_{(0.05)}$	0.90	13.35	0.45
CV (%)	5.50	7.35	7.35

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

Here, T_1: Planting at 5 November, T_2: Planting at 20 November, T_3: Planting at 5 December

Table 17. Effect of different organic nutrient sources on number marketable of bud, marketable yield per plant and marketable yield per hectare of Brussels sprouts.

Treatments	No. of marketable buds/plant	Marketable yield/plant (g)	Marketable yield/ha (t)
N_0	14.30 d	140.77 d	4.69 d
N_1	19.78 c	211.86 c	7.06 c
N_2	20.96 b	240.78 b	8.03 b
N_3	22.59 a	264.49 a	8.82 a
$LSD_{(0.05)}$	1.04	15.42	0.52
CV (%)	5.50	7.35	7.35

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

Here, N_0: Control (no manure application), N_1: Cowdung @ 15 t/ha, N_2: Mushroom spent compost @ 7.5 t/ha, N_3: Vermicompost @ 5 t/ha.

Table 18. Combined effect of planting time and organic nutrient sources on number marketable of bud, marketable yield per plant and marketable yield per hectare of Brussels sprouts.

Treatments	No. of bud	Marketable yield/plant (g)	Marketable yield/ha (t)
T_1N_0	15.55 f	161.10 ef	5.37 ef
T_1N_1	22.67 b	254.86 bc	8.5 bc
T_1N_2	23.56 b	301.08 a	10.04 a
T_1N_3	25.78 a	327.54 a	10.92 a
T_2N_0	14.11 fg	138.97 fg	4.63 fg
T_2N_1	19.00 de	201.91 d	6.73 d
T_2N_2	20.78 cd	235.02 c	7.83 c
T_2N_3	22.56 bc	261.92 b	8.73 b
T_3N_0	13.22 g	122.23 g	4.07 g
T_3N_1	17.67 e	178.82 de	5.96 de
T_3N_2	18.56 e	186.23 de	6.21 de
T_3N_3	19.44 de	204.00 d	6.8 d
$LSD_{(0.05)}$	1.81	26.70	0.89
CV (%)	5.50	7.35	7.35

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

Here,

T_1: Planting 5 November

T_2: Planting 20 November

T_3: Planting 5 December

N_0: Control (no manure application)

N_1: Cowdung @ 15 t/ha

N_2: Mushroom spent compost @ 7.5 t/ha

N_3: Vermicompost @ 5 t/ha

4.19 Performance on economic return

4.19.1 Cost of production

Due to effect of different treatment combinations showed major differences in terms of cost of production of Brussels sprouts (Appendix XI and Table 19). The highest cost of production of Brussels sprouts (231,600 Tk/ha) was obtained from T_1N_3, T_2N_3 and T_3N_3. The lowest cost of production of Brussels sprouts (148,350 Tk/ha) was obtained from T_1N_0, T_2N_0 and T_3N_0.

4.19.2 Gross return

In case of gross return, different treatment combination showed considerable gross return of Brussels sprouts production (Appendix XI and Table 19). The highest gross return of Brussels sprouts (600,600 Tk/ha) was obtained from T_1N_3 and the second highest gross return of Brussels sprouts production (552,200 Tk/ha) was obtained from T_1N_2. The lowest gross return of Brussels sprouts production (223,850 Tk/ha) was obtained from T_3N_0.

4.19.3 Net return

Different treatment combinations showed large differences in terms of net return from Brussels sprouts production (Appendix XI and Table 19). The highest net return of Brussels sprouts production (369,000 Tk/ha) was obtained from T_1N_3 and the second highest net return of Brussels sprouts production (328,925 Tk/ha) was obtained from T_1N_2. The lowest net return of Brussels sprouts production (75,500 Tk/ha) was obtained from T_3N_0.

