GROWTH AND YIELD OF BROCCOLI AS INFLUENCED BY VERMICOMPOST AND GA_3

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It is a fact that the remembrance of Allah brings peace in the heart. It is better to ponder over the verses to bring us even closer to Allah (swt).

DEDICATED TO-

MY BELOVED PARENTS

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CERTIFICATE

This is to certify that the thesis entitled ***"GROWTH AND YIELD OF BROCCOLI AS INFLUENCED BY VERMICOMPOST AND GA$_3$"*** *submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE in HORTICULTURE****, embodies the result of a piece of authentic research work carried out by* ***Md. Mainul Islam Ahad,*** *Registration No.* ***13-05269*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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- Author

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ABSTRACT

A field experiment was accomplished in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2018 to March 2019 to study on influence of Vermicompost and GA_3 on growth and yield of broccoli. The experiment comprised of three levels of vermicompost viz., V_0 (Control)), V_1 (5 t/ha), V_2 (10 t/ha) and four levels of GA_3 viz., M_0 (control), M_1 (50 ppm), M_2 (80 ppm) and M_3 (110 ppm) were used in this experiment arranged in Randomized Complete Block Design (RCBD) with three replications. Data on different growth and yield attributes were taken in which all the treatments showed significant variation. The maximum yield (27.29 t/ha) was recorded from V_2 (10 t/ha), while the lowest (19.79 t/ha) was recorded from V_0. GA_3 exhibited a significant influence on total yield per plant. The maximum yield (26.27 t/ha) was recorded from M_2 (80 ppm), whereas the lowest (19.80 t/ha) was recorded from M_0. Yield per plant was significantly influenced by the treatment combinations of vermicompost and GA_3 of broccoli. The maximum yield (32.41 t/ha) was recorded from the treatment combination of V_2M_2, whereas the lowest (18.19 t/ha) was recorded from V_0M_0. From growth and yield point of view, it is apparent that the combination of 10t/ha vermicompost with 80 ppm GA_3 is suitable for broccoli cultivation.

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ABBREVIATIONS AND ACCORONYMS

AEZ	Agro-ecological Zone
Agric.	Agricultural
ANOVA	Analysis of Variance
BARI	Bangladesh Agricultural Research Institute
Biol.	Biology
CV	Coefficient of variance
DAT	Days After Transplanting
et al.	And others
Ex.	Experiment
FAO	Food and Agriculture Organization of the United Nations
g	Gram
Hort.	Horticulture
i.e.	That is
J.	Journal
Kg	Kilogram
LSD	Least Significance difference
mm	Millimeter
RCBD	Randomized Complete Blocked Design
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
spp.	Species
Technol.	Technology
UNDP	United Nations Development Programme
Viz.	Namely
%	Percent
LAI	Leaf Area Index
RGR	Relative Growth Rate
NAR	Net Assimilation Rate
MSTAT	Michigan State University Statistical Package for Data Analysis
etc.	Etcetera

CHAPTER-I
INTRODUCTION

Broccoli (*Brassica oleracea L. var. italica*) belongs to family Brassicaceae and considers a number of cole vegetable crops; which includes cabbage, cauliflower, chinese cabbage, broccoli, brussels sprouts and kohlrabi. It is well known that, Broccoli has enormous nutritional and medicinal values due to its high contents of vitamins (A, B_1, B_2, B_5, B_6 and E), minerals (Ca, Mg, Zn and Fe) and antioxidant substances which prevent the formation of cancer-causing agents (Beecher, 1994). Broccoli is widely, cultivated in many European and American countries. In Bangladesh, Broccoli still a grown in a very limited scattered areas and the total cultivated area is not exactly known. Organic manures such as cattle manure and poultry manure improve the soil structure, aeration, slow release nutrient which support root development leading to higher yield and better quality of broccoli plants (Abou El-Magd *et al.*, 2005).

Moreover, organic matter plays an important role in the chemical behavior of several metals in soils throughout its active groups (flavoric and humid acids) which have the ability to retain the metals in complex and chelate forms. Organic manure plays direct role in plant growth as a source of all necessary macro and micronutrients in available forms during mineralization, improving the physical and physiological properties of soils. Mineral fertilizer improves growth and yield of Broccoli due to the role of nitrogen, phosphorus and potassium on the meristematic activity. It has been widely used for increasing crop production.

Broccoli closely related to cauliflower. Sprouting broccoli has about 130 times more vitamin A contents than cauliflower and 22 times more than cabbage (Singh, 2007). However, due to increase in its popularity, there is a trend to increase cultivation by farmers, as well as consumption by consumers. But the main problems are availability

of quality seed, low yield and short shelf life. There is an ample scope for increasing yield of Broccoli under Bangladesh conditions and it has a great export potential. In recent years a great deal of research work has been reported on the uses of plant growth regulators in vegetable crops. Growth regulators are organic compounds other than nutrients; small amount which are capable of modifying growth. Plant growth regulators modify the physiological processes within the plant, which ultimately affect the growth, yield and quality of the crop. Among, plant growth regulators, GA_3 exhibited beneficial effect in several cole crops by stimulating cell division or cell enlargement or both (Badawi and Sahhar, 1978) and foliar application of different concentrated GA_3 provide more yield (Rana *et al*., 2011; Jiang *et al*., 2008). GA_3 have close relation with growth and yield of broccoli and determination of exact concentrations of GA_3 is important for growth and yield of broccoli. GA_3 influence plant growth and yield of broccoli but the effects of this factor on the growth and yield of broccoli have not been studied in details under Bangladesh conditions. Therefore, to get the highest yield such studies under Bangladesh conditions are needed.

Among various organic products, vermicompost has been recognized as potential soil amendment. Vermicompost is a product of non-thermophilic biodegradation of organic material by combined action of earthworms and associated microbes. It is a highly fertile, finely divided peat-like material with high porosity, aeration, water holding capacity and low C:N ratios. So, vermicompost is very essential for the growth and yield of broccoli.

If the light of the above perspective, the present experiment was conducted with broccoli as the test crop having different combination of vermicompost with GA_3 to find out the best combination of organic matter and growth regulator for broccoli production.

Considering the above fact, the study was undertaken with the following objectives:

1. To identify the optimum level of vermicompost on growth and yield of Broccoli
2. To determine the optimum concentration of GA_3 on growth and yield of Broccoli
3. To find out the suitable combination of vermicompost and GA_3 for ensuring the maximum growth and yield of Broccoli

CHAPTER II
REVIEW OF LITERATURE

Broccoli is one of the non-traditional and relatively new "Cole" crops in Bangladesh. The demand of vegetable is increasing day by day in our country and horizontal expansion of vegetable yield per unit area should be increased to meet this ever-increasing demand of vegetable but it will require adoption of new technology such as high management package, high yielding cultivar, higher input use etc. Management practices have considerable effects on the growth and development of any crop particularly vegetable crops. Among these, Vermicompost is a modern concept as a management practices and GA_3 is a most important and common practices and both are also important factors. Numerous studies have been performed evaluating the influence of GA_3 and Vermicompost on growth and yield of broccoli. But research works related to GA_3 and Vermicompost on broccoli are limited in Bangladesh context. However, some of the important and informative works and research findings related to GA_3 and Vermicompost on broccoli and other crops so far been done at home and abroad have been reviewed in this chapter under the following headings.

2.1 Influence of Vermicompost on crop growth and yield

Ishtiyaq *et al*. (2015) conducted to investigate the effect of different rates (2, 4 and 6 t/ha) of macrophyte-based vermicompost on germination, growth and yield of *Solanum melongena* under field conditions. The data revealed that different rates of vermicompost produced varied and significant effect (P\0.05) as compared to the control on germination, growth and yield parameters with maximum value recorded at 6 t/ha, followed by 4 t/ha and the least at 2 t/ha. The dose of 6 t/ha significantly (P\0.05) increased germination (22.56 ± 2.5 %), number of fruits per plant (3.55 ± 0.07), mean fruit weight (73± 5.0 g), yield per plant (1.48 ± 0.05 kg) and marketable fruits (28.66 ± 3.0 %) when compared with the control. This study suggests that

macrophyte-based vermicompost as a potential source of plant nutrients for sustainable crop production.

Sumi (2015) conducted an experiment at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka to find out the effect of cowdung and vermicompost on growth and yield of chilli. The experiment consisted of two factors Factor A: Different levels of cowdung such as C_0: 0 t/ha, C_1: 10 t/ha, C_2: 15 t/ha and C_3: 20 t/ha; Factor B: Different levels of vermicompost such as V_0: 0 t/ha, V_1: 5 t/ha and V_2: 7 t/ha. The two factors experiment was laid out in Randomized Complete Block Design with three replications. In case of different levels of cowdung, the highest number of fruits per plant (58.62) and yield (9.26 t/ha) were found from C_2, while the lowest number of fruits per plant (45.29) and yield (6.06 t/ha) from C_0. For different levels of vermicompost, the highest number of fruits per plant (54.38) and yield (8.40 t/ha) were recorded from V_1, whereas the lowest number of fruits per plant (50.16), and yield (7.00 t/ha) from V_0. Due to interaction effect, the highest number of fruits per plant (61.07), and yield (10.08 t/ha) were recorded from C_2V_1, whereas the lowest number of fruits per plant (43.94) and yield (5.13 t/ha) from C_0V_0. From growth and yield point of view, it is apparent that the combination of 15t/ha cowdung and 5 t/ha vermicompost was suitable for chilli cultivation.

Akter (2014) conducted the field experiment at the Horticulture Farm, Sher-e-Bangla Agricultural University (SAU), Dhaka during the period from 15 October, 2013 to 23 February, 2014 to evaluate the effect of different levels of vermicompost on the growth and yield of cabbage. The experiment comprised of two different factors such as Factor A: Three varieties viz; V_1: Atlas 70, V_2: Autumn Queen and V_3: Profit and Factor B: Four vermicompost levels; VC_0: control, VC_1: 3.6 t/ha, VC_2: 7.2 t/ha, and VC_3: 10.8 t/ha of vermicompost. The experiment was set up in Randomized Complete Block Design (RCBD) with three replications. There were 12 treatment combinations. 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, VC_3 gave the highest (64.78 t/ha) yield and lowest (14.79t/ha) from VC_0. For interaction effect, V_2VC_3 gave the highest (71.80 t /ha) yield and the lowest (14.44 t/ ha) from V_3VC_0. So, Autumn Queen with vermicompost level 10.8 t/ha gave the best performance.

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.

Getnet and Raja (2013) conducted an experiment during October 2011 to February 2012 to study impact of vermicompost on growth and development of Cabbage, *Brassica oleracea* Linn. and their sucking pest. Vermicompost was applied at the rate of 25, 50, 100 and 200 g/plant individually. Each application 10 plants were selected and vermicompost application was continued on bimonthly basis. Totally 40 plants were used for control group in which 10 plants were selected randomly.

Total number of leaves per plant; leaf length and width; plant stand height and root length; cabbage head round distance and weight and aphid population built-up were the parameters studied in experimental and control cabbage plants. Significant differences ($p<0.05$; LSD) were observed in the growth and development and pest infestation level between vermicompost applied and control plants. The number of plant stand height, cabbage head, leaves of cabbage were also significantly different ($p<0.05$; LSD) in experimental cabbage compared to control. Maximum number of cabbage plant was infested by aphid in control than experimental groups. In conclusion vermicompost have significant impact on cabbage growth promotion and reduce the aphid infestation.

Rai *et al*. (2013) studied the effect of vermicompost, integrated with different rates of recommended doses of NPK for growth, yield and quality of cabbage. The investigation was laid out in RBD with ten treatments viz., T1: 100% NPK (RR), T2:75% NPK (RR)+VC 3 ton/ha, T3:75% NPK (RR)+VC 2 ton/ha, T4:75% NPK (RR)+VC 1 ton/ha, T5:75% NPK (RR), T6:50% NPK (RR)+VC 3 ton/ha, T7:50% NPK (RR)+VC 2 ton/ha, T8: 50% NPK (RR)+VC 1 ton/ha, T9:50% NPK (RR) and T10: VC 5 ton/ha. The results revealed that combined use of vermicompost and recommended dose of NPK were statistically significant towards the growth and yield of cabbage. The combined use of recommended dose of 75% NPK (RR) +VC 3 ton/ha, had recorded the maximum gross weight of the plant and net weight of the head. Application of vermicompost along with inorganic fertilizers reduced the days taken to maturity. The minimum days to 100% head maturity was also obtained from combined application of vermicompost. Most of the quality attributes like, total protein, total sugar, starch and ascorbic acid were found to be highest with 75% NPK (RR)+VC 3 ton/ha vermicompost except total chlorophyll content. It was concluded that application of vermicompost in combination with inorganic NPK fertilizers increased the productivity of cabbage besides sustaining soil fertility status.

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.

Ramírez *et al*. (2014) conducted a field experiment to evaluate different vermicompost doses in tomato crops (*Solanum lycopersicum L*.) in northern Sinaloa, Mexico. Vermicompost doses of 0, 500, 1000, 1600, 2000 and 4000 kg per hectare were tested including a control, in a completely randomized design with three replicates per treatment. The estimated variables were fruit size, number and weight. The addition of more than 4000 kg/ha of vermicompost significantly increased the fruit number and size in tomato plants hence it is considered a viable option for use in commercial tomato crops.