4.19.4 Benefit cost ratio

Different treatment combination showed differences on benefit cost ratio of Brussels sprouts production (Appendix XI and Table 19). Results indicated that the highest benefit cost ratio (2.59) was obtained from T_1N_3 and the second highest benefit cost ratio (2.47) was obtained from T_1N_2. The lowest benefit cost ratio (1.51) was obtained from T_3N_0. From economic point of view, it is apparent from the above results that the combination of T_1N_3 was more profitable treatment combination than rest of the combination.

Table 19. Cost and return of Brussels sprouts cultivation as influenced by different planting time and organic nutrient sources.

Treatment	Cost of production (Tk/ha)	Yield (t/ha)	Gross return (Tk/ha)	Net return (Tk/ha)	Benefit cost ratio
T_1N_0	148,350	5.37	295,350	147,000	1.99
T_1N_1	189,975	8.5	467,500	277,525	2.46
T_1N_2	223,275	10.04	552,200	328,925	2.47
T_1N_3	231,600	10.92	600,600	369,000	2.59
T_2N_0	148,350	4.63	254,650	106,300	1.72
T_2N_1	189,975	6.73	370,150	180,175	1.95
T_2N_2	223,275	7.83	430,650	207,375	1.93
T_2N_3	231,600	8.73	480,150	248,550	2.07
T_3N_0	148,350	4.07	223,850	75,500	1.51
T_3N_1	189,975	5.96	327,800	137,825	1.73
T_3N_2	223,275	6.21	341,550	118,275	1.53
T_3N_3	231,600	6.8	374,000	142,400	1.61

Here,

T_1: Planting 5 November

T_2: Planting 20 November

T_3: Planting 5 December

N_0: Control (no manure application)

N_1: Cowdung @ 15 t/ha

N_2: Mushroom spent compost @ 7.5 t/ha

N_3: Vermicompost @ 5 t/ha

Rate of Brussels sprouts @ 55,000 Tk./ton

Gross return = Total yield (t/ha) × Tk. 55,000

Net return = Gross return - Total cost of production

Benefit Cost Ratio (BCR) = Gross return/Total cost of production

CHAPTER V

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

The experiment was conducted in the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka during the period from October 2018 to April 2019 to find out the effect of planting times and organic nutrient sources on the growth and yield of Brussels sprouts. The experiment consisted of two factors: Factor A: Planting time (three levels) as T_1: Transplanting at 05 November; T_2: Transplanting at 20 November; T_3: Transplanting at 05 December and Factor B: Different organic nutrient sources as N_0: Control i.e. no manure application; N_1: Cowdung @ 15 t/ha; N_2: Mushroom spent compost @ 7.5 t/ha; N_3: Vermicompost @ 5 t/ha. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

Planting time had significant effect on different growth, yield and yield contributing characters of Brussels sprouts. Results revealed that the tallest plant (59.90 cm) at 85 DAT was recorded from T_1 (planting at 05 November) whereas the shortest plant (57.88 cm) was recorded from T_2 (planting at 20 November). The maximum number of leaf per plant (36.88) at 85 DAT was recorded from T_1 (planting at 05 November) and the minimum number of leaves (34.31) was recorded from T_3 (planting at 05 December). The minimum days from transplanting to bud initiation (67.20 days) was recorded from T_1 (planting at 05 November) and the maximum days from transplanting to bud initiation (70.69 days) was recorded from T_3 (planting at 05 December). The highest diameter of stem (2.67 cm) was recorded from T_3 (planting at 05 December) and the lowest diameter of stem (2.53 cm) was recorded from T_2 (planting at 20 November). The highest length of root (31.63 cm) was recorded from T_3 (planting at 05 December) and the lowest length of root (29.90 cm) was recorded from T_1 (planting at 05 November). The maximum leaf area (650.71cm^2) and fresh weight of leaves per plant (530.65 g) were found from T_1 (planting at 05 November) and the minimum leaf area (638.99 cm^2) and fresh weight of leaves per plant were found from T_3 (planting at 05 December). The highest dry matter content of leaf (17.5 %) was recorded from T_1 (planting at 05 November) and the lowest dry matter content of leaf (14.94 %) was recorded from T_3 (planting at 05 December). The highest fresh weight of stem (209.87 g) was found from T_1 (planting at 05 November) and the lowest fresh weight of stem per plant (193.75 g) was found from T_2 (planting at 20 November). The highest dry matter content in stem (23.68 %) was found from T_3 (planting at 05 December) and the lowest dry matter content of stem (22.32 %) was found from T_2 (planting at 20 November). The highest dry matter content of bud (12.73 %) was found from T_3 (planting at 05 December) and the lowest dry matter content of bud (11.82 %) was found from T_2 (planting at 20 November). The highest length of marketable bud (4.42 cm), diameter of marketable bud (4.42 cm), weight of single marketable bud (11.78 g), number of marketable bud per plant (21.89), marketable yield per plant (261.15 g) and marketable yield per ha (8.70 t) were recorded from T_1 (planting at 05 November) and the lowest length of marketable bud (3.8 cm), diameter of marketable bud (2.4 cm), weight of single marketable bud (9.97 g), number of marketable bud per plant (17.22), marketable yield per plant (172.82 g) and marketable yield/ha (5.76 t) were recorded from T_3 (planting at 05 December).

Significant variation was recorded with different organic nutrient sources on the growth, yield and yield contributing characters of Brussels sprouts. Results revealed that the tallest plant (63.39 cm) at 85 DAT was recorded from N_3 (vermicompost @ 5 t/ha) and shortest plant (51 cm) at 85 DAT was recorded from N_0 (control i.e. no manure). The maximum number of leaves per plant (38.67) was recorded from N_3 (vermicompost @ 5 t/ha) and the minimum number of leaves per plant (30.31) was recorded from N_0 (control i.e. no manure). The minimum days from transplanting to bud initiation (68.3) was recorded from N_1 (cowdung @ 15 t/ha) and the maximum days from transplanting to bud initiation was recorded from N_0 (control i.e. no manure). The highest diameter of stem (2.71 cm) was recorded from N_3 (vermicompost @ 5 t/ha) and the lowest diameter of stem (2.51 cm) was recorded from N_0 (control i.e. no manure). The maximum length of root (33.94 cm) was recorded from N_1 (cowdung @ 15 t/ha) and the minimum length of root (27.42 cm) was recorded from N_0 (control i.e. no manure). The maximum leaf area (704.35 cm^2), fresh weight of leaves per plant (657.41 g), dry matter content of leaf (17.03 %), fresh weight of stem per plant (219.22 g) and dry matter content of stem (24.39 %) were recorded from N_3 (vermicompost @ 5 t/ha) and the minimum leaf area (573.76 cm^2), fresh weight of leaves per plant (312.88 g), dry matter content of leaf (14.86 %), fresh weight of stem per (184.00 g) and dry matter content of stem (21.08 %) were recorded from N_0 (control i.e. no manure). The highest dry matter content of bud (12.80 %) was recorded from N_1 (cowdung @ 15 t/ha) and the lowest dry matter content of bud (11.19 %) was recorded from N_0 (control i.e. no manure). The maximum length of marketable bud (4.41 cm), diameter of marketable bud (2.52 cm), weight of single marketable bud (11.6 g), number of marketable bud per plant (22.59), marketable yield per plant (264.49 g) and marketable yield/ha (8.82 t) were recorded from (vermicompost @ 5 t/ha). On the other hand, the minimum length of marketable bud (3.74 cm), diameter of marketable bud (2.33 cm), weight of single marketable bud (9.82 g), number of marketable bud/plant (14.30), marketable yield per plant (140.77 g) and marketable yield/ha (4.69 t) were recorded from N_0 (control i.e. no manure).