Azarmi *et al*. (2008) analyzed the effects of vermicompost on growth, yield and fruit quality of tomato (*Lycopersicon esculentum* var. super beta) in a field condition. The experiment was a randomized complete block design with four replications. The different rates of vermicompost (0, 5, 10 and 15 t/ha) was incorporated into the top 15cm of soil. During experiment period, fruits were harvested twice in a week and total yield were recorded for two months. At the end of experiment, growth characteristics such as leaf number, leaf area and shoot dry weights were determined. The results revealed that addition of vermicompost at rate of 15 t/ ha significantly (at $p < 0.05$) increased growth and yield compared to control. Vermicompost with rate of 15 t/ ha increased EC of fruit juice and percentage of fruit dry matter up to 30 and 24%, respectively. The content of K, P, Fe and Zn in the plant tissue increased 55, 73, 32 and 36% compared to untreated plots respectively.

The result of their experiment showed addition of vermicompost had significant ($p < 0.05$) positive effects on growth, yield and elemental content of plant as compared to control.

John *et al*. (2013) studied the effect of vermicompost on the growth and yield of *Capsicum annum*. Their study revealed that the total macronutrients andmicronutrients showed elevated levels in vermicompost when compared to control. The vermicompost applied plant *Capsicum annum* showed an increased shoot length and number of leaves when compared to the inorganic fertilizer applied plant.

A field experiment was conducted by Reddy and Rao (2004) to study the Growth and yield of bitter gourd (*Momordica charantia L*.) as influenced by vermicompost and nitrogen management practices in Hyderabad, Andhra Pradesh, India, consisting of 4 levels of vermicompost (0, 10, 20 and 30 t/ha) and 3 levels of N (20, 40 and 80 kg/ha). Application of vermicompost and N significantly increased the vine length, number of branches, number of fruits per vine and fruit yield/ha. Delayed flowering was observed with higher levels of N and Vermicompost. Application of 13.8 ton vermicompost and 34.18 kg N (through urea)/ha was found beneficial in improving the yield of bitter gourd.

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A study was conducted by Reddy and Reddy (2005) in Andhra Pradesh, India during 1996-98 to determine the effects of different levels of vermicompost (0, 10, 20 and 30 t/ha) and nitrogen fertilizer (0, 50, 100, 150 and 200 kg/ha) on the growth and yield of onion (cv. N-53) and their residual effect on succeeding radish in an onion-radish (cv. Sel-7) cropping system. The plant height, number of leaves per plant, leaf area, bulb length, diameter and weight and yield of onion increased significantly with increasing levels of vermicompost (from 10 to 30 t/ha) and nitrogen fertilizer (from 50 to 200 kg/ha). A similar increase in radish yield was also observed due to the residual effect of different levels of vermicompost and nitrogen applied to the preceding crop (onion). Among the various treatment combinations, vermicompost at 30 t/ha + 200 kg N/ha recorded the highest plant height and number of leaves per plant in onion and radish, but was at par with the treatment with vermicompost at 30 t/ha + 150 kg N/ha in terms of bulb length, bulb weight and onion yield recorded.

A study was conducted by Vadiraj *et al*. (1998) at Saklespur, Karnataka, India, on a red sandy loam soil, with 7 turmeric [*Curcuma longa*] cultivars. Rhizomes were planted on raised beds which had well-rotted farmyard manure (20 t/ha) incorporated. Immediately after planting, vermicompost was applied at 0 or 10 t/ha. All plots were mulched uniformly with forest litter. A second application of vermicompost (10 t/ha) was made 90 days after planting. Rhizomes were harvested after 240 days. The cultivars responded positively to vermicompost application, plant height varying from 18.3 to 26.6 cm in control plots and from 28.9 to 33.9 cm in the treated plots. Among the cultivars, Armoor and Suroma responded best to vermicompost. Yield increases for the treated plots, over the control, ranged from 6.7% (BSR-1) to 25.5% (Armoor).

Mahtoj and Yadav (2005) conducted a pot culture experiment during winter season of 2001-02 to investigate the effect of vermicompost on growth and productivity in vegetables peas. The dry weight in vegetable peas was significantly influenced by vermicompost.

Rodriguez *et al*. (2000) investigated the effect of vermicompost on plant nutrition, yield and incidence of root and crown rot of gerbera. Vermicompost incorporation at 20%, with or without chemical fertilizer, reduced the incidence of diseased plants and the disease growth rate. The macro and micronutrient content except (K and Mn) were at optimum level in plants treated with 20% vermicompost with or without chemical fertilizer. In contrast, plants from treatments without vermicompost had the lower content of macro and micronutrient, except K and Mn.

Singh *et al*. (2005) conducted a study to assess the effect of vermicompost on cauliflower productivity and profitability considering soil health under small production systems. The data were gathered through farmer participatory verification trials during 2002-04 in five villages of Rajaulatu Panchayats of Namkum Block in Ranchi district, Jharkhand. It was found that the return per rupee spent in plots with vermicompost was Rs. 3.30, Rs 1.98 in plots applied with chemical fertilizers. The farmer's reaction on the use of vermicompost was highly positive because of its simplicity and compatibility with the farming system components and with the household internal resources, as well as its cost effectiveness.

Sohrab and Sarwar (2001) conducted an experiment and found that in case of Lady's finger (okra), the vermicompost had played very effective role in all economic aspects of the vegetables crop. The yield of lady's finger was 18.40 t/ha from the experimental plots treated with vermicompost in one season. On the contrary, production of 12.43 t/ha was estimated on the basis of harvested crop from untreated plots.

An experiment was conducted by Siag and Yadav (2004) in Rajasthan, India, during 1999-2001 to study the effect of vermicompost (0, 1, 2 and 3 t/ha) and fertilizers (0, 50 and 100% recommended dose) on mungbean (Vignaradiata) yield. Significant

increase in seed yield was observed by the application of vermicompost up to 2 t/ha owing to increased secondary branches per plant, pods per plant. Increased in secondary branches and nodules per plant resulted in improved yield attributes and seed yield over the control. Application of vermicompost (2 t/ha) along with 50% recommended dose of fertilizers (10 kg N and 8.7 kg P/ha) was found to be the optimum dose for mungbean grown on sandy-loam soil.

Reshid *et al*. (2014) conducted that a plastic pot set-up with soil was used to determine the effects and efficiency level of vermicompost on the growth and yields of tomatoes (*Solanum lycopersicum L.).* The study was conducted through effect of increasing concentration of Vermicompost (control, 10%, 20%, 30% and 40%w/w) in target plant growth. The present study was carried out on the basis of Randomized Complete Block Design (RCBD) with 5 treatments and 3 replications. The obtained results from the present research indicated that applied vermicompost especially; at 20% level had significantly improving effects on better growth and development of vermicompost treated tomatoes as they had higher leaf area, leaf dry mass, fresh stem and dry weight, number of fruits and yields. Low doses of vermicompost (10%) and high doses (40%) produced lower yields of the tomato plants. Generally, the addition of vermicompost led to improve the yield of tomato cultivars as compared to control. Hence, it could be suggested that treated plants, with this vermicompost increased the growth, yield and the above chemical compositions and pH of the soil.

Kumar *et al*. (2013) conducted that Field efficacy of six botanicals in the management of major pests viz., spotted leaf beetle *Epilachna vigintioctopunctata* and shoot and fruit borer *Leucinodes orbonalis* of brinjal was evaluated in combination with vermicompost, farmyard manure and straight fertilizers as main treatments and six botanicals as sub treatments employing the split plot design.

Organic manures proved to be superior when compared to the fertilizers as regards pest incidence. Vermicompost was significantly more effective as regards fruit borer infestation. NSKE 5% extract proved to be the most effective against fruit borer. Neemgold (Azadirachtin) 5 ml/l, Pongamia glabra 5% leaf extract and Annona squamosa 5% leaf extract also were effective in reducing the fruit borer incidence. Murraya koenigi 5% extract and chilli-garlic 5% extract were less effective. Significantly highest marketable yield was obtained in Neemgold (Azadirachtin) 5 ml/l followed by NSKE 5%.

Mamta *et al*. (2012) conducted that the study was aimed at understanding the effect of vermicompost on the growth and productivity of brinjal plant. The vermicompost of cow dung, garden waste and kitchen waste in combination were used with brinjal plants under field conditions. The different treatments affected the seed germination of the test crop significantly. Plant height, number of leaves and fruit weight were higher in the vermicompost treated field as compared to control and no disease incidence was observed in the fruits of vermicompost treated plot. The study revealed that vermicompost amendments affected brinjal crop differently and we recommend that while raising brinjal crop farmers should use vermicompost instead of synthetic fertilizers.

Lallawmsanga *et al*. (2012) conducted that the ameliorating effect of vermicompost and cowdung compost on growth and biochemical characteristics of *Solanum melongena* treated with paint industrial effluent was evaluated in this study. The color and odor of the effluent samples, physical and chemical parameters like pH, EC, TDS, TS, EC and heavy metals were analyzed. The effluent contained sulphates, chlorides, phosphates, dissolved solids and other pollutants in higher amounts. The effect of effluent with water, vermicompost and cow dung were studied on shoot length, root length, leaf area, fresh weight, dry weight and biochemical parameters like Chlorophyll a, Chlorophyll b, Total

Chlorophyll and Carotenoids of *S. melongena*. It was noted that the length of the root and shoot, fresh and dry weight of the plant was considerably decreased with increase in concentration of the effluent. There was a gradual increase in all the parameters except the leaf area with increase in effluent concentration with vermicompost and cow dung. There was no change in the chlorophyll content on 80% effluent with vermicompost when compared to the control, whereas reduction in the carotenoids content was noted in 80% effluent with vermicompost.

Jagadeesha (2008) conducted a field experiment was conducted at the University of Agricultural Sciences, Dharwad during kharif season of 2007 to study the effect of organic manures and biofertilziers on plant growth, seed yield and quality parameters in tomato. Results of field experiment in kharif 2007 revealed that, application of RDF (60:50:30 kg NPK/ha) + biofertilzier (Azospirillum and P solubilizing bacteria 2.5 kg/ha each) records higher plant height (64.37, 109.50 and 162.33 cm), number of leaves (92.50, 153.33 and 146.50), leaf area (898.05, 4314.31 and 4310.94 cm^2) and leaf area index (898.05, 4314.31 and 4310.94 cm^2) at 30, 60 and 90 DAT respectively and records lesser days to 50 percent flowering (38.00) followed by FYM (50%) + vermicompost (50%) + biofertilzier. The application of RDF + biofertilziers records higher seed yield (106.87 kg/ha) followed by FYM (50%) + vermicompost (50%) (101.94 kg/ha) over FYM alone. The seed yield was significantly higher with the application of RDF + biofertilziers was attributed to number of fruits per plant (45.22) number of seeds per fruit (109.45) fruit weight per plant (1280.98 g) and 1000 seed weight (2.84 g).

Hangarge *et al*. (2004) conducted that a field experiment was conducted during the kharif and rabi seasons of 1996/97 to study the influence of vermicompost and other organics on the fertility and productivity of soil (Vertisol) under chilli-spinach cropping system in Parbhani, Maharashtra, India. The application of vermicompost at 5 t/ha + organic booster at 1 litre m^{-2}, and soil conditioner (Tera

care) at 2.5 t/ha + organic booster at 1 litre m^{-2} enhanced the availability of N, P, K and organic C content in soil. The recommended rates of NPK and organic sources each alone did not have any significant effect. The combined effect of organic + organic sources proved to be better than either organic alone or combination of organic + inorganic fertilizer.

Subhasmita *et al*. (2004) conducted that the effects of vermicompost based on karanj, niger, mahua, Indian mustard, groundnut or neem oilseed cake, and NPK (120:80:60 kg/ha) as control, on leaf damage by *L. trifolii* and on the yield of chilli cv. Suryamukhi were studied in a pot experiment. Leaf damage varied from 20.0 to 53.3%, whereas fruit yield per plant ranged from 9.7 to 21.3%. The vermicompost based on mahua oilseed cake resulted in the lowest percentage of leaf damage (16.7%), whereas the vermicompost based on groundnut oilseed cake recorded the highest fruit yield (21.3 g per plant).

Yadav and Vijayakumari (2004) conducted a pot experiment at Avinashilingam University, Coimbatore, Tamil Nadu, India, to assess the effect of vermicomposted vegetable waste, alone and in combination with different organic manures and chemical fertilizer, on the biochemical characters of chilli (*Capsicum annuum*). The reducing sugar, free amino acid and phenol contents were higher in the vermicompost treatment on 30 (70.27, 7.98, 14.62 mg/g), 60 (95.51, 17.66, 22.32 mg/g) and 90 days after sowing (33.67, 3.17, 11.85 mg/g). The protein content was higher in vermicompost treatment on 60 and 90 days after sowing (113.37 and 79.69 mg/g, respectively), whereas it was higher in vermicompost+farmyard manure (FYM) treatment on 30 (35.73 mg/g) days after sowing. The carbohydrate content was higher in vermicompost+FYM treatment on 30 and 90 (4.67 and 6.46 mg/g, respectively) days after sowing, while on 60 days after sowing, it was higher in the vermicompost treatment (15.34 mg/g). Chlorophyll a (0.23 mg/g), chlorophyll b (0.38 mg/g) and total chlorophyll (0.62

mg/g) were higher in vermicompost+neem cake treatment on 30 days after sowing. On 60 days after sowing, higher chlorophyll b (2.61 mg/g) and total chlorophyll (3.62 mg/g) contents were observed in the treatment containing vermicompost alone. On 90 days after sowing, chlorophyll a (1.01 mg/g) and total chlorophyll (1.92 mg/g) content was higher in vermicompost alone, and chlorophyll b (1.07 mg/g) in the vermicompost+FYM treatment.