Due to the interaction effect of planting time and organic nutrient sources, the tallest plant (63.83 cm) at 85 DAT was recorded from T_3N_3 (planting at 05 December with vermicompost @ 5 t/ha) and the shortest plant (50.58 cm) was recorded from T_2N_0 (planting at 20 November with control i.e. no manure). The maximum number of leaves per plant (39.58) at 85 DAT was recorded from both T_1N_2 (planting at 05

November with spent mushroom compost @ 7.5 t/ha) and T_1N_3 (planting at 05 November with vermicompost @ 5 t/ha). The minimum number of leaves per plant (29.25) at 85 DAT was recorded from T_3N_0 (planting at 05 December with control i.e. no manure). The minimum days from transplanting to bud initiation (66.45) was recorded from T_1N_1 (planting at 05 November with cowdung @ 15 t/ha) and the maximum days from transplanting to bud initiation (72) was recorded from T_3N_0 (planting at 05 December with control i.e. no manure). The maximum length of root (36.42 cm) was recorded from T_3N_1 (planting at 05 December with cowdung @ 15 t/ha) and the minimum length of root (26.58 cm) was recorded from T_1N_0 (planting at 05 November with control i.e. no manure). The maximum leaf area (730.58 cm^2) was found from T_3N_3 (planting at 05 December with vermicompost @ 5 t/ha) and the minimum leaf area (567.67 cm^2) was recorded from T_2N_0 (planting at 20 November with control i.e. no manure). The highest fresh weight of leaves per plant (721.5 g) and dry matter content of leaf (18.99 %) were recorded from T_1N_3 (planting at 05 November with vermicompost @ 5 t/ha). The lowest fresh weight of leaves per plant (292.65 g) and dry matter content of leaf (14.20 %) were recorded from T_3N_0 (planting at 05 December with control i.e. no manure). The highest fresh weight of stem per plant (239.67 g) and dry matter content of stem (25.49%) were obtained from T_3N_3 (planting at 05 December with vermicompost @ 5 t/ha). The lowest fresh weight of stem per plant (169.67 g) and dry matter content of stem (19.57%) were found from T_2N_0 (planting at 20 November with control i.e. no manure). The highest dry matter content of bud (13.66%) was recorded from T_3N_1 (planting at 05 December with cowdung @ 15 t/ha) and the lowest dry matter content of bud (10.64%) was recorded from T_1N_0 (planting at 05 November with control i.e. no manure). The maximum bud length (4.85 cm) was found from T_1N_3 (planting at 05 November with vermicompost @ 5 t/ha) and the minimum bud length (3.41 cm) was found from T_3N_0 (planting at 05 December with control i.e. no manure). The maximum diameter of marketable bud (2.63 cm) and weight of single marketable bud (12.79 g) were found from T_1N_2 (planting at 05 November with spent mushroom compost @ 7.5 t/ha). The minimum diameter of marketable bud (2.30 cm) and weight of single marketable bud (9.24 g) were found from T_3N_0 (planting at 05 December with control i.e. no manure). The maximum number of marketable buds per plant (25.78), marketable yield per plant (327.54 g) and marketable yield per hectare (10.92 t) were recorded from T_1N_3 (planting at 05 November with vermicompost @ 5 t/ha). On the other hand, minimum number of marketable buds per plant (13.22), marketable yield per plant (122.23 g) and marketable yield per hectare (4.07 t) were recorded from T_3N_0 (planting at 05 December with control i.e. no manure).

In terms of economic performance, the highest gross return (600,600 Tk/ha), net return (369,000 Tk/ha) and benefit cost ratio (2.59) were obtained from T_1N_3 (planting at 05 December with control i.e. no manure) where the lowest gross return (223,850 Tk/ha), net return (75,500 Tk/ha) and benefit cost ratio (1.51) were obtained from T_3N_0 (planting at 05 December with control i.e. no manure).

5.2 Conclusion

Regard as the above summary, it can be concluded that planting at 05 November with vermicompost @ 5 t/ha performed the best result among other treatments in terms for growth, yield as well as the highest economic return of Brussels sprouts.

5.3 Suggestions

i. Results are presented on the basis of one-year experiment; further trials are needed to substantiate the results.

ii. Further experiment regarding its suitability is needed in different Agro Ecological zones (AEZ) of the country for regional adaptability and performance before commercial cultivation.

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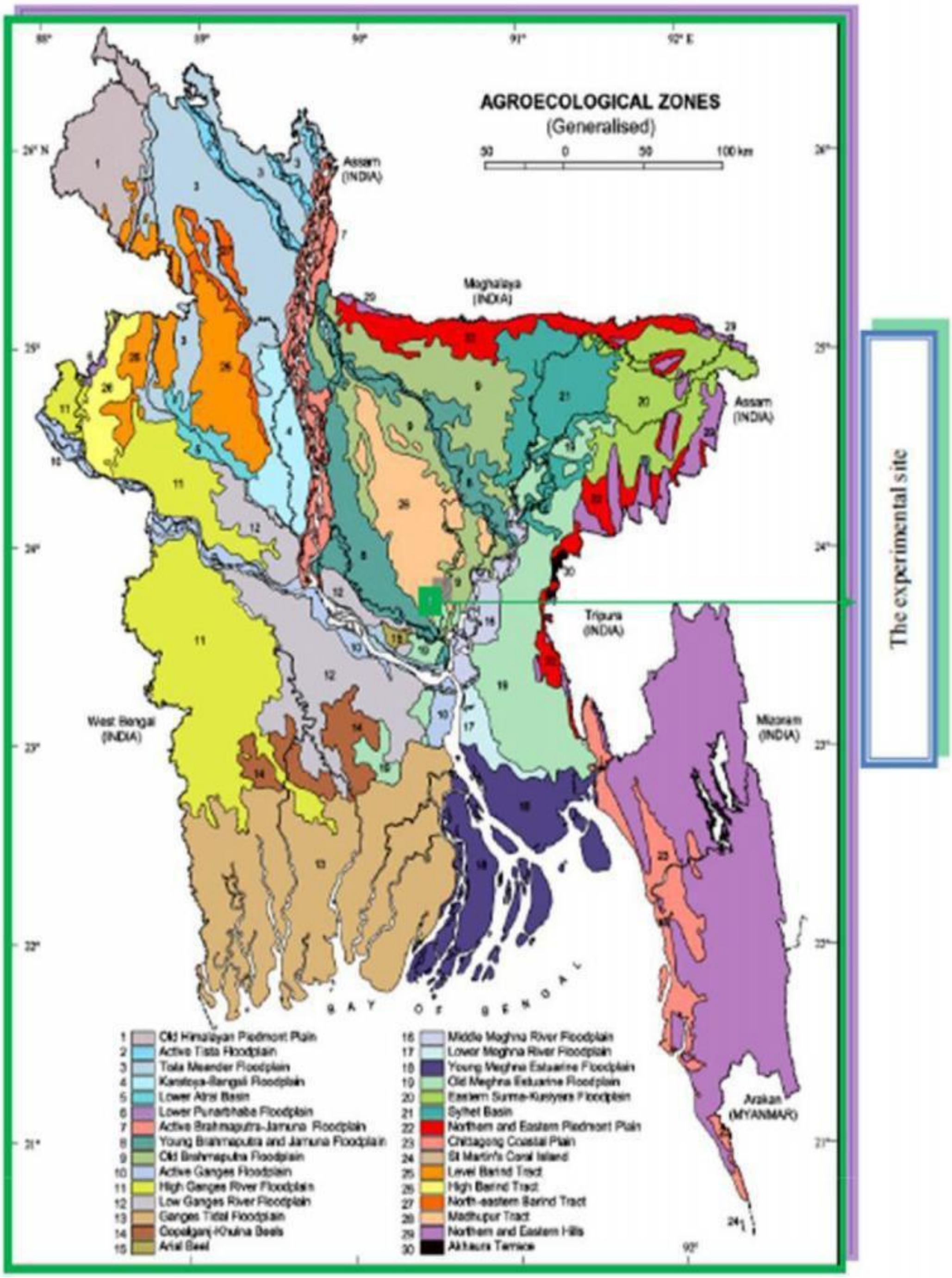
APPENDICES

APPENDICES

Appendix I. Map showing the experimental site under study.