Hiranmai and Vijayakumari (2003) conducted a pot experiment to evaluate the effect of vermicompost applied singly and in combination with different organic manures (farmyard manure (FYM), compostedcoir pith, composted press mud, composted sugarcane trash, biofertilizer, greenmanure, and neem cake) and inorganic fertilizers on the biometric and yield parameters of chilli (*Capsicum annuum*). The biometric parameters varied significantly among the treatments. Vermicompost alone and admixed with FYM, green manure, neem cake and NPK fertilizers were effective in improving various biometric parameters. Better yield parameters were observed in the vermicompost treatment.

Hangarge *et al*. (2002a) studied the effects of single or combined applications of vermicompost (5 t/ha), coirpith compost (2.5 t/ha), organic booster (1 litre m^{-2}), cow dung urine slurry (1 litre m^{-2}) and NPK fertilizer (25, 50 and 100%) on the yield and nutrient uptake of chilli (*Capsicum annuum*) cv. Parbhani Tajes were determined in a field experiment conducted in Parbhani, Maharashtra, India, during 1996-97. Application of coirpith compost+organic booster resulted in the highest yield (105.67 q/ha), yield components and N (51.10 kg/ha), P (5.39 kg/ha) and K (49.34 kg/ha) uptake of chilli.

Hangarge *et al*. (2002b) evaluate the effect of vermicompost and soil conditioner (Tera care) on physical properties of soil and yields of crops under chilli-spinach cropping system, field experiment was conducted during kharif and rabi season

1996-97 on Vertisol at Marathwada Agricultural University, Parbhani. There were eleven treatments replicated thrice in randomized block design. The results indicated that application of soil conditioner @ 2.5 t/ha in combination with organic booster @ 1 litre per m^2 improved the physical condition of soil by reducing bulk density, increasing porosity, water holding capacity and infiltration rate. The yields of green chilli and spinach were significantly increased due to application of soil conditioner and vermicompost along with organic booster as compared to recommended dose of NPK.

A field experiment was carried out by Abou El-Maged *et al*. (2006) at El-Kassasein, Ismailia Governorate, Egypt. During the two successive seasons of 2003/2004 and 2004/2005 to study the response of vegetative growth and yield of some broccoli varieties (Southern star, Perennial crop, Prominence, Atlantic F1 and Monotop) to apply organic manures (Cattle and poultry manures) compared with mineral fertilization. Results indicated that the highest vegetative growth of broccoli plants was recorded by Atlantic F1cvs in the two seasons. Moreover, the highest total yield of broccoli was obtained by perennial crop and Southern star cvs varieties. In the first and second seasons, respectively. The highest vegetative growth of broccoli plants was recorded by plants which was supplied with 100% cattle manure. However, the highest total yield and quality of broccoli were recorded by adding poultry manure in the two seasons. Using poultry manure with Southern star cv. gave the highest total yield and quality of broccoli.

2.2 Influence of GA_3 on crop growth and yield

An experiment was conducted by Reza *et al*. (2015) to find out the influence of GA_3 on growth, yield and yield contributing characters of broccoli (*Brassica oleracea var. Italica*). Four levels of GA_3 viz. C: Control, C:25 ppm GA_3, C: 50 ppm GA_3 and C: 75 ppm GA_3 was used on the experiment. The maximum plant height (31.5

cm), number of leaves (16.6/plant), number of main fingers (12.0/main curd), main curd length (21.3 cm), main curd diameter (19.3 cm), main curd weight (668.0 g/plant) and yield (24.5 t/ha) was found from the application of 50 ppm GA_3 while the minimum from control. It was revealed that, 50 ppm GA_3 gave maximum yield/ha (24.5 tons).

Afrin (2014) conducted an experiment in the Horticulture Farm, Shar-e-Bangla Agricultural University, Dhaka during October 2012 to March 2013. The experiment consisted of two factors, such as Factor A: Three levels of Gibberellic acid (GA_3) i.e. G_0: 0 (control); G_1: 60 ppm GA_3 and G_2: 90 ppm GA_3, respectively and Factor B: Four levels of phosphorus i.e. P_0: 0 (control); P_1: 120; P_2: 140 and P_3: 160 kg P_2O_5 /ha. The experiment was laid out in Randomized Complete Block Design with three replications. Gibberellic acid and phosphorus fertilizer influenced significantly on most of the parameters. In case of GA_3, the highest curd yield (20.64 t/ha) was found from G_1 and the lowest curd yield (18.21 t/ha) was found from G_0. For phosphorous, P_2 performed the highest curd yield (21.52 t/ha) and the lowest (16.18 t/ha) was from P_0. For combined effect, the highest curd yield (23.57 t/ha) was obtained from G_1P_2 and the lowest curd yield (16.25 t/ha) from G_0P_0. So, 60 ppm GA_3 with 140 kg P_2O_5/ha was the best for growth and yield of broccoli.

A field experiment was carried out by Manjit Singh *et al*. (2011) during the winter season on sprouting broccoli cultivar Palam Samridhi at Horticultural Research Centre and Department of Horticulture, H.N.B Garhwal University, Srinagar (Garhwal) Uttarakhand, India. 4 weeks old seedlings were treated before transplanting by dipping their roots for 24 h in different concentration of GA_3 (gibberellic acid), kinetin and their combinations solutions. The GA_3, kinetin and their combination significantly influenced the growth performance, yield andquality characters of sprouting broccoli. GA_3 30 mg L^{-1} + kinetin 30 mg L^{-1}

treatment gave maximum growth and yield of sprouting broccoli whereas, highest vitamin A content found with 40 mg L^{-1} GA_3 and vitamin C was found maximum in GA_3 20 mg L^{-1} + kinetin 20 mg L^{-1} dipping.

Studies on influence of GA, NAA and CCC at three different concentrations on different growth parameters of cabbage (cv. PRIDE OF INDIA) were studied by Lendve *et al*. (2010) found that application of GA 50 ppm was found significantly superior over most of the treatments in terms of number of the leaves, plant spread, and circumference of stem, left area, fresh and dry weight of the leaves, shape index of head, length of root, fresh and dry weight of root. Except treatment GA 75 ppm, gave better results for days required for head initiation and head maturity.

The growth and flowering response of a cold-requiring cauliflower (*Brassica oleracea* var. *botrytis* cv. '60 day') to a range of temperatures under 10 h photoperiod and to growth regulator application were investigated by Guo *et al*. (2004). Endogenous gibberellin (GA_3) concentrations were also assessed under these treatments. Flowering and growth of the inflorescence stalk were correlated with plant developmental stage at the time of a vernalizing cold treatment. Temperature and its duration also affected flowering and inflorescence development. The most effective temperature for inflorescence induction was 100C. Flowering did not occur in non-vernalized plants (250C) even though they had been treated with GA_3. Application of GA_3 promoted inflorescence stalk elongation greatly in vernalized plants (100C), but less so in partially vernalized plants (15 or 200C). Paclobutrazol sprayed at the 8-9 leaf stage significantly suppressed inflorescence stalk length and slightly delayed flower bud formation and anthesis. Vernalization at 100C increased endogenous GA_3 content in both leaves and the inflorescence stalk irrespective of GA_3 treatment.

Vijay and Ray (2000) carried out an experiment that thirty-day old cauliflower (cv. Pant Subhra) seedlings that were transplanted into experimental plots treated with 50 or 100 ppm GA_3, 5 or 10 ppm IBA, or 200 ppm NAA at 15 and 30 days of growth. The results clearly revealed that GA_3 at 100 ppm produced the tallest plants, the largest curds and highest curd yields.

Nidhi-Arora *et al*. (1997) conducted an experiment with Seeds of cauliflower (*Brassica oleracea* var. *botrytis*) cultivars Snowball 16 and Hisar 1 were cultured on MS medium without growth regulators, and cotyledons of resulting 5 to 6-day old seedlings were cultured on 6 different modified MS media. Of the BAP [benzyladenine] concentrations, 2.0 mg/litre was best for shoot regeneration. Addition of IAA (0.1 mg/litre) in combination with BAP (1.0, 2.0 and 5.0 mg/litre) showed that shoot regeneration was maximum at 0.1 mg IAA + 1.0 mg BAP/litre. The two cultivars differed significantly for percentage regeneration and Snowball 16 responded the best to in vitro culture.

Dharmender *et al*. (1996) conducted an experiment to find out the effect of GA_3 or NAA (both at 25, 50 or 75 ppm) on the yield of cabbage (cv. Pride of India) in the field at Jobner, Rajstan, India. They recorded the highest yield following treatment with GA_3 at 50 ppm followed by NAA at 50 ppm (557.54 and 528.66 q/ha respectively). They also reported that combination and higher concentrations of plant growth regulators proved less effective and were uneconomic in comparison to control.

Aditya and Fordham (1995) carried out an experiment in the field and greenhouse to study the effects of cold exposure and GA_3 during early growth stages on the date of flowering of the tropical cauliflower cv. Early Patnai and the temperate cv. Lawyna. Flowering in cv. Early Patnai was advanced by approximately 25 days

following vernalization (1 week at 100C) of 3-week-old plants. They reported that one-week old plants failed to respond to this treatment suggesting juvenile phase lasting up to about the 6-leaf stage in this cultivar.

Islam *et al*. (1993) determined the effective concentration of NAA and GA_3 for promoting growth, yield and ascorbic acid content of cabbage. They used 12.5, 25, 50 and 100 ppm of both the NAA and GA_3 and applied in three different methods i.e. seedling soaked for 12 hours, spraying at 15 and 30 days of transplanting. They found that ascorbic acid content increased up to 50 ppm when sprayed twice with both the growth regulator, while its content was declined afterwards. They also added that two sprays with 50 ppm GA_3 was suitable both for higher yield and ascorbic acid content of cabbage.

Reddy (1989) reported that exogenous application of GA_3 and Urea either alone or in combination enhanced curd size as well as yield. Greatest plant height at curd formation (58.2 cm), curd diameter at maturity (26.8 cm) and increase yield over the control (164%) were obtained with two application of GA_3.

Sharma and Mishra (1989) stated that plant height, curd formation and curd size of cauliflower can increase with foliar application of plant growth regulator. Several experiments were conducted to increase the yield of cauliflower. GA_3 and IAA have a positive effect on curd formation and size of cauliflower.

Muthoo *et al*. (1987) showed that the foliar application of different concentration of GA_3, NAA and molybdenum increased the average fresh and dry weight of leaves. Curd and yield of cauliflower among the individual treatments, gibberellic acid proved to be the best for the vegetative growth of curd and yield of cauliflower (q/ha) followed by naphthalene acetic acid. The effect of treatment combination $G_2N_2M_2$ (100 ppm GA_3, 120 ppm NAA and 0.2% molybdenum) gave

best result for all parameters of growth and yield.

Patil *et al*. (1987) conducted an experiment in a field trial with the cultivar Pride of India applied GA_3 and NAA each at 25, 50, 75 and 100 ppm one month after transplanting. Both the GA_3 and NAA increased the plant height significantly. The maximum plant height and head diameter and head weight were noticed with GA_3 at 50 ppm followed by NAA at 50 ppm. Significant increase in number of outer and inner leaves was noticed with both GA_3 and NAA. Head formation and head maturity was 13 and 12 days earlier with 50 ppm GA_3. Maximum number of leaves and maximum yield (23.83 t/ha) were obtained with 50 ppm GA_3.

Mishra and Singh (1986) conducted an experiment with all possible combinations of the levels of nitrogen (0, 0.5, and 1.0 per cent), boron (0, 0.1, 0.2 per cent) and GA_3 (0, 25, and 50 ppm) in the form of Urea, boric acid, and GA_3 were sprayed on snowball-16 cauliflower respectively. Results revealed that there was significant increase in growth characters namely plant height, diameter of stem, number of leaves per plant, weight of plant, curd yield and nitrogen content in stem and leaves due to N, B and GA_3 applications. However, length of stem was increased only by GA_3 spray.

Islam (1985) conducted an experiment at the Bangladesh Agricultural University Farm, Mymensingh with applying various growth regulators (CCC, GA_3, NAA and IBA) at 30 days after transplanting of 32 day old seedlings, CCC decreased the plant height, size of loose leaves, diameter of cabbage of head and finally the yield. GA_3 increased the plant height, number of loose leaves per plant, size of leaf and finally the yield.

Yabuta *et al*. (1981) reported that application of GA_3 had significantly increased marketable weight, petiole length, and number of leaves, leaf area and height of many leafy vegetables.

Yabuta *et al*. (1981) reported that application of GA_3 had significantly increased marketable weight, petiole length, and number of leaves, leaf area and height of many leafy vegetables.

Abdalla *et al*. (1980) conducted an experiment with cauliflower varieties and the plants were treated with different concentration of IBA (5-40 ppm), GA_3 (10-80 ppm) or NAA (120-160 ppm) 4 weeks after twice more at fortnightly intervals. NAA at 160 ppm gave the best result with regard to curd diameter, weight and color. Similar results were obtained from plants treated with GA_3 at 80 ppm and NAA at 40 ppm.

CHAPTER III
MATERIALS AND METHODS

This chapter deals with the major information regarding materials and methods that were used in conducting the experiment. It consists of a short description of locations of the experimental site, characteristics of soil, climate, materials, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, harvesting, data recording procedure, statistical analysis etc., which are presented as follows;

3.1 Experimental site

The research work relating to determine the growth and yield of broccoli as influenced by Vermicompost and GA_3 was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka-1207 during September, 2018 to May, 2019.

3.2 Location

3.2.1 Geographical Location

The experimental area was situated at 23°77'N latitude and 90°33'E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004). The experimental field belongs to the Agro ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988a).

This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands' surrounded by floodplain (Anon., 1988b).

3.2.2 Climate

Area has subtropical climate, characterized by high temperature, high relative humidity and heavy rainfall in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March). Weather information regarding temperature, relative humidity, rainfall and sunshine hours prevailed at the experimental site during the study period was presented in Appendix I.

3.3 Characteristics of soil

Soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish-brown mottles. Soil pH ranged from 6.1- 6.3 and had organic matter 0.84%. Experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resource and Development Institute (SRDI), Dhaka. Physicochemical properties of the soil are presented in Appendix II.

3.4 Raising of seedlings

Seedlings of broccoli were raised at the Horticulture Farm SAU, Dhaka, under special care in two seedbeds of 3m x 1m size under the polythene tunnel. Soil of the seedbed was well ploughed with a spade and converted into loose friable and dried masses to obtain good tilth aiming to provide a favorable condition for the growth of young seedlings. All the weeds, stubbles and dead roots of the previous crop were removed. Seed bed was dried in the sun to destroy soil insect and protect the young seedlings from the infestation of damping off disease. Decomposed cow dung was applied to the prepared seedbed at the rate of 10 t/ha.No chemical fertilizers were applied for raising the seedlings. Ten grams of seed were sown in each seedbed on October 22, 2018. After sowing the seeds were covered with finished light soil. At the end of germination, shading was done by polythene to protect the young seedlings from

scorching sunshine and heavy rainfall. Light watering, weeding and mulching were done when necessary to provide seedlings with good or ideal conditions for better growth.

3.5 Treatments of experiment

The research work was conducted with two sets of treatment consisting of 3 levels of Vermicompost and 4 levels of GA_3. The factors with their levels are as follows:

Factor A: Different levels of Vermicompost (3)

V_0: control

V_1: 5 t/ha

V_2: 10 t/ha

Factor B: Different levels of GA_3 (4)

M_0: control

M_1: 50 ppm

M_2: 80 ppm

M_3: 110 ppm

There were 12 (3 × 4) treatments combination such as V_0M_0, V_0M_1, V_0M_2, V_0M_3, V_1M_0, V_1M_1, V_1M_2, V_1M_3, V_2M_0, V_2M_1, V_2M_2 and V_2M_3.

3.6 Design of the experiment

Two-factor experiment consisting of 12 treatment combinations was laid out in the randomized complete block design (RCBD) with three replications. At first the whole experimental area was marked with the measuring tape and rope. Total experimental area (28.1m x 7.1 m) was divided into three equal blocks, representing the replications. The total number of plots was 36. Size of each unit plot was 1.8m x 1.2m and the planting distance were 40 cm x 60 cm and there are nine plants were transplanted in each plots. There were 12 unit plots in each block. The distance between two adjacent blocks and plots were kept 75 cm and 50 cm, respectively.

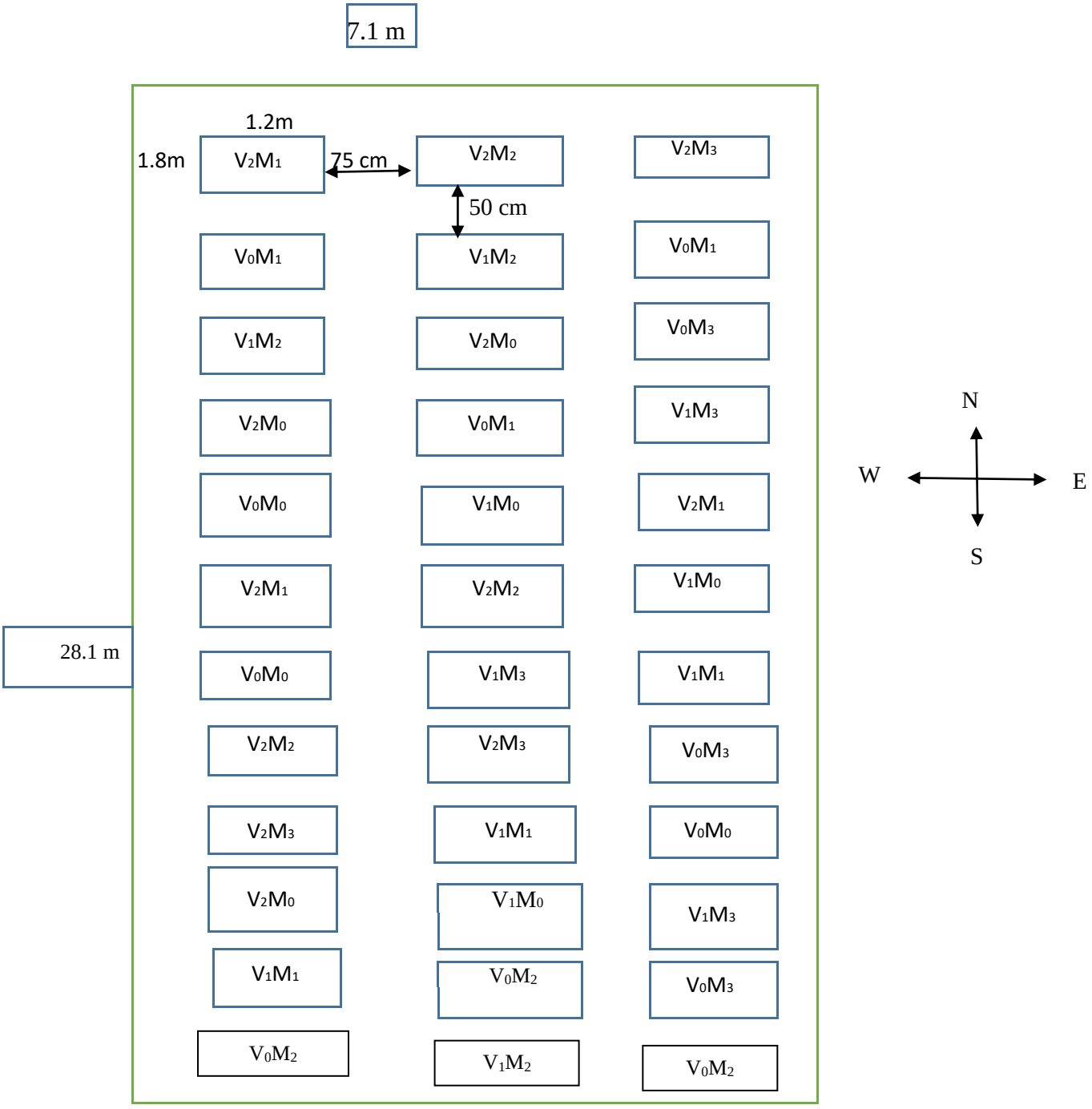

Figure 1. Layout of the experimental field

Factor A: Different levels of Vermicompost (3)
V_0: control
V_1: 5 t/ha
V_2: 10 t/ha
Factor B: Different levels of GA_3 (4)
M_0: control
M_1: 50 ppm
M_2: 80 ppm
M_3: 110 ppm

3.7 Methods of Broccoli cultivation

3.7.1 Land preparation

Experimental plot was fallow during land preparation. The land was first opened on October 20, 2018 with a power tiller and it was exposed to the sun for few days prior to next ploughing followed by laddering to obtain good tilth. Weeds were uprooted and stubbles were removed from the field with the help of spades. Big clods were broken into fine soil particles and the surface was leveled until the desired tilth obtained. The soil was treated with insecticides (Cinocarb 3G @ 4kg/ha) at the time of final land preparation to protect young plants from the attack of insects such as cutworm and mole cricket. Experimental field was made plain and the plots were laid out according to plan.

3.7.2 Application of manures and fertilizers

The following doses of manures and fertilizers recommended for Broccoli production by Rashid (1999).

Manures and Fertilizers	Dose(Kg/ha)
Well decomposed Cowdung	15000
N	115
P	29.5
K	100

The above doses of manures and fertilizers were converted into Vermicompost as per treatment of the experiment. GA_3 was applied as per treatment schedule.

3.7.3 Transplanting

Healthy and uniform sized twenty-five days old seedlings were transplanted in the experimental plots on 23 November 2018. Seedlings were uprooted carefully from the seedbed to avoid damage the root system. To minimize the damage the roots of the seedlings, the seedbed was watered one hour before uprooting the seedlings. Transplanting was done in the afternoon according to the treatment. The seedlings were watered immediately after transplanting. The young transplants were shaded by banana leaf during day time to protect them from scorching sunshine up to 7 days until they were set in the soil. Transplants were kept open at night to allow them receiving dew. A number of seedlings were also planted in the border of the experimental plots for gap filling.

3.7.4 Intercultural operations

Following intercultural operations were done during the period of field experiment:

a. Gap filling

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. Those seedlings were re-transplanted with a big mass of soil with roots to minimize transplanting shock. Replacement was done with healthy seedlings having a ball of earth which were also planted on the same date by the side of the unit plot. Transplants were given shading and irrigation for 7 days for their proper establishment.

b. Weeding

Hand weeding was done at 15, 30 and 45 days after transplanting to keep the plots free from weeds.

c. Mulching

Mulching was done as soon as the soil became workable after irrigation by breaking the crust of the soil for easy aeration and to conserve soil moisture as and when needed. This operation was done by khurpi or nirani.

d. Earthing up

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

e. Irrigation

Light watering was given at every morning and afternoon according to its requirements and was continued for a week for well establishment of the transplanted seedlings.

f. Pest and disease control

Insect infestation was a serious problem during the period of establishment of seedling in the field. In spite of Cinocarb 3G applications during final land preparation few young plants were damaged due to the attack of mole cricket and cut worm. Cut worms were controlled both mechanically and spraying Darsban 29 EC @ 3%. Some of plants were infected by Alternaria leaf spot disease caused by *Alternaria brassicae*. To prevent the spread of the disease Rovral @ 2 g per liter of water was sprayed in the field. The diseased leaves were also collected from the infested plant and removed from the field. The nightingale visited the fields in the morning and afternoon. The birds were found to puncture the soft leaves and newly initiated curd and were controlled by striking kerosene tin frequently during day time.

3.8 Harvesting

Harvesting of the broccoli var. Premium crop was not possible on a certain or particular date because curd initiation as well as curd maturation period in different plants were not uniform or similar probably due to different management practices and genetic or other factors. Only the compact mature curds were harvested with 2-4 cm stalk by using a sharp knife. According to Thompson and Kelly (1997) the curds were harvested in compact condition before the flower buds opened. Before harvesting of the broccoli head, compactness of the head was tested by pressing with thumbs. After harvesting the main curd, secondary shoots were developed from the leaf axils, which also developed into small secondary curds and were harvested over a period of time. The crop under investigation was harvested for the first time on January 28, 2018 and the last harvesting was done on February 12, 2018.

3.9 Data collection

Five plants were randomly selected from the middle rows of each unit plot for avoiding border effect except yields of curds, which was recorded plot wise. 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 height of the plant, number of leaves per plant and length of longest leaf and breadth of longest leaf were collected 30, 45, 55 and 65 days after transplanting (DAT). All other parameters were recorded during harvest and after harvest. Data were recorded on the following parameters:

3.9.1 Growth parameters

3.9.1.1 Plant height

Plant height was measured from sample plants by using meter scale 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, 10 days interval starting from 30 days after

transplanting (DAT) and continued upto 65 DAT to observe the growth rate of plants.

3.9.1.2 Number of leaves per plant

The number of leaves was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at 15, 10 days interval starting from 30 DAT and continued upto 65 DAT and finally the mean values were calculated and was expressed in centimeter (cm).

3.9.1.3 Length of largest leaf

The length of largest leaf was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at 15, 10 days interval starting from 30 DAT and continued upto 65 DAT and finally the mean values were calculated and was expressed in centimeter (cm).

3.9.1.4 Breadth of largest leaf

Breadth of largest leaf was recorded from 5 selected plants at 30, 45, 55 and 65 days after transplanting and finally the mean values were calculated and was expressed in centimeter (cm).

3.9.1.5 Days required for first curd initiation

Each plant of the experiment plot was kept under close observation from 40 DAT to count days required for initiation. Total number of days from the date of transplanting to the visible curd initiation was recorded.