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

Month	Air temperature (°C)		Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
October, 2018	31.9	23.6	72	45	6.5
November, 2018	30.2	19.7	68	13	7.2
December, 2018	26	16.4	68	13	7.5
January, 2019	27.1	14.6	59	1	7.9
February, 2019	28.3	16.8	63	115	6.9
March, 2019	31.5	21.1	61	39	6.9
April, 2019	33.6	23.6	69	212	6.8

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 on plant height at different days after transplanting (DAT) of Brussels sprouts.

Source of variation	Degree of Freedom	Mean square			
		Plant height (cm) at			
		40 DAT	55 DAT	70 DAT	85 DAT
Replication	2	13.41	13.29	7.92	8.98
Planting Time (A)	2	9.41*	15.67**	22.55**	12.85*
Organic nutrient source (B)	3	73.40**	150.37**	201.05**	288.33**
Interaction (A×B)	6	0.40	2.60	2.80	2.27
Error	22	2.61	2.04	2.35	2.36

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix V. Analysis of variance on number of leaves at different days after transplanting (DAT) of Brussels sprouts.

Source of variation	Degree of Freedom	Mean square			
		Number of leaves at			
		40 DAT	55 DAT	70 DAT	85 DAT
Replication	2	2.41	2.46	2.73	12.95
Planting Time (A)	2	0.65	12.86**	24.26**	21.65**
Organic nutrient source (B)	3	17.88**	62.00**	91.64**	123.63**
Interaction (A×B)	6	0.20	0.83	1.48	1.41
Error	22	0.38	1.18	1.46	2.51

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix VI. Analysis of variance on Days from transplanting to bud initiation, stem length, stem diameter and length of root of Brussels sprouts.

Source of variation	Degree of Freedom	Mean square			
		Days to bud initiation	Stem length (cm)	Stem diameter (cm)	Length of root (cm)
Replication	2	2.078	8.418	0.082	19.799
Planting Time (A)	2	37.337**	13.632*	0.071*	11.158
Organic nutrient source (B)	3	8.459**	328.002**	0.063*	65.659**
Interaction (A×B)	6	0.178	2.438	0.004	4.538
Error	22	0.831	3.879	0.019	11.026

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix VII. Analysis of variance on leaf area, fresh weight of leaf per plant and dry matter content of leaf of Brussels sprouts.

Source of variation	Degree of Freedom	Mean square		
		Leaf area (cm^2)	Fresh weight of leaf/plant (g)	Dry matter content of leaf (%)
Replication	2	8920.9	18482	0.266
Planting Time (A)	2	446.6	21632*	19.931**
Organic nutrient source (B)	3	26893.2**	183769**	7.496**
Interaction (A×B)	6	1924.5	22525**	0.802
Error	22	2191.2	5116	0.810

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix VIII. Analysis of variance on fresh weight of stem per plant, dry matter content of stem and dry matter content of bud of Brussels sprouts.

Source of variation	Degree of Freedom	Mean square		
		Fresh weight of stem/plant (g)	Dry matter content of stem (%)	Dry matter content of bud (%)
Replication	2	201.080	18.769	1.948
Planting Time (A)	2	1024.190	6.061	2.581
Organic nutrient source (B)	3	2191.820*	18.003*	5.105**
Interaction (A×B)	6	556.650	3.047	0.604
Error	22	619.540	5.363	0.793

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix IX. Analysis of variance on length of marketable bud, diameter of marketable bud and weight of single marketable bud of Brussels sprouts.

Source of variation	Degree of Freedom	Mean square		
		Length of marketable bud (cm)	Diameter of marketable bud (cm)	Weight of single marketable bud (g)
Replication	2	0.100	0.005	0.499
Planting Time (A)	2	1.148**	0.030	9.885**
Organic nutrient source (B)	3	0.730**	0.070**	5.767**
Interaction (A×B)	6	0.033	0.008	0.509
Error	22	0.058	0.013	0.273

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix X. Analysis of variance on number marketable of bud, marketable yield per plant and marketable yield per hectare of Brussels sprouts.