3.9.1.6 Weight of primary curd

The curds from sample plants were harvested, cleaned and weighted. The weight of every primary curd was weighted by weighing machine and mean values was counted.

3.9.1.7 Diameter of primary curd

The curds from sample plants were sectioned vertically at the middle position with a sharp knife. The diameter of the curd was measured in centimeter (cm) with a meter scale as the horizontal distance from one side to another side of the widest part of the sectioned curd and mean value was recorded.

3.9.1.8 Length of stem

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

3.9.1.9 Diameter of stem

The diameter of the stem was measured at the point where the central stem was cut off. The diameter of the stem was recorded in three dimensions with scale and the average of three figures was taken into account in centimeter (cm).

3.9.1.10 Weight of leaves per plant

Weight of leaves was recorded including the weight of all leaves and expressed in gram (g).

3.9.1.11 Number of secondary curds per plant

The total number of secondary curds per plant was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at during harvest.

3.9.1.12 Weight of secondary curd

The secondary curds from sample plants were harvested, cleaned and weighted. The weight of every secondary curd from each plant was weighted by weighing machine and added them in plant wise and finally mean values was calculated and recorded.

3.10 Performance on yield

3.10.1 Yield/plot

Yield per unit plot was calculated by adding the weight of all the central curds and secondary curds produced in the respective plot. Yield of all plants in each unit plot was recorded and was expressed in kilogram (kg).

3.10.2 Yield/hectare

Yield per hectare was calculated out by converting per plot yield data to per hectare and was measured in ton (t).

3.11 Statistical analysis

Data were collected from the experimental plot in respect of various characteristics were compiled and tabulated in proper form for statistical analysis. Collected data on different parameters were statistically analyzed using the MSTAT computer package program. Least Significant Difference (LSD) technique at 5% level of significance was used to compare the mean differences among the treatments (Gomez and Gomez, 1984).

CHAPTER-IV
RESULTS AND DISCUSSION

This chapter comprises of the presentation and discussion of the results obtained due to the influence of different levels of Vermicompost and GA_3 and their possible combined effect on the growth and yield of Broccoli. The results are presented in Table 1 to 15, figures 2 to 5 and necessary discussions have been presented under the following sub-headings. The analysis of variances for different characters is given in Tables 1 to 15 and appendix III-VII.

4.1 Plant height

Different levels of Vermicompost application showed significant effect on plant height of broccoli at different days after transplanting (Figure 2 and Appendix III). The tallest plant at 30 DAT (26.96 cm), 45 DAT (42.03 cm), 55 DAT (47.88 cm) and 65 DAT (77.20 cm) was recorded from 10 t/ha vermicompost application. In comparison, the shortest plant at 30 DAT (14.38 cm), 45 DAT (28.80 cm), 55 DAT (34.38 cm) and 65 DAT (64.15 cm) was observed in control treatment of vermicompost. Plant height increased with increased application of vermicompost. Vermicompost ensured favorable condition for the growth of broccoli with cell division and elongation of cell and the ultimate result was the tallest plant. Mamta *et al*. (2012) observed the similar result. They reported that plant height was higher in the vermicompost treated field as compared to control. Ali *et al*. (2011) observed that the plant height of chilli variety (Sanjibani) in the vermicompost used field were higher than the control.

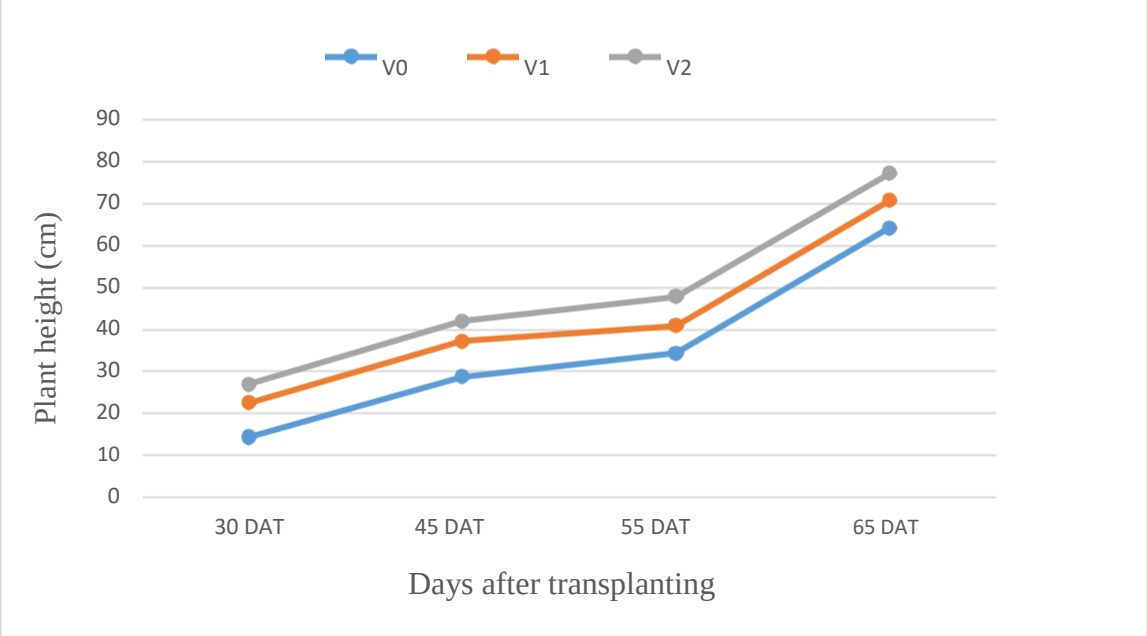

Fig. 2. Effect of vermicompost on plant height of broccoli

V_0: control, V_1: 5 t/ha and V_2: 10 t/ha

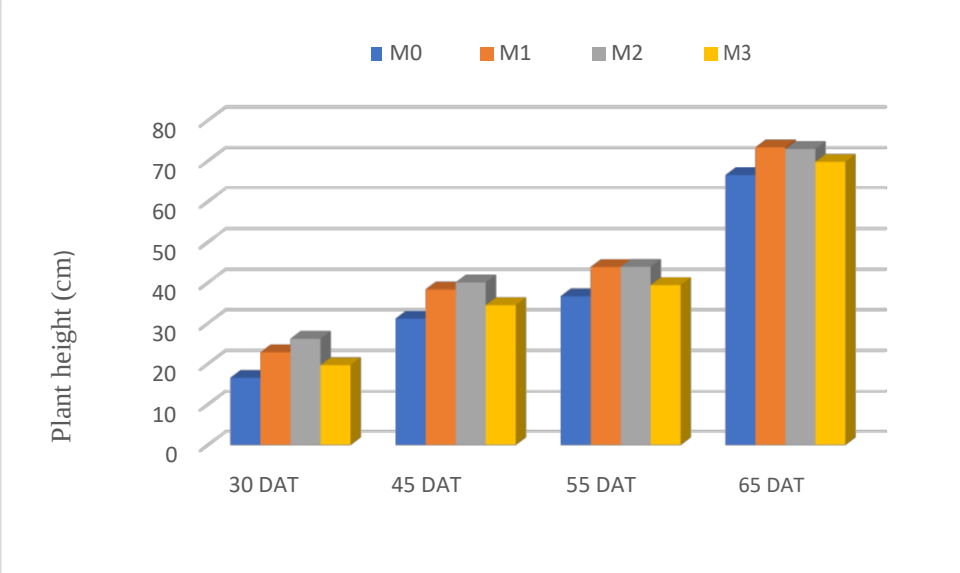

Fig. 3. Effect of GA_3 on plant height of Broccoli

M_0: control, M_1: 50 ppm, M_2: 80 ppm and M_3: 110 ppm

Table 1. Combined effect of Vermicompost and GA_3 on plant height of Broccoli

Treatments combinations	Plant height (cm) at			
	30 DAT	45 DAT	55 DAT	65 DAT
V_0M_0	12.46 j	26.37 i	32.16 i	62.20 h
V_0M_1	14.93 hi	29.80 gh	35.67 g	65.37 fg
$V0M_2$	15.63 hi	30.33 gh	36.27 fg	65.30 fg
V_0M_3	14.50 i	28.73 hi	33.07 h	63.70 g
V_1M_0	17.53 gh	32.50 fg	38.20 ef	68.10 ef
V_1M_1	24.67 cd	40.47 c	45.37 c	75.20 c
V_1M_2	27.33 bc	39.47 c	39.07 de	68.27 ef
V_1M_3	20.90 ef	36.33 de	40.97 d	71.37 d
V_2M_0	19.70 fg	34.57 ef	40.27 de	69.57 de
V_2M_1	29.00 b	44.80 b	50.60 b	79.53 b
V_2M_2	35.53 a	50.43 a	56.43 a	85.33 a
V_2M_3	23.60 de	38.33 cd	44.20 c	74.37 c
Level of sig.	**	**	**	**
LSD $_{(0.05)}$	2.72	2.74	2.27	2.27
CV (%)	7.54	4.50	4.57	5.31

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

V_0: control, V_1: 5 t/ha and V_2: 10 t/ha

M_0: control, M_1: 50 ppm, M_2: 80 ppm and M_3: 110 ppm

Different concentrations of GA_3 showed significant differences on plant height of broccoli at 30, 45, 55 and 65 DAT (Figure 3 and Appendix III). At 30, 45, 55 and 65 DAT, the tallest plant (26.17 cm, 40.08 cm, 43.92 cm and 73.37 cm) was found from M_2 (M_2: 80 ppm), which was statistically identical (22.87 cm, 38.36 cm, 43.88 cm and 72.97 cm) with M_1 (M_1: 50 ppm), while the shortest plant (16.56 cm, 31.14 cm, 36.67 cm and 66.55 cm) was found from M_0 (control i.e. no GA_3) (Figure 3). Sharma and Mishra (1989) reported that plant height increased with foliar application of GA_3.

Due to combined effect of different levels of vermicompost and different concentrations of GA_3 showed significant differences on plant height of broccoli at

30, 45, 55 and 65 DAT (Table 1 and Appendix III). At 30 DAT, 45 DAT, 55 DAT and 65 DAT, the tallest plant (35.53 cm, 50.43 cm, 56.43 cm and 85.33 cm, respectively) was recorded from the treatment combination of (V_2M_2). On the other hand, the shortest plant at 30 DAT, 45 DAT, 55 DAT and 65 DAT (12.46 cm, 26.37 cm, 32.67 cm and 62.20 cm, respectively) was observed in control treatment combination (V_0M_0).

4.2 Number of Leaves per plant

Vermicompost had a significant influence on the number of leaves of broccoli plants at 30, 45, 55 and 65 DAT (Table 2, Appendix III). At 30 DAT, V_2 produced the highest number of leaves (10.77) and the lowest (7.90) was measured from V_0. At 45 DAT, the highest number of leaves per plant (14.62) was recorded from V_2 while the lowest (11.69) was recorded from V_0. At 55 DAT, the highest number of leaves per plant (17.21) was measured from V_2 while the lowest (12.99) was recorded from V_0. At 65 DAT, the highest number of leaves per plant (19.19) was measured from V_2 while the lowest (15.15) was recorded from V_0 treatment.

GA_3 had a significant influence on number of leaves of broccoli plants at 30, 45, 55 and 65 DAT (Table 2 and Appendix III). At 30 DAT, M_2 produced the highest number of leaves per plant (10.51) which was statistically similar to that of M_1 and M_3 where as M_0 produced the lowest (7.84). At 45 DAT, M_2 produced the highest number of leaves per plant (14.29) whereas M_0 produced the lowest number of leaves (11.73). At 55 DAT, M_2 produced the highest number of leaves per plant (17.09) whereas M_0 produced the lowest number of leaves (13.40). At 65 DAT, the highest number of leaves (19.44) per plant was recorded from M_2 and the lowest (14.32) was measured in M_0.

The number of leaves was significantly influenced by the combined effect of vermicompost and GA_3 at 30, 45, 55 and 65 DAT (Table 3, Appendix III). At 30

DAT, the highest number of leaves per plant (12.17) was measured from V_2M_2 which was statistically similar to that of V_2M_3 while the lowest (6.83) was recorded from V_0M_0. At 45 DAT, the highest number of leaves per plant (16.00) was recorded from V_2M_2 which was statistically similar to that of V_2M_3 while the lowest (10.83) was recorded from V_0M_0. At 55 DAT, the highest number of leaves per plant (20.40) was measured from V_2M_2 while the lowest (11.23) was recorded from V_0M_0. At 65 DAT, the highest number of leaves per plant (23.07) was measured from V_2M_2 while the lowest (13.80) was recorded from V_0M_0.

Table 2. Effect of Vermicompost and GA_3 on number of leaves per plant of Broccoli

Treatments	Number of Leaves per plant at			
	30 DAT	45 DAT	55 DAT	65 DAT
	Effect of vermicompost			
V_0	7.90 c	11.79 c	12.99 c	15.15 c
V_1	9.72 b	13.62 b	15.93 b	18.58 b
V_2	10.77 a	14.62 a	17.21 a	19.19 a
Level of sig.	**	**	**	**
LSD $_{(0.05)}$	0.31	0.23	0.59	0.28
CV (%)	7.02	6.93	6.63	7.28
Treatments	Effect of GA_3			
M_0	7.844 c	11.73 c	13.40 d	14.32 d
M_1	10.16 a	14.17 a	16.38 b	17.33 c
M_2	10.51 a	14.29 a	17.09 a	19.44 a
M_3	9.356 b	13.18 b	14.63 c	18.20 b
Level of sig.	**	**	**	**
LSD $_{(0.05)}$	0.36	0.26	0.68	2.09
CV (%)	7.02	6.93	6.63	7.28

V_0: control, V_1: 5 t/ha and V_2: 10 t/ha

M_0: control, M_1: 50 ppm, M_2: 80 ppm and M_3: 110 ppm

Table 3. Combined effect of Vermicompost and GA_3 on number of leaves per plant of broccoli

Treatments combinations	Number of Leaves per plant at			
	30 DAT	45 DAT	55 DAT	65 DAT
V_0M_0	6.83 f	10.83 g	11.23 h	13.80 e
V_0M_1	7.96 e	11.77 f	14.17 efg	14.27 cd
V_0M_2	8.83 d	12.80 e	13.43 fg	17.77 bcd
V_0M_3	7.96 e	11.77 f	13.13 g	15.27 cd
V_1M_0	7.86 e	11.87 f	14.40 efg	14.07 d
V_1M_1	10.73 b	14.90 b	16.47 cd	19.43 ab
V_1M_2	10.53 b	14.07 cd	17.43 bc	17.50 bcd
V_1M_3	9.76 c	13.63 d	15.40 de	22.40 a
V_2M_0	8.83 d	12.50 e	14.57 ef	15.10 cd
V_2M_1	11.77 a	15.83 a	18.50 b	18.30 bc
V_2M_2	12.17 a	16.00 a	20.40 a	23.07 a
V_2M_3	10.33 bc	14.13 c	15.37 de	19.33 ab
Level of sig.	**	**	**	**
LSD $_{(0.05)}$	0.62	0.46	1.18	3.62
CV (%)	7.02	6.93	6.63	7.28

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

V_0: control, V_1: 5 t/ha and V_2: 10 t/ha

M_0: control, M_1: 50 ppm, M_2: 80 ppm and M_3: 110 ppm

4.3 Length of largest leaf

Vermicompost had a significant influence on the length of largest leaf of broccoli plants at 30, 45, 55 and 65 DAT (Figure 4, Appendix IV). At 30 DAT, V_2 produced the highest length of largest leaf (28.98 cm) and the lowest (18.52 cm) was measured from V_0. At 45 DAT, the highest length of largest leaf (46.53 cm) was recorded from V_2 while the lowest (36.90 cm) was recorded from V_0. At 55 DAT, the highest length of largest leaf (56.73 cm) was measured from V_2 while the lowest (47.20 cm) was recorded from V_0. At 65 DAT, the highest length of largest leaf (59.91 cm) was measured from V_2 while the lowest (50.30 cm) was recorded from V_0.

GA_3 had a significant influence on length of largest leaf of broccoli plants at 30, 45, 55 and 65 DAT (Figure 5 and Appendix IV). At 30 DAT, M_2 produced the highest length of largest leaf (26.29 cm) which was statistically similar to that of M_1 and M_3 where as M_0 produced the lowest (21.51 cm). At 45 DAT, M_2 produced the highest length of largest leaf (44.69 cm) whereas M_0 produced the lowest (40.06 cm). At 55 DAT, M_2 produced the highest length of largest leaf (55.06 cm) whereas M_0 produced the lowest (50.49 cm). At 65 DAT, the highest length of largest leaf (58.16 cm) was recorded from M_2 and the lowest (53.41 cm) was measured in M_0.

The length of largest leaf was significantly influenced by the interaction effect of vermicompost and GA_3 at 30, 45, 55 and 65 DAT (Table 4, Appendix III). At 30 DAT, the highest length of largest leaf (30.67 cm) was measured from V_2M_2 which was statistically similar to that of V_2M_3 while the lowest (15.46 cm) was recorded from V_0M_0. At 45 DAT, the highest length of largest leaf (50.03 cm) was recorded from V_2M_2 which was statistically similar to that of V_2M_3 while the lowest (35.13 cm) was recorded from V_0M_0. At 55 DAT, the highest length of largest leaf (60.57 cm) was measured from V_2M_2 while the lowest (45.73 cm) was recorded from V_0M_0. At 65 DAT, the highest length of largest leaf (63.60 cm) was measured from V_2M_2 while the lowest (48.60 cm) was recorded from V_0M_0.

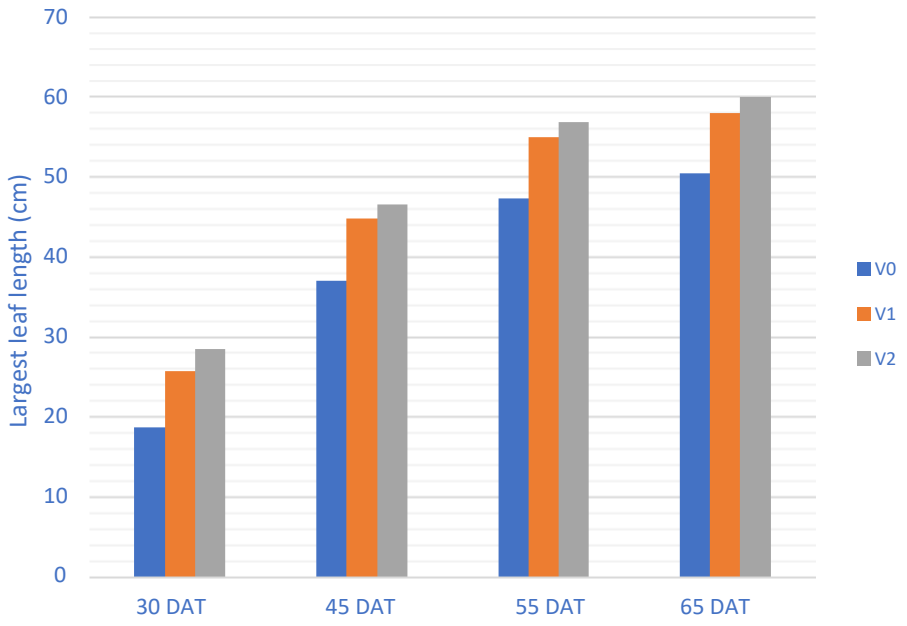

Fig. 4. Effect of vermicompost on length of largest leaf of broccoli

V_0: control, V_1: 5 t/ha and V_2: 10 t/ha

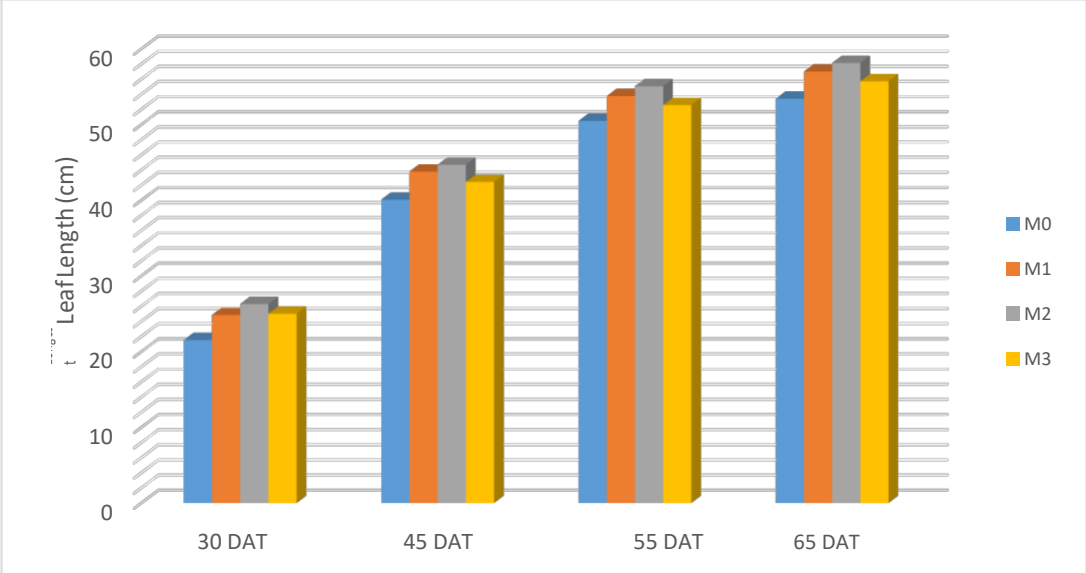

Fig. 5. Effect of GA_3 on largest leaf length of broccoli

M_0: control, M_1: 50 ppm, M_2: 80 ppm and M_3: 110 ppm

Table 4. Combined effect of Vermicompost and GA_3 on length of largest leaf of Broccoli

Treatments combinations	Length of longest leaf (cm) at			
	30 DAT	45 DAT	55 DAT	65 DAT
V_0M_0	15.46 h	35.13 f	45.73 f	48.60 g
V_0M_1	19.40 fg	37.87 ef	47.80 ef	50.83 fg
V_0M_2	21.53 efg	39.37 def	49.80 def	52.93 efg
V_0M_3	17.67 g	35.57 f	45.83 f	49.03 g
V_1M_0	23.30 def	41.50 cde	51.80 cde	54.73 def
V_1M_1	25.33 cde	45.37 abc	55.40 bc	58.57 bcd
V_1M_2	26.67 abcd	44.67 bc	54.80 bc	57.87 bcd
V_1M_3	27.67 abc	47.20 ab	57.47 ab	60.57 abc
V_2M_0	25.77 bcd	43.53 bcd	53.93 bcd	56.90 cde
V_2M_1	29.73 ab	48.10 ab	58.07 ab	61.60 ab
V_2M_2	30.67 a	50.03 a	60.57 a	63.60 a
V_2M_3	29.77 ab	44.47 bc	54.37 bcd	57.53 bcd
Level of sig.	**	**	**	**
LSD $_{(0.05)}$	3.82	4.31	4.24	4.13
CV (%)	9.24	5.96	5.26	5.08

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

V_0: control, V_1: 5 t/ha and V_2: 10 t/ha

M_0: control, M_1: 50 ppm, M_2: 80 ppm and M_3: 110 ppm

4.4 Breadth of largest leaf

Vermicompost had a significant influence on the breadth of largest leaf of broccoli plants at 30, 45, 55 and 65 DAT (Table 5, Appendix IV). At 30 DAT, V_2 produced the highest breadth of largest leaf (13.61 cm) and the lowest (6.73 cm) was measured from V_0. At 45 DAT, the highest breadth of largest leaf (18.43 cm) was found from V_2 while the lowest (11.78 cm) was recorded from V_0. At 55 DAT, the highest breadth of largest leaf (20.35 cm) was measured from V_2 while the lowest (13.440 cm) was recorded from V_0. At 65 DAT, the highest breadth of largest leaf (22.63 cm) was measured from V_2 while the lowest(14.63 cm) was recorded from V_0.

GA_3 had a significant influence on breadth of largest leaf of broccoli plants at 30, 45, 55 and 65 DAT (Table 5 and Appendix IV). At 30 DAT, M_2 produced the highest breadth of largest leaf (13.17 cm) which was statistically similar to that of M_1 and M_3 where as M_0 produced the lowest (8.40 cm). At 45 DAT, M_2 produced the highest breadth of largest leaf (17.66 cm) whereas M_0 produced the lowest (13.51 cm). At 55 DAT, M_2 performed the highest breadth of largest leaf (19.54 cm) whereas M_0 produced the lowest (14.84 cm). At 65 DAT, the highest breadth of largest leaf (21.60 cm) was recorded from M_2 and the lowest (17.52 cm) was measured in M_0.

The breadth of largest leaf was significantly influenced by the interaction effect of vermicompost and GA_3 at 30, 45, 55 and 65 DAT (Table 6, Appendix IV). At 30 DAT, the highest breadth of largest leaf (17.07 cm) was measured from V_2M_2 which was statistically similar to that of V_2M_3 while the lowest (5.76 cm) was recorded from V_0M_0. At 45 DAT, the highest breadth of largest leaf (20.20 cm) was recorded from V_2M_2 which was statistically similar to that of V_2M_3 while the lowest (10.43 cm) was recorded from V_0M_0. At 55 DAT, the highest breadth of largest leaf (22.93 cm) was measured from V_2M_2 while the lowest (11.90 cm) was recorded from V_0M_0. At 65 DAT, the highest breadth of largest leaf (24.47 cm) was measured from V_2M_2 while the lowest (14.53 cm) was recorded from V_0M_0.