Source of variation	Degree of Freedom	Mean square		
		No. of buds	Marketable yield/plant (g)	Marketable yield/ha (ton)
Replication	2	0.467	146.4	0.163
Planting Time (A)	2	66.120**	23631.5**	26.257**
Organic nutrient source (B)	3	116.494**	25898.0**	28.776**
Interaction (A×B)	6	2.361	1166.1**	1.296**
Error	22	1.138	248.6	0.276

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix XI. Production cost of Brussels sprouts per hectare.

A. Input cost (Tk./ha)

Treatment Combination	Labour Cost	Ploughing cost	Seed Cost	Irrigation	Pesticides	Bamboo sticks	Organic Manure			Sub-Total (A)
							Cowdung	Mushroom spent compost	Vermicompost	
T_1N_0	40,000	12,000	10,000	10,000	3,000	10,000	0	0	0	85,000
T_1N_1	40,000	12,000	10,000	10,000	3,000	10,000	37,500	0	0	122,500
T_1N_2	40,000	12,000	10,000	10,000	3,000	10,000	0	67,500	0	160,000
T_1N_3	40,000	12,000	10,000	10,000	3,000	10,000	0	0	75,000	160,000
T_2N_0	40,000	12,000	10,000	10,000	3,000	10,000	0	0	0	85,000
T_2N_1	40,000	12,000	10,000	10,000	3,000	10,000	37,500	0	0	122,500
T_2N_2	40,000	12,000	10,000	10,000	3,000	10,000	0	67,500	0	160,000
T_2N_3	40,000	12,000	10,000	10,000	3,000	10,000	0	0	75,000	160,000
T_3N_0	40,000	12,000	10,000	10,000	3,000	10,000	0	0	0	85,000
T_3N_1	40,000	12,000	10,000	10,000	3,000	10,000	37,500	0	0	122,500
T_3N_2	40,000	12,000	10,000	10,000	3,000	10,000	0	67,500	0	160,000
T_3N_3	40,000	12,000	10,000	10,000	3,000	10,000	0	0	75,000	160,000

Here, T_1: Planting at 5 November, T_2: Planting at 20 November, T_3: Planting at 5 December N_0: Control (no manure application), N_1: Cowdung @ 15 t/ha, N_2: Mushroom spent compost @ 7.5 t/ha, N_3: Vermicompost @ 5 t/ha.

Cowdung @ 500 Tk/ton, Mushroom spent compost @ 9,000 Tk/ton and Vermicompost @ 15,000 Tk/ton

Appendix XI. Production cost of Brussels sprouts per hectare (Cont'd)

B. Overhead cost (Tk. /ha)

Treatment combination	Cost of lease of land for 6 months (12% of value of land Tk. 900000/ year)	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 months (Tk. 12% of cost/year)	Subtotal (Tk) (B)	Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)]
T_1N_0	54,000	4,250	5,100	63,350	148,350
T_1N_1	54,000	6,125	7,350	67,475	189,975
T_1N_2	54,000	7,625	9,150	70,775	223,275
T_1N_3	54,000	8,000	9,600	71,600	231,600
T_2N_0	54,000	4,250	5,100	63,350	148,350
T_2N_1	54,000	6,125	7,350	67,475	189,975
T_2N_2	54,000	7,625	9,150	70,775	223,275
T_2N_3	54,000	8,000	9,600	71,600	231,600
T_3N_0	54,000	4,250	5,100	63,350	148,350
T_3N_1	54,000	6,125	7,350	67,475	189,975
T_3N_2	54,000	7,625	9,150	70,775	223,275
T_3N_3	54,000	8,000	9,600	71,600	231,600

Here, T_1: Planting at 5 November, T_2: Planting at 20 November, T_3: Planting at 5 December N_0: Control (no manure application), N_1: Cowdung @ 15 t/ha, N_2: Mushroom spent compost @ 7.5 t/ha, N_3: Vermicompost @ 5 t/ha.