Table 5. Effect of Vermicompost and GA_3 on breadth of largest leaf of Broccoli

Treatments	Breadth of largest leaf (cm) at			
	30 DAT	45 DAT	55 DAT	65 DAT
	Effect of Vermicompost			
V_0	6.73 c	11.78 c	13.44 c	14.63 b
V_1	12.13 b	17.04 b	18.42 b	21.86 b
V_2	13.61 a	18.43 a	20.35 a	22.63 a
Level of sig.	**	**	**	**
LSD $_{(0.05)}$	0.88	0.82	1.38	2.23
CV (%)	9.64	6.16	8.24	7.65
Treatments	Effect of GA_3			
M_0	8.40 d	13.51 c	14.84 c	17.52 c
M_1	11.64 b	16.72 a	18.21 ab	20.72 a
M_2	13.17 a	17.66 a	19.54 a	21.60 a
M_3	10.08 c	15.11 b	17.01 b	17.66 b
Level of sig.	**	**	**	**
LSD $_{(0.05)}$	1.02	0.84	1.59	2.57
CV (%)	9.64	6.16	8.24	7.65

V_0: control, V_1: 5 t/ha and V_2: 10 t/ha

M_0: control, M_1: 50 ppm, M_2: 80 ppm and M_3: 110 ppm

Table 6. Combined effect of Vermicompost and GA_3 on breadth of largest leaf of Broccoli

Treatments combinations	Breadth of largest leaf (cm) at			
	30 DAT	45 DAT	55 DAT	65 DAT
V_0M_0	5.76 i	10.43 g	11.90 g	14.53 f
V_0M_1	6.96 gh	11.73 f	13.47 f	15.67 d
V_0M_2	8.06 fg	13.17 ef	15.03 ef	17.27 cd
V_0M_3	6.13 h	11.77 f	13.37 f	11.07 e
V_1M_0	9.23 ef	14.57 de	15.33 ef	18.20 bcd
V_1M_1	12.77 cd	17.93 b	19.33 bcd	21.73 abc
V_1M_2	14.37 bc	19.60 a	20.67 abc	23.07 ab
V_1M_3	12.13 d	16.07 cd	18.33 cd	20.43 abcd
V_2M_0	10.20 e	15.53 d	17.30 de	19.83 abcd
V_2M_1	15.20 b	20.50 a	21.83 ab	24.77 a
V_2M_2	17.07 a	20.20 a	22.93 a	24.47 a
V_2M_3	11.97 d	17.50 bc	19.33 bcd	21.47 abc
Level of sig.	**	**	**	**
LSD $_{(0.05)}$	1.768	1.643	2.767	4.460
CV (%)	9.64	6.16	8.24	7.65

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

V_0: control, V_1: 5 t/ha and V_2: 10t/ha

M_0: control, M_1: 50 ppm, M_2: 80 ppm and M_3: 110 ppm

4.5 Days required for first curd initiation

Different levels of vermicompost application showed significant effect on first curd initiation of broccoli (Table 7 and Appendix V). The maximum days required for first curd initiation (53.01) was recorded from control treatment of vermicompost. In comparison, the minimum days required for first curd initiation (47.45) was observed in V_2.

Significant variation was found for different GA_3 on days required for first curd initiation of broccoli (Table 8 and Appendix V). The minimum days required for first curd initiation (48.77) was found from M_2whereas the maximum days required for first curd initiation (51.73) from M_0.

Vermicompost and GA_3 showed significant differences on days required for first curd initiation of broccoli due to their combined effect (Table 9 and Appendix V). The minimum days required for first curd initiation (45.78) was attained from V_2M_2 treatment combination and the maximum days required for first curd initiation (55.33) was found from V_0M_0 treatment combination.

4.6 Weight of primary curd

Different levels of vermicompost application showed significant effect on the weight of primary curd of broccoli (Table 7 and Appendix V). The maximum (468.40 g) primary curd weight was recorded from V_2 treatment followed by V_1 (443.10 g)treatments respectively. The lowest (330.69 g) primary curd weight was found from V_0 treatment.

There was significant influence of different concentrations of GA_3 of broccoli on the primary curd weight (Table 8 and Appendix V). The primary curd attained the maximum (456.90 g) weight observed from M_2 treatment. The lowest (359.14 g) primary curd weight was found from M_0 treatment.

The combined effect of different vermicompost and GA_3 had significant influenced on the primary curd weight of broccoli (Table 9 and Appendix V). The highest (531.00 g) central curd weight was found from V_2M_2. This was followed by the treatment combinations V_2M_1 (501.10 g) and V_1M_2 (489.20 g). The lowest (316.32 g) weight of primary curd was observed in V_0M_0 treatment combination.

4.7 Diameter of primary curd

Significant variation was recorded in terms of diameter of primary curd due to application of different levels of vermicompost in broccoli (Table 7 and Appendix V). The highest diameter of primary curd (11.35 cm) was recorded from V_2 and the lowest (7.81 cm) was recorded from V_0.

Due to application of different levels of GA_3 showed significant on diameter of primary curd in broccoli (Table 8 and Appendix VI). The highest diameter of primary curd (10.71 cm) was recorded from M_2, which was statistically identical (10.06 cm) with M_1, while the lowest diameter (9.06 cm) from M_0.

Significant variation was recorded due to combined effect of different levels of vermicompost and GA_3 in terms of diameter of primary curd (Table 9 and Appendix V). The highest diameter of primary curd (11.87 cm) was found from V_2M_2 treatment combination, whereas the lowest diameter (7.20 cm) was recorded from V_0M_0 treatment combination.

Table 7. Main effect of vermicompost on days of first curd initiation, weight of primary curd, diameter of primary curd and length of stem of broccoli

Treatments	Days required for first curd initiation	Weight of primary curd	Diameter of primary curd	Length of Stem
V_0	53.01 a	330.69 c	7.81 c	18.01 c
V_1	48.33 b	443.1 b	10.47 b	20.11 b
V_2	47.45 c	468.4 a	11.35 a	21.52 a
Level of sig	**	**	**	**
LSD $_{(0.05)}$	1.10	2.30	0.69	0.93
CV (%)	4.60	5.59	8.37	5.66

V_0: control, V_1: 5 t/ha and V_2: 10 t/ha

Table 8. Main effect of GA_3 on days required for first curd initiation, weight of primary curd, diameter of primary curd and length of stem of broccoli

Treatments	Days required for first curd initiation	Weight of primary curd	Diameter of primary curd	Length of Stem
M_0	51.73 a	359.14 d	9.06 d	18.11 d
M_1	49.00 c	434.5 b	10.06 b	19.82 b
M_2	48.77 d	456.9 a	10.71 a	20.39 a
M_3	50.24 b	405.8 c	9.61 c	19.06 c
Level of sig	**	**	**	**
LSD $_{(0.05)}$	1.27	2.26	0.80	1.08
CV (%)	4.60	5.59	8.37	5.66

M_0: control, M_1: 50 ppm, M_2: 80 ppm and M_3: 110 ppm

Table 9. Combined effect of Vermicompost and GA_3 on days required for first curd initiation, weight of primary curd, diameter of primary curd and length of stem of broccoli

Treatments combinations	Days required for first curd initiation	Weight of primary curd	Diameter of primary curd	Length of Stem
V_0M_0	55.33 g	316.32 l	7.20 e	17.00 d
V_0M_1	52.23 ab	330.5 j	7.84 d	17.83 c
V_0M_2	51.07 bc	350.5 i	8.50 cd	18.67 bc
V_0M_3	53.43 a	325.5 k	7.73 d	18.53 bc
V_1M_0	50.49 bcd	370.2 h	9.66 bc	19.53 bc
V_1M_1	48.19 de	472.0 d	10.63 ab	20.40 ab
V_1M_2	49.46 cd	489.2 c	10.87 ab	20.60 ab
V_1M_3	49.17 cd	440.9 f	10.70 ab	19.90 abc
V_2M_0	49.36 cd	390.4 g	10.30 ab	19.60 bc
V_2M_1	46.57 ef	501.1 b	11.70 a	20.63 ab
V_2M_2	45.78 a	531.0 a	11.87 a	21.90 a
V_2M_3	48.11 de	451.1 e	10.40 ab	19.93 abc
Level of sig.	**	**	**	**
LSD $_{(0.05)}$	2.20	4.61	1.38	1.87
CV (%)	4.60	5.59	8.37	5.66

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

V_0: control, V_1: 5 t/ha and V_2: 10 t/ha

M_0: control, M_1: 50 ppm, M_2: 80 ppm and M_3: 110 ppm

4.8 Length of stem

Different levels of Vermicompost showed significant variation on length of stem of broccoli (Table 7 and Appendix V). The highest length of stem (21.52 cm) was found from V_2 which was statistically similar (20.11 cm) with V_1, while the lowest length of stem (18.01 cm) was recorded from V_0.

Significant variation was recorded on length of stem of broccoli due to different levels of GA_3 under the present trial (Table 8 and Appendix V). The highest length of stem (20.39 cm) was recorded from M_2 which was statistically similar (19.82 cm) by M_1, whereas the lowest length of stem (18.11 cm) was recorded from M_0.

Manjit Singh (2011) showed that GA_3 increase the length of stem upto a certain limit of GA_3 concentration.

Combined effect of different levels of vermicompost and GA_3 showed significant differences on length of stem of broccoli (Table 9 and Appendix V). The highest length of stem (21.90 cm) was recorded from V_2M_2 which was statistically similar to V_1M_1,V_1M_2,V_1M_3 &V_2M_1 treatment combination, again the lowest length of stem (17.00 cm) was found from V_0M_0.

4.9 Diameter of stem

Different levels of vermicompost showed significant variation for diameter of stem of broccoli (Table 10 and Appendix VI). The highest diameter of stem (3.78 cm) was obtained from V_2 which was statistically similar (3.45 cm) with V_1, whereas the lowest diameter of stem (2.30 cm) was recorded from V_0.

Significant variation was recorded on diameter of stem of broccoli for different levels of GA_3(Table 11 and Appendix VI). The highest diameter of stem (3.46 cm) was found from M_2 which was statistically similar (3.38 cm) to M_1, while the lowest diameter (2.60 cm) was found from M_0. Sharma and Mishra, (1989) reported that curd size increased with foliar application of GA_3.

Combined effect of different levels of vermicompost and GA_3 significant differences on diameter of stem of broccoli (Table 12 and Appendix VI). The highest diameter of stem (4.13 cm) was recorded from V_2M_2 and the lowest diameter of stem (2.00 cm) was found from V_0M_0.

4.10 Weight of leaves per plant

Different levels of vermicompost showed significant variation on weight of leaves of broccoli under the present trial (Table 10 and Appendix VI). The maximum weight of leaves (97.01 g) was recorded from V_2 which was statistically identical

(90.27 g) to V1, while the minimum weight of leaves (70.79 g) was found from V_0.

Significant variation was recorded on fresh weight of leaves of broccoli due to application of different levels of GA_3 (Table 11 and Appendix VI). The maximum weight of leaves (95.17 g) was recorded from M_2 which was followed (90.91 g) by M_1, whereas the minimum weight of leaves (75.36 g) was recorded from M_0 (Table 10). Lendve *et al*. (2010) found that application of GA_3 50 ppm was found significantly superior in terms of weight leaves.

Due to the combined effect of different levels of vermicompost and GA_3 showed significant differences on weight of leaves of broccoli ((Table 12 and Appendix VI). The maximum weight of leaves (110.00 g) was recorded from V_2M_2 and the minimum fresh weight (65.38 g) was found from V_0M_0.

Table 10. Main effect of vermicompost on diameter of stem, weight of leaves per plant, number of secondary curd, weight of secondary curd of Broccoli

Treatments	Diameter Of Stem	Weight of Leaves per Plant	Number of Secondary curd	Weight of secondary curd
V_0	2.30 c	70.79 c	1.91 c	76.08 c
V_1	3.45 b	90.27 b	2.49 b	81.21 b
V_2	3.78 a	97.01 a	2.78 a	84.57 a
LSD $_{(0.05)}$	0.93	0.95	0.34	0.63
CV (%)	8.43	6.27	8.31	4.93

V_0: control, V_1: 5 t/ha and V_2: 10 t/ha

Table 11. Main effect of GA_3 on diameter of stem, weight of leaves per plant, number of secondary curd, weight of secondary curd of broccoli

Treatments	Diameter of stem	Weight of leaves per plant	Number of Secondary curd	Weight of secondary curd
M_0	2.60 d	75.36 d	2.13 d	76.16 d
M_1	3.38 a	90.91 b	2.38 b	81.04 b
M_2	3.46 a	95.17 a	2.52 a	83.23 a
M_3	3.20 c	82.66 c	2.25 c	77.89 c
LSD $_{(0.05)}$	0.37	1.10	0.39	0.73
CV (%)	8.43	6.27	8.31	4.93

M_0: control, M_1: 50 ppm, M_2: 80 ppm and M_3: 110 ppm

Table 12. Combined effect of vermicompost and GA_3 on diameter of stem, weight of leaves per plant, number of secondary curd, weight of secondary curd of broccoli

Treatments combinations	Diameter Of stem	Weight of leaves per plant	Number of Secondary curd	Weight of secondary curd
V_0M_0	2.00 e	65.38 j	1.63 c	73.83 i
V_0M_1	2.43 cd	71.87 i	2.00 b	75.43 h
V_0M_2	2.53 cd	75.70 h	2.06 b	75.80 gh
V_0M_3	2.23 d	70.23 i	1.96 b	75.07 hi
V_1M_0	2.73 cd	78.13 g	2.26 ab	76.87 fg
V_1M_1	3.73 ab	95.13 d	2.50 ab	81.97 d
V_1M_2	3.70 ab	99.81 c	2.50 ab	83.80 c
V_1M_3	3.70 ab	88.00 e	2.71 ab	78.13 f
V_2M_0	3.06 bc	82.57 f	2.50 ab	77.77 f
V_2M_1	3.96 a	105.7 b	2.93 a	85.73 b
V_2M_2	4.13 a	110.0 a	3.00 a	90.10 a
V_2M_3	3.66 ab	89.73 e	2.66 ab	80.47 e
LSD $_{(0.05)}$	0.64	1.91	0.68	1.67
CV (%)	8.43	6.27	8.31	4.93

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

V_0: control, V_1: 5 t/ha and V_2: 10 t/ha

M_0: control, M_1: 50 ppm, M_2: 80 ppm and M_3: 110 ppm

4.11 Number of Secondary curd

The number of secondary curds per plant varied significantly among different levels of vermicompost (Table 10 and Appendix VI). The maximum (2.78) number of secondary curds was obtained when the plants were supplied V_2 treatment and it was followed by V_1(2.49) treatment. V_0 treatment gave the lowest (1.91) number of secondary curds.

The number of secondary curds had significant difference due to the application of different concentrations of GA_3 of broccoli (Table 11 and Appendix VI). The highest (2.52) number of secondary curd per plant was counted from M_2 treatment. The lowest (2.13) number of secondary curds was found from M_0 treatment.

The results on combined effect of different levels of vermicompost and GA_3 on number of secondary curds per plant have been presented in Table 12. The highest (3.00) number of secondary curds was counted from when plants grown under treatment combination of V_2M_2. Which was similar to treatment combinations of V_2M_1 (2.93) and V_2M_3 (2.66) respectively. The lowest number of secondary curds (1.63) was observed in V_0M_0 treatment combination.

4.12 Weight of secondary curd

The effect of different levels of vermicompost on secondary curd weight was statistically significant (Table 10 and Appendix VI). The maximum (84.57 g) weight of secondary curd was recorded from the plants which received V_2 treatment which was followed by V_1 (81.21 g) treatment. The minimum (76.08 g) weight of secondary curd was recorded from control (V_0) treatment.

The weight of secondary curd was found to vary due to the use of different concentrations of GA_3 of broccoli (Table 11 and Appendix VI). The maximum (83.23 g) weight of secondary curd per plant was recorded from M_2 treatment. The lowest (76.16 g) weight of secondary curd was observed from M_0 treatment.

The combined effect of different levels of vermicompost and GA_3 had significant variation on secondary curd weight (Table 12 and Appendix VI). The highest (90.10 g) weight of secondary curd was recorded from the V_2M_2 combination followed by treatment combination V_2M_1 (85.73 g). The lowest secondary curd weight (73.83 g) was measured from the V_0M_0 treatment combination.

4.13 Yield per plot

Yield per plot varied significantly due to application of different levels of vermicompost (Table 13 and Appendix VI). The maximum (5.94 kg) yield per plot was recorded from V_2 treatment which was followed by V_1 treatment (5.49 kg), while V_0 treatment gave the lowest (4.26 kg) yield per plant.

The yield of broccoli per plot was significantly influenced due to the application of different concentrations of GA_3 of broccoli (Table 14 and Appendix VI). The highest (5.68 kg) yield per plot was produced from M_2 which was statistically similar to M_1 (5.67 kg) and the lowest (4.33 kg) yield per plot was noted from M_0 treatment.

The combined effect of different levels of vermicompost and GA_3 on yield per plot was significantly influenced(Table 15 and Appendix VI). The highest (7.13 kg) yield per plot was recorded from V_2M_2 treatment combination which was statistically similar to V_2M_1 (6.61 kg) treatment combination. The lowest (3.90 kg) yield per plot was observed in V_0M_0 treatment combination.

Table 13. Main effect of vermicompost on the yield of broccoli

Treatments	Yield per plot (kg)	Yield per hectare (ton)
V_0	4.26 c	19.79 c
V_1	5.49 b	25.11 b
V_2	5.94 a	27.29 a
Level of sig	0.01	0.01
LSD $_{(0.05)}$	0.43	1.60
CV (%)	9.72	7.86

V_0: control, V_1: 5 t/ha and V_2: 10 t/ha

Table 14. Main effect of GA_3 on the yield of broccoli

Treatments	Yield per plot (kg)	Yield per hectare (ton)
M_0	4.33 d	19.80 c
M_1	5.67 a	26.06 a
M_2	5.68 a	26.27 a
M_3	5.26 b	24.13 b
Level of sig	0.01	0.01
LSD $_{(0.05)}$	0.47	1.84
CV (%)	9.72	7.86

M_0: control, M_1: 50 ppm, M_2: 80 ppm and M_3: 110 ppm

Table 15. Combined effect of vermicompost and GA_3 on the yield of broccoli

Treatments combinations	Yield per plot (kg)	Yield per hectare (ton)
V_0M_0	3.90 f	18.190 f
V_0M_1	4.29 e	20.32 e
V_0M_2	4.44 e	20.76 e
V_0M_3	4.40 e	19.90 e
V_1M_0	4.86 de	21.72 de
V_1M_1	6.11 bc	28.74 b
V_1M_2	5.45 cd	25.00 cd
V_1M_3	5.56 cd	24.96 cd
V_2M_0	4.21 e	19.49 e
V_2M_1	6.61 ab	29.74 ab
V_2M_2	7.13 a	32.41 a
V_2M_3	5.80 bc	27.54 bc
Level of sig.	0.01	0.01
LSD $_{(0.05)}$	0.86	3.20
CV (%)	9.72	7.86

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

V_0: control, V_1: 5 t/ha and V_2: 10 t/ha

M_0: control, M_1: 50 ppm, M_2: 80 ppm and M_3: 110 ppm

4.14 Yield per hectare

Yield per hectare of broccoli varied significantly for different levels of vermicompost of broccoli (Table 13 and Appendix VI). The highest yield (27.29 ton/ha) was recorded from V_2, while the lowest (19.79 ton/ha) was recorded from V_0.

Significant variation was recorded for different concentrations of GA_3 in yield per hectare of broccoli (Table 14 and Appendix VI). The highest yield per hectare (26.27 ton) was found from M_2, which was identical to (26.06 ton/ha) by M_1, whereas the lowest (19.80 ton/ha) was recorded from M_0.

Yield per hectare of broccoli showed significant differences due to the combined effect of Vermicompost and GA_3 (Table 15 and Appendix VI). The highest yield per hectare (32.41 ton/ha) was recorded from V_2M_2 which was statistically similar to V_2M_1 whereas the lowest (18.19 ton/ha) was recorded from V_0M_0.

CHAPTER V
SUMMARY AND CONCLUSION

The field experiment was conducted in the Horticultural farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from October 2018 to March2019 to find out the effect of Vermicompost and GA_3 on the growth and yield of Broccoli. The experiment consisted of two factors, Factor A: Different levels of Vermicompost such as V_0: control, V_1: 5 t/ha and V_2: 10 t/ha. Factor B: Different concentrations of GA_3 such as M_0: Control, M_1: 50 ppm, M_2: 80 ppm and M_3:110 ppm. Data on different growth and yield contributing characters were recorded.

The two-factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. There were altogether 12 treatment combinations in this experiment. Unit plot size was of 1.8 x 1.2 m where 75 cm and 50 cm gap between the blocks and plots, respectively were maintained. The experimental plots were fertilized with Vermicompost or with GA_3 as per treatment. The Broccoli seed of cv. Premium crop were used as per treatment. Data were collected from 5 randomly selected plants in each plot. Yield was recorded from all plants of each plot. Data on plant height, number of leaves per plant, length of largest leaf, breadth of largest leaf, days required for first curd initiation, weight of primary curd, diameter of primary curd, length of stem, diameter of stem, weight of leaves per plant, number of secondary curd per plant, weight of secondary curd, yield per plot and yield per hectare were recorded. All collected data of the present study were analyzed statistically and the mean differences were adjudged by Least Significant Difference (LSD) test.

The result of the experiment revealed that almost all the parameters studied were significantly influenced by different vermicompost. More or less, all the characters

attained highest values when 10 t/ha vermicompost was applied. The control gave the lowest value in all the characters studied. The maximum yield 5.94 kg/plot and 27.29 ton/ha were obtained by 10 t/ha vermicompost and the minimum yield 4.26 kg/plot and 19.79 ton/ha were found in the control plot.

Different concentrations of GA_3 played vital role on the growth and yield of broccoli. GA_3 had significant effect on more or less all the characters. The maximum yield 5.68 kg/plot and 26.27 ton/ha were obtained from M_2 treatment and the minimum yield 4.33 kg/plot and 19.80 ton/ha were found in the control plot.

The combined effect of different levels of vermicompost and GA_3 exhibited significant variation for all the parameters under study. The maximum yield 7.13 kg/plot and 32.41 ton/ha were recorded from the treatment combination of V_2M_2. The minimum yield 3.90 kg/plot and 18.19 ton/ha were found from control (V_0M_0) treatment combination.

Conclusion

The present study revealed that on the basis of growth and yield point, 10 ton/ha of Vermicompost and 80 ppm of GA_3 (V_2M_2) is suitable for Broccoli cultivation.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Another experiment may be carried out with various levels of Vermicompost.
2. Others level of GA_3 also may be used for further study.
3. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional compliance and other performance.

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APPENDIX

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

Year	Month	Air temperature (°c)			Relative humidity (%)	Rainfall (mm)
		Maximum	Minimum	Average		
2018	October	30.97	23.31	27.14	75.25	208
	November	29.45	18.63	24.04	69.52	00
	December	26.85	16.23	21.54	70.61	00
2019	January	24.52	13.86	19.19	68.46	04
	February	28.88	17.98	23.43	61.04	06

Source: Bangladesh Meteorological Department (climate division) Agargoan, Dhaka-1212.

Appendix II. Characteristics of Horticulture Farm soil as analyzed by Soil Resources Development Institute (SRDI), Khamar Bari, Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Horticulture Farm , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land t}pe	High land
Soil scries	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Fallow – Broccoli

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Particle size analysis	
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (mc/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI

Appendix III: Analysis of variance on plant height, number of leaves per plant, length of largest leaf of Broccoli

Source of variation	Degrees of freedom (df)	Mean square of							
		Plant height (cm) at				Number of leaves at			
		30 DAT	45 DAT	55 DAT	65 DAT	30 DAT	45 DAT	55 DAT	65 DAT
Replication	2	7.286	3.947	45.242	45.992	0.811	1.583	4.951	5.831
Vermicompost	2	489.407 **	537.245**	516.864**	494.783 **	25.397 **	24.62 **	56.063 **	46.643 **
GA_3	3	153.630**	144.312**	106.117**	89.359 **	12.628 **	12.574 **	25.181 **	48.463**
V×M	6	24.410**	25.635**	44.942 **	45.647 **	0.700 **	1.191 **	3.451 **	14.961**
Error	22	2.585	2.624	0.655	0.580	0.136	0.076	0.490	4.581

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability and NS Non-significant

Appendix IV: Analysis of variance on Length of largest leaf and Breadth of largest leaf

Source of variation	Degrees of freedom (df)	Mean Square of							
		Length of largest leaf (cm) at				Breadth of largest leaf (cm) at			
		30 DAT	45 DAT	55 DAT	65 DAT	30 DAT	45 DAT	55 DAT	65 DAT
Replication	2	47.185	63.547	68.369	75.575	27.759	16.556	28.759	18.426
Vermicompost	2	344.520 **	307.830	300.020**	305.53 **	157.072**	148.016 **	152.427	211.803**
GA_3	3	37.477 **	36.568	33.882 **	36.962**	37.781 **	29.991**	35.816	39.465 **
V×M	6	3.738 **	10.116	11.795 **	11.751 **	3.975 **	2.418**	1.864**	5.636**
Error	22	5.088	6.495	6.294	5.960	1.090	0.941	2.671	6.937

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant

Appendix V: Analysis of variance on days required for first curd initiation, weight of primary curd, diameter of primary curd and length of stem

Source of variation	Degrees of Freedom (df)	Mean Square of			
		Days of first curd initiation	Weight of primary curd	Diameter of primary Curd	Length of Stem
Replication	2	262.920	427.922	87.580	193.592
Vermicompost	2	96.121**	64566.056**	35.831**	21.737**
GA_3	3	16.666**	16041.206**	3.088 **	4.264**
V×M	6	1.831 **	2099.120**	0.361**	0.650**
Error	22	1.691	7.434	0.671	1.225

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant

Appendix VI: Analysis of variance on diameter of stem, weight of leaves per plant, number of secondary curd, weight of secondary curd, yield pet plant and yield per hectare

Source of variation	Degrees of freedom (df)	Mean Square of					
		Diameter of stem	Weight of leaves per Plant	Number Of Secondary Curd	Weight of Secondary Curd	Yield pet plant (kg)	Yield per hectare (ton)
Replication	2	9.543	466.099	7.319	629.882	16.523	95.277
Vermicompost	2	6.806**	2223.445 **	2.310**	64452.836 **	9.084**	178.591 **
GA_3	3	1.350**	697.730**	0.285**	16059.628 **	3.633**	81.055 **
V×M	6	0.098**	65.295**	0.047 **	2103.683 **	1.111**	20.286 **
Error	22	0.147	1.273*	0.163	16.339	0.259	3.574

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant