EFFECT OF DIFFERENT LEVELS OF VERMI-COMPOST AND MACRO NUTRIENTS ON THE GROWTH AND YIELD OF GARLIC (*Allium sativum*)

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This is to certify that the thesis entitled, ***"EFFECT OF DIFFERENT LEVELS OF VERMI-COMPOST AND MACRO NUTRIENTS ON THE GROWTH AND YIELD OF GARLIC (Allium sativum)"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE*** *in* ***HORTICULTURE****, embodies the result of a piece of bonafide research work carried out by* ***MD. MURSHEDUL ALAM****, Registration No. 13-05508 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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TO

MY BELOVED PARENTS

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ABSTRACT

A field experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during October 2019 to July 2020 to study the effect of different levels of vermi-compost and macro nutrients on the growth and yield of garlic. Garlic variety 'BARI Rashun-3' was used as planting material in this study. The experiment consists of single factor. Twelve treatment combinations were tested in this experiment: T_0 = Control, T_1 = 2 t ha^{-1} vermi-compost, T_2 = 4 t ha^{-1} vermi-compost, T_3 = 6 t ha^{-1} vermi-compost, T_4 = 50% NPKS (RDF), T_5 = 100% NPKS (RDF), T_6 = 2 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_7 = 4 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_8 = 6 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_9 = 2 t ha^{-1} vermi-compost + 100% NPKS (RDF), T_{10} = 4 t ha^{-1} vermi-compost + 100% NPKS (RDF) and T_{11} = 6 t ha^{-1} vermi-compost + 100% NPKS (RDF). The experiment was laid out in Randomized Complete Block Design (RCBD) with 12 treatment combinations having three replications. Data on different growth and yield parameter of garlic were recorded and significant variation was observed for different treatments. Plant height and number of leaves plant^{-1} value of garlic was recorded to be the maximum from treatment T_{10} (4.00 t ha^{-1} vermi-compost + 100% NPKS (RDF)) at different days after sowing (DAS). But, the highest bulb diameter (3.32 cm), the longest clove (3.44 cm), the highest bulb length (2.43 cm), the maximum number of cloves bulb^{-1} (21.25), the maximum fresh weight of bulb (35.11 g), the maximum dry weight of bulb (4.95 g), the highest fresh clove weight (6.93 g), the maximum dry clove weight (1.89 g), the maximum fresh weight of leaves plant^{-1} (25.31 g), the maximum dry weight of leaves (3.31 g), the highest bulb yield plot^{-1} (1.45 kg) and the maximum yield of garlic (14.53 t ha^{-1}) was recorded from T11 (6.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment. The highest benefit cost ratio (2.57) was attained from the treatment combination of T_{11} (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF)). The second best benefit cost ratio (2.52) was acquired in T_{10} (4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF)).

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LIST OF ABBREVIATIONS

ABBREVIATION	ELLABORATION
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agra.	Agricultural
Agron.	Agronomy
Annu.	Annual
Appl.	Applied
Vm	Vermi-compost
Biol.	Biology
Chem.	Chemistry
cm	Centi-meter
CV	Coefficient of Variance
DAS	Days After Storage
DAP	Days After Planting
Dev.	Development
Ecol.	Ecology
Environ.	Environmental
etci	and others
Exptl.	Experimental
g	Gram (s)
Hortc.	Horticulture
i.e.	that is
J.	Journal
kg	Kilogram (s)
LSD	Least Significant Difference
M.S.	Master of Science
m^2	Meter squares
mg	Milligram
Nutr.	Nutrition
Physiol.	Physiological
Progress.	Progressive
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
T	Tuber size
Soc.	Society
SRDI	Soil Resource Development Institute
t ha^{-1}	Ton per hectare
UNDP	United Nations Development Programme
Viz	*videlicet* (L.), Namely
%	Percentage
@	At the rate of
μMol	Micromole

LIST OF ABBREVIATIONS

BBS	Bangladesh Bureau of Statistics
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAS	Days After Sowing
eds.	editors
et al.	et alia (and others)
etc.	et cetera (and other similar things)
FAO	Food and Agricultural Organization
L.	Linnaeus
i.e.	id est (that is)

CHAPTER I

INTRODUCTION

Garlic (*Allium sativum* L.) belonging to the family Alliaceae is the second most widely used cultivated vegetable bulb crops after onion in the world. It has a wide area of adaptation and cultivation throughout the world (Mohd *et al.*, 2011). The world production is about three million metric tonnes per annum, with major producers being China, United States of America, Egypt, Korea, Russia and India (Kioko *et al.*, 2017). Garlic has many germplasms that differ in bulb size, bulb color, number of cloves per bulb and storage life (Dekerson and wall, 1994).

Garlic has been considered as a rich source of carbohydrates, proteins and phosphorus. It is popular all over the world as a valuable spice for different dishes. Aqueous extracts of garlic cloves (allicin and related disulphides) significantly reduce cholesterol level in men (Augusti, 1977). It is also used as a popular remedy for various diseases. According to the Unani and Ayurvedic medicines in the treatments of diseases like chronic infection of stomach and intestine, dysentery, typhoid, cholera and diseases of lungs garlic is successfully used (Chopra *et al.*, 1958). In recent, oil, powder are prepared from it for adding flavor to the curries (Pruthi, 1976). Besides, it is also used in preparing chutneys, pickles, tomato ketchup etc.

The average yield of garlic in Bangladesh is only 8.41 t ha^{-1} (BBS, 2020), which is very low as compared to that of other countries. In Bangladesh about 263000 metric tons of garlic was produced from approximately 31260 hectares of land in 2019-2020 (BBS, 2020). The requirement of garlic in Bangladesh is about 85,000 metric tons (Rahim, 1992). The crop is extensively cultivated during the winter season of Bangladesh. Garlic ranks second in world production among the Alliums after onion (Purseglove, 1975). The world production of garlic was 222.82 lakh MT., from 3.71 lakh hectare areas (Ahmed, 2006). China rank 1st in area and production (7.79 lakh ha and 179.68 lakh MT., respectively) and India is the second in area (2.05 lakh ha) and production (10.70 lakh MT). Egypt tops in list (23.83t/ha) productivity followed by China (23.06 t ha^{-1}) (Ahmed, 2006). The major causes of low yields include depletion of macro and micro- nutrients from the soil, use of low yielding varieties and poor management practices (Tadesse, 2015).

The growth and yield of garlic crop is greatly influenced by both inorganic and organic nutrients (Degwale, 2016). Studies have indicated application of inorganic fertilizers by small holder farmers have led to increased yield at the expense of product quality and environmental degradation (Mbithi *et al.*, 2015). Hence, the concern on the effects of agrochemicals especially chemical fertilizers on the environment (Hamma *et al.*, 2013). Consequently, the current effort to search for alternative source of nutrients to crops such as organic manures. Although organic manures contain plant nutrients in small quantities as compared to the inorganic fertilizers, the presence of growth promoting substances like enzymes and hormones, make them essential for the improvement of soil fertility and productivity (Bhuma, 2001).

Vermicompost has emerged as an alternative to conventional organic fertilizers due to its addition benefits to the soil. Also, some problems, such as nutrient loss, nutrient toxicity, and salinity that may be associated with organic amendments under certain conditions could also be avoided by vermicompost application especially due to its slow and more release of nutrients to the soil environment (Lazcano *et al.*, 2008). Vermicompost and compost can meet the nutrient demand of greenhouse and field crops and significantly reduce the use of fertilizers (Acharya and Kumar, 2018). Vermicompost increases soil fertility without polluting the soil, as well as quantity and quality of crops (Chanda *et al.*, 2011). These increases in plant productivity have been attributed to enhanced soil structure and soil microbial population that have higher level of activity and greater production of biological metabolites, such as plant growth regulators (Zucco *et al.*, 2015).

Bulb development in garlic depend on an increase in total soluble carbohydrate in photosynthetic activity of the leaves which depend on light and nutrition (Arguleo *et al.*, 2007). Growth and yield of garlic is influenced by different nutrients management and other factors during their production in field. Garlic productivity, in many countries, is low due to low yielding varieties and environmental factors (Nonnecke, 1989). In many garlic producing areas lack of available nutrients is frequently the limiting factor next to the soil water as their uptake and liberation of N, P and S from soil organic matter depends upon availability of water (FAO, 2003). For increase garlic production different fertilizers application (type, time and rate) is one of the limiting factors of garlic production that should be considered (Brewster and Butler, 1989, Diriba-Shiferaw *et al.*, 2013).Nutrients needs of a crop is depend on its physiological requirements and yield potentials, thus, balance fertilizer is the basis of more production (Ryan, 2008).The existing practice of fertilizer application is below the recommended level and farmer use only N containing fertilizer mostly Urea. However, the use of balance fertilizer in sufficient quantity is essential for high yield and good quality garlic production.

Garlic growers in the central high lands of Ethiopia tend to rely on fertilizer sources that contain only nitrogen (N) and phosphorus (P), resulting in steady decline in other nutrients in the soil. Smaller potassium (K) and sulfur (S) uptake relative to N uptake can predispose the crop to serious disease and insect damage (Bhuma, 2001). All the plants are characterized by a shallow root system which explains why fertilizers should be banded at 8-10 cm below the seed row (SOPIB, 2001). Due to the shallow root system, it is preferable to split fertilizer application (before sowing or planting, at the fully expanded leaf stage, and just before bulb formation). High nutrient availability is important during bulb formation. The bulb comprises small bulb called cloves (Wadjito *et al.*, 1988). Availability of Nitrogen and Phosphorous is of prime importance for growing plants as it is a major and indispensable source of protein and nucleic acid molecules.

Therefore, nutrient management with each other may lead to better performance of the crops. The present study was undertaken to observe the following objectives:

1. To find out the optimum level of vermicompost at the highest yield.
2. To find out the effect of NPKS on the growth and yield of garlic.
3. To assess the combined effect of vermicompost and NPKS on the growth and yield of garlic.

CHAPTER II

REVIEW OF LITERATURE

Garlic is an important spice crop in Bangladesh for its culinary and medicinal uses. The production of garlic bulb is greatly influenced by organic and inorganic fertilizers. They play an important role on growth and yield of garlic. To ensure better yield, proper nutrient management need to be assured. Vermicompost is a good source of organic manure. The present study has been under taken to investigate the performance of vermicompost and macronutrients on the growth and yield of garlic. Research findings related to the present study have been reviewed here.

Gichaba *et al.* (2020) conducted the study to evaluate the effects of goat manure-based vermicompost on growth and yield of garlic. The experiment was conducted in two sites naming Chuka and Embu. The treatments consisted of goat manure-based vermicompost at five levels (0, 5, 10, 20 and 30 t ha^{-1}), inorganic fertilizer (NPK 17-17-17) at the rate of 200 kg ha^{-1} and goat manure (30 t ha^{-1}) and the combination were: K_0 is 0 t ha^{-1}, K_1 is 5 t ha^{-1}, K_2 is 10 t ha^{-1}, K_3 is 20 t ha^{-1}, K_4 is 30 t ha^{-1}, K_5 is NPK (17-17-17) and K_6 is goat manure (30 t ha^{-1}). Planting cloves of a local garlic variety (moyale) were sown. The results showed statistically significant ($p<0.05$) effect of application of goat manure-based vermicompost on growth and yield of garlic. Application of goat manure-based vermicompost showed higher performance for plant height, stem diameter and leaf length throughout the growth period, compared to inorganic fertilizer and goat manure. The highest mean plant height (41.80 cm and 41.61 cm, respectively) at Chuka and Embu at 86 days after emergence (DAE), the largest mean stem diameter (0.86 cm and 1.24 cm, respectively) at Chuka and Embu at 86 DAE and the highest mean leaf length (31.48 cm and 27.82 cm, respectively) at Chuka and Embu at 86 DAE was recorded from treatment K_4 (30t ha^{-1}). Goat manure-based vermicompost also showed higher performance for bulb fresh weight, bulb diameter, number of cloves per bulb and bulb yield compared to inorganic fertilizer and goat manure. The treatment K_4 recorded the highest mean bulb fresh weight (18.19 gm and 12.66 gm, respectively), bulb diameter (3.92 gm and 3.50 gm, respectively), number of cloves (7.46 and 5.90, respectively) and bulb yield per hectare (4084.24 kg ha^{-1} and 2842.58 kg ha^{-1}, respectively). The results of this study demonstrate that application of goat manure based vermicompost enhanced plant growth and improved garlic yield.

García *et al.* (2019) carried out the experiment to study the foliar application of humic liquid extract from vermicompost on garlic (*Allium sativum* L.) production and fruit quality. Foliar application of liquid humic extract (HEVC) was performed 45 days after plantation through the application directly onto the leaves when the plants' sixth true leaf had already emerged. The HEVC was obtained by extracting a basic medium of HS from the vermicompost of cattle manure. Three different dilutions 1:40, 1:60 and 1:80 (v:v) of HEVC were applied in addition to the control treatment without HEVC application. A manual sprinkler was used for foliar application. The liquid humic extract from vermicompost (HEVC) applied to the garlic crop has a high amount of HS in its composition. Humic substances have a structure composed primarily of carbohydrates and peptides as well as modified lignin fragments. These structural features justify the positive stimulus effects on different forms of plant metabolism. The foliar application of HEVC improves the productive, commercial and internal quality parameters of fruits compared to the control treatment. The application of HEVC in the 1:40 (v:v) ratio was the most promising treatment in terms of increasing in the fruit quality indices as well as promoting improvements in bulb caliber, numbers of garlic cloves and internal substance content in the fruit. The use of HEVC can be a sustainable alternative within the small-scale garlic phytotechnology package.

Kumar *et al.* (2019) conducted the research to study the effect of organic manure on growth, yield and quality of garlic (*Allium sativum* L.) under Hadauti region. The treatment combination in this experiment were as follows: T_0:Control,T_1:RDF (NPK) 100%, T_2:Vermicompost 100%, T_3:FYM 100%,

T_4:50% RDF + 50% Vermicompost, T_5:50% RDF + 50% FYM, T_6:50% Vermicompost + 50% FYM, T_7:75% RDF + 25% Vermicompost, T_8:75% RDF + 25% FYM and T_9:50% RDF + 25% FYM + 25% Vermicompost. In this experiment it was indicated that the tallest plant at 30, 60 and 90 days after sowing was recorded from the treatment T_7(75% RDF + 25% Vermicompost) and followed by T_4(50% RDF+50% Vermicompost) and T_0(control) respectively, while the shortest plant was recorded under the control treatment. It was clearly indicating that maximum number of leaves per plant at 30, 60 and 90 days after sowing were found with the treatment T_7 (75% RDF + 25% Vermicompost) 4.80, 4.61, 6.11 per plant followed by T_4 (50% RDF + 50% Vermicompost) 3.75, 4.86, 6.34 and T_0 (control) respectively while minimum number of leaves per plant was recorded under the control treatment. The maximum clove length is recorded under treatment T_7 (75% RDF + 25 % Vermicompost) 2.66 cm followed by T_4 (50% RDF + 50% Vermicompost) 2.59 cm. While minimum in treatment T_0 (control) 1.67 cm. Length of clove was measure after harvesting. T_5 Treatment and T_6 Treatment also show possible significant response for length of cloves. Length of clove show positive response of good yield. It was clearly indicated that maximum yield (310.66 q/ha) was found with the treatment T_7 (75% RDF + 25 % Vermicompost) followed by T_4 (284.32 q ha^{-1}) (50% RDF + 50% Vermicompost). The maximum number of bulb/kg (48.74 bulb/kg) was recorded in treatment T_7 (75% RDF + 50% Vermicompost) and followed by T_4 (39.10 bulb/kg) (50% RDF + 50% Vermicompost).

Yatsenko *et al.* (2019) conducted a field experiment for the purpose of improving the quality of garlic organic products, the influence of humus and different norms of vermicompost on the yield, nutritional value and antibacterial properties of common garlic (*Allium sativum* L.). The treatment consisted of three levels of vermicompost (1, 3 and 5 t/ha) and one level of humus (30/ha).The maximum weight of the bulb of the garlic cultivar ‘Sofiivskyi’ (46.9 g) and garlic cultivar ‘Prometei’ (60.4 g) was recorded from the fertilizer of vermicompost 5 t ha^{-1}. The maximum yield of the garlic cultivar 'Sofiivskyi' (17.3 t ha^{-1}) and garlic cultivar 'Prometei' (20.3 t ha^{-1}) was recorded from the fertilizer of vermicompost (5 t ha^{-1}). The use of the vermicompost for garlic gave an increase in the yield at the level of 1.7–3.9 t ha^{-1} of the garlic cultivar 'Prometei' compared to the control 'Sofiiskyi' and 2.2–5.2 t ha^{-1} in relation to the control of the garlic cultivar 'Prometei'. It was established that the caloric content of the product with the fertilizer of vermicompost might have increased to 22.68 g 100 g^{-1} fresh weight (FW), with the fertilizer of 5 t ha^{-1} of vermicompost, and the total content of sugar was increased by 21.52–40.81% depending on the cultivar. The content of vitamins increased in parallel with increasing in the rate of vermicompost. The antibacterial effect of the garlic essential oils against *Staphylococcus aureus*, *Escherichia coli* and *Bacillus subtilis* was significant; the diameters of the inhibition zone were *S. aureus* is 21.35–27.10 mm, *E. coli* - 16.97–26.46 mm, *B. subtilis* - 16.42–25.36 mm and the number of *Mycobacterium smegmatis* colonies decreased by 23.96–43.44%. This study has been proved that garlic juice had played a very important role in struggling with the studied bacteria (*S. aureus*, *E. coli and B. subtilis*); therefore, it can replace chemical antibiotics that have always had unwanted side effects on the body such as allergy and antimicrobial resistance. The obtained data showed that using of vermicompost was more effective than fertilizer of humus.

Kenea and Gedamu (2018) undertook a study to assess the response of garlic variety 'Chelenko I' to vermicompost and mineral N fertilizer application on growth and bulb yield of the crop. The treatment consisted of a combination of four levels of vermicompost (0, 2.5, 5 and 7.5 t ha^{-1}) and five levels of mineral N fertilizer (0, 52.5, 80, 105 and 130 kg N ha^{-1}). Results revealed that significant ($P < 0.05$) maximum leaf length (41.08 cm), bulb weight (39.17 g $bulb^{-1}$), harvest index (63.94%) and total bulb yield (12.93 t ha^{-1}) were recorded at the rate of 7.5 t ha^{-1} of vermicompost application while maximum average leaf width (1.25 cm), clove number (13.57 cm), and bulb dry matter

(51.66%) were obtained at maximum rate of 130 kg·ha^{-1} mineral N fertilizer. The results indicated that application of vermicompost at 7.5 t ha^{-1} and 130 kg N ha^{-1} mineral fertilizer gave the highest total garlic bulb yield of 12.9 and 12.69 t ha^{-1}, respectively.

Patidar *et al*. (2017) conducted a field experiment to find out dose of sulphur and vermicompost to obtain better growth, yield and quality of garlic (*Allium sativum* L.). Sixteen treatment combinations of 4 levels of sulphur (0, 25, 50 and 75 kg S ha^{-1}) and 4 levels of vermicompost (0, 2, 4 and 6 t ha^{-1}) were tested. The G-282 variety of garlic was sown. Application of 50 kg sulphur and 4.0 t vermicompost ha^{-1} individually recorded significantly higher plant height, number of leaves per plant, neck thickness of bulb, polar diameter of bulb, equatorial diameter of bulb, number of cloves per bulb, fresh weight of 20 cloves, fresh weight of bulb, dry weight of bulb, bulb yield, TSS, volatile oil content and sulphur content of bulb. This combination significantly increased the bulb yield by 25.70% and 20.69% over their respective control.

Yimer (2016) conducted a field experiment to study the effect of vermicompost on growth, yield and quality of garlic (*Allium sativum* L.). A locally grown garlic cultivar called Tsedey 92 (G-493) was used for the study. The treatment consisted of three levels of vermicompost (0, 2.5 and 5 t ha^{-1}). The results revealed that increasing rate of vermicompost significantly ($P<0.05$) affected days to emergence. The effect of vermicompost also significantly ($P<0.05$) influenced days to maturity, leaf number, leaf area index, mean clove weight, mean bulb weight, fresh biomass yield, total bulb yield, dry matter percent and total soluble solid. The highest bulb dry matter percent (51.05) and total bulb yield (7.78 t ha^{-1}) was recorded at 5 t vermicompost ha^{-1}. Increasing level of vermicompost also significantly ($P<0.05$) affected marketable and unmarketable bulb yield, and mean clove number. The highest marketable and the lowest unmarketable yield was obtained at 5 t ha^{-1} vermicompost. Marketable yield of garlic was increased by 9.96% and unmarketable bulb yield was decreased by 12.83% at an application rate of 5 t vermicompost ha^{-1}

over the control. Total soluble solid was also increased from 5.13 to 5.69 ° Brix by applying 5 t vermicompost ha^{-1} over the control. Harvest index was also significantly ($P < 0.05$) affected by the increased application of vermicompost. The maximum harvest index 68.36% was also recorded at application of 5 t vermicompost ha^{-1}. It was concluded that, application of 5 t ha^{-1} vermicompost led to the maximum growth, yield and quality of the garlic crop.

Valiki *et al.* (2015) investigated the influence of vermicompost and chemical fertilizers on growth parameters and essential oil of garlic (*Allium sativum*). The experiment was designed with 7 treatments. Treatments were included witness (control), 5, 10, 15, 20 and 25 t·ha^{-1} vermicompost and NPK Fertilizers (Chemical treatments include a mixture of 40 kg ha^{-1} N, 50 kg ha^{-1} K, 60 kg ha^{-1} P). Results showed that all agronomic traits were significantly affected by vermicompost and chemical fertilizers compared to the control. The maximum shoot wet weight and shoot dry weight recorded in chemical and vermicompost treatments, respectively. The maximum number of bulblets per plant and dry weight of bulb observed in vermicompost treatment (20 t ha^{-1}) about 57.82 and 15.40 g, respectively. The maximum bulb diameter (6.65 cm) and bulb wet weight (16.10 g) obtained from 15 t ha^{-1} of vermicompost. By examining the different fertilizer treatments, it was observed that by increasing amounts of vermicompost about 15, 20 and 25 t ha^{-1} to the soil, the number of bulbs of garlic bulblets increased. In contrast, control treatments, chemical treatment and 5 t ha^{-1} of vermicompost produced the lowest number of bulblets. Chemical fertilizer increased the size of the bulb, but had little effect on the weight of the bulb and bulb dry weight. Chemical fertilizer increased the diameter of the bulb and bulb weight compared to control, but compared to the vermicompost treatments (10, 15, 20 and 25 t ha^{-1}), bulb diameter was smaller. Among all treatment, vermicompost had the highest effect on essential oil compared to chemical fertilizer. In general, 15 t ha^{-1} of vermicompost treatment compared to other treatments was appropriate for yield and production essential oil and reducing the cost of crop production.

Suthar (2009) set up a field experiment to study the impact of vermicomposted and composted farmyard manure (FYM) along with some combination of NPK fertilizers, on field crop of garlic (*Allium sativum* L.). A total of six experimental plots were prepared: T_1 (recommended dose of NPK), T_2 (vermicompost @ 15 t ha^{-1}), T_3 (20 t ha^{-1} vermicompost), T_4 (15 t ha^{-1} vermicompost + 50% NPK), T_5 (15 t ha^{-1} farmyard manure), and T_6 (farmyard manure 15 t ha^{-1} + 100% recommended NPK) to test the plant production patterns, under field conditions. The maximum range of some plant parameters i.e. root length, shoot length, leaf length, fruit weight, number of cloves in garlic fruit and number of leaves per plant was in the T_4 treatment plot. The maximum fruit weight, number of cloves per fruit, number of leaves per plant and the maximum dry mass (g) of a whole plant were recorded in T_2 (57.62 g), T_1 (40.44), T_3 (7.31) and T_4 (58.5) treatment, respectively. Also, the average fruit weight was approximately 26.4% greater in T_4 than recommended NPK treatment plot (T_1). The vermicomposted FYM showed a comparatively better result of plant production than composted manure. The plant growth results indicate the presence of some growth-promoting substances in worm-processed material (vermicompost). The vermicomposted FYM also contained a considerable amount of some essential plant micronutrients e.g. Cu (0.973 mg kg^{-1}), Fe (8.68 mg kg^{-1}), Mn (13.64 mg kg^{-1}) and Zn (16.91 g kg^{-1}) that might be responsible for better plant growth and productivity.

Argiiello *et al.* (2006) conducted a field experiment where the objectives of the work were to a) determine vermicompost effect on bulbification dynamics in terms of garlic (*Allium sativum* L.) bulb dry weight and sucrose metabolism and b) evaluate the impact of vermicompost on garlic bulb yield and quality. The treatments were soil (control) and 1 soil : 1 vermicompost (by volume). Plant height did not differ during the first 60 days after sowing. These results can be explained by the fact that clove seed sprouting and the start of the aboveground growth were supported by carbohydrate reserves in the clove seed. After 60 d after sowing, plant height was increased by vermicompost. In this study dry weight remained constant regardless of treatments until 100 days from sowing. The increase in aboveground growth by the use of vermicompost corresponds to a significant advance of the onset of the bulbing stage (about 18 to 20 days earlier than that of the control plants. Similar evidence of earlier bulbing (5 to 6days) was observed when applying urea fertilizer. Vermicompost increases the bulb dry weight by the accumulation of non-structural carbohydrates whose distribution patterns change, thus favouring the metabolism of fructan precursors and accumulating as scorodose. Such reserve substance accumulation in the vermicompost treatment, represented by scorodose polysaccharide, occurs for a longer period due to the earlier start of bulbing. This response translates into a 2-fold increase of the bulb's thy weight, increased size, and; therefore, higher quality and yield at harvest. The use of vermicompost as a substrate caused early bulling (18 to 20 days) and lengthened bulb filling period. Bulb filling period corresponded to an increase in the total soluble carbohydrates and a later modification in non-structural carbohydrate distribution patterns regarding fructan (scorodose) metabolism. The vermicompost treatment increased scorodose accumulation, which was directly related to the harvest index, resulting in greater yield and bulb quality. Bulb quality was not modified in terms of bulb pungency and soluble solids content by the use of vermicompost.

Khan *et al.* (2016) carried out this experiment with an aim to find out the balance dose of NPK fertilizer kg ha^{-1} i.e. 90:90:75, 100:100:120, 60:60:45 and control treatment for garlic. Significant effect on leaf area, bulb weight and yield were recorded over control treatment while plant height, number of leaf $plant^{-1}$, stem diameter, number of cloves $bulb^{-1}$ and single clove weight were not affected by fertilizer application. Significant differences were recorded in yield of garlic after application of NPK fertilizers. Maximum yield (21111 kg ha^{-1}) was recorded in plots which received 90:90:75 kg NPK ha^{-1} which was statistically different from rest the treatments. The yield (17500 and 18056 kg ha^{-1}) was obtained from plots where 120:120:100 kg NPK ha^{-1} and 60:60:45 kg

NPK ha^{-1} was applied which were statistically at par with each other. The lowest yield (15833 kg ha^{-1}) were recorded in control treatment. There was an increase of 33% in yield by application of NPK at the rate of 90:90:75 kg NPK ha^{-1} over control whereas for plots receiving NPK at the rate of 120:120:100 kg ha^{-1} and 60:60:45 kg ha^{-1} had 10.5% and 14% increase in yield over control, respectively.

Assefa *et al.* (2015) conducted the study to investigate the effect of N, P, S, and Zn fertilizers and compost on yield and growth parameters of garlic (*Allium sativum* L.) and specify optimum fertilizer dose at field level. The treatment combination was as follows: T_0 is control; T_1 is 130 kg ha^{-1} nitrogen and 20 kg ha^{-1} phosphorous; T_2 is 130 kg ha^{-1} nitrogen, 20 kg ha^{-1} phosphorous and 21 kg ha^{-1} sulphur; T_3 is 130 kg ha^{-1} nitrogen, 20 kg ha^{-1} phosphorous, 21 kg ha^{-1} sulphur and 15 kg ha^{-1} Zinc and T_4 is 12,000 kg ha^{-1} compost. The results showed that a combination of N, P, S, and Zn fertilizers gave a significant higher yield over the control plot. The mean bulb yield obtained from plots fertilized with N-P-S-Zn, N-P-S, N-P fertilizers and compost was 4760, 4388, 4240 and 3451 kg ha^{-1}, respectively while 2996.5 kg ha^{-1} was the lowest average yield obtained from control plot. Similarly, the yield and growth parameters were increased progressively with combined application of N, P, S, and Zn. It was concluded that for increased garlic yield in the study area, application of 130 kg N, 20 kg P, 21 kg S and 15 kg Zn fertilizers per hectare could be needed.

Diriba-Shiferaw *et al.* (2013) conducted a study on Andosol and Vertisol soils for two consecutive (dry and main rainy) seasons to assess the effect of various rates of compound fertilizers on growth, and nutrient content and uptake of garlic. The treatments were consisting of different compound fertilizers containing different nutrients at different rates except the control and Diammonium phosphate (DAP) or recommended N and P fertilizers. Treatments consisted of control (without fertilizer), one level of DAP/NP (92 N + 40 P kg ha^{-1}), three levels of Azofertil (100, 200 and 300 kg ha^{-1}), four levels of Basic (100, 200, 400 and 600 kg ha^{-1}) and three levels of D-coder (100, 200 & 400 kg ha^{-1}) fertilizers. Garlic variety called “Tseday” was used for the experiment. The morphological characters like plant height, neck thickness and leaf area index of garlic at different growth stages, and the contents and uptake of nutrients like nitrogen, phosphorus, potassium and sulphur of the crop were significantly increased due to the applications of higher levels of Azofertil, Basic and D-coder compound fertilizers on Andosol soil during both seasons. However, the lowest growths, and nutrients content and uptake were recorded from the garlic plants fertilized with lower levels of the three compound fertilizers, recommended NP and the control plot, especially on Vertisol. Generally, plant growths, and nutrients contents and uptake of garlic exhibited good results with the application of D-coder fertilizer at the rate of 200 kg ha^{-1} followed by Azofertil at the rate of 300 kg ha^{-1} on Andosol during dry season by irrigation.

Rodríguez *et al*. (2012) carried out the research work to study the effect of three organic fertilizations on garlic production and to determine the macronutrient content in leaves during the crop cycle. The treatments were: T_0: inorganic fertilization (100 kg ha^{-1} of diammonic phosphate + 100 kg ha^{-1} of urea); T_1: (16.071 kg ha^{-1} of Bovine Manure-Onion compost + 50 kg ha^{-1} of phosphate rock); T_2: (2000 kg ha^{-1} of Bio Organutsa Nitro Plus a commercial organic fertilizer + 50 kg ha^{-1} of phosphate rock); and T_3: BioOrganutsa Nitro Plus + vermicompost tea (same as T_2 + 1,25 L vermicompost tea). During both years, the number of leaves, plant height and dry matter weight along the cycle were increasing in all treatments. T_2 and T_3 showed the highest values with respect to T_1. Nitrogen and Potassium content in leaves decreased gradually in all treatments after the beginning of bulb formation. At harvest, T_2 and T_3 presented the highest yield, weight and diameter bulbs in 2008, while T_1 obtained the lowest values of these parameters. In 2007, T_3 showed significant differences with respect to T_1 as regards the 3 parameters. The commercial organic fertilizer + phosphate rock incorporated alone or in combination with vermicompost tea, can be an alternative to inorganic fertilization in garlic crop. It would be necessary to try different doses of compost to prove if it had same value as a fertilizer.

Farooqui *et al*. (2009) conducted a study to enhance the productivity of garlic through assessing the effect of different levels of nitrogen and sulphur. The experiment consisting of 4 levels of nitrogen (50, 100, 150 and 200 kg ha^{-1}) and 4 levels of sulphur (0, 20, 40 and 60 kg ha^{-1}) which were applied as basal dose and top dressing. Application of 200 kg nitrogen ha^{-1} significantly increased the plant height (cm), number of leaves per plant, neck thickness (cm), bulb diameter (cm), number of cloves per bulb, fresh weight of 20 cloves (g), dry weight of 20 cloves (g), fresh weight of bulb (g), dry eight of bulb (g) and bulb yield (q ha^{-1}). Among various levels of sulphur, 60 kg S ha^{-1} exhibited the best growth and yield attributes. Significantly higher yield of garlic was obtained with the treatment combination of (200 kg N ha^{-1} + 60 kg S ha^{-1}).

Kabir (2004) carried out an experiment to investigate the performance of organic and inorganic fertilizers on the growth and yield of garlic. There were thirteen treatments consisting of cow dung (T_1), Poultry dropping (T_2), Mustard oil cake (T_3), Bone meal raw (T_4), Bone meal boiled (T_5), Poultry dropping + Cow dung (T_6), Cow dung + Mustard oil cake (T_7), Mustard oil cake + Poultry dropping (T_8), Poultry dropping + Mustard oil cake + Cow dung (T_9), inorganic- Urea + TSP + MP (T_{10}), Urea + TSP + MP + Poultry dropping (T_{11}), Urea + TSP + MP + Cow dung (T_{12}) and Urea + TSP + MP + Mustard oil cake (T_{13}). The rates of Cow dung, Poultry dropping, Mustard oil cake, Bone meal (raw), Bone meal (boiled), Urea, TSP and MP were 10 t, 3 t, 5 t, 2 t, 2 t, 130 kg, 110 kg and 210 kg per hectare. respectively. The results of the experiment demonstrated that organic and inorganic fertilizers had significant influences on almost all the parameters studied except number of leaves per plant at 30 DAP. The tallest plant (52.07 cm) and the highest number of leaves (8.09) were obtained from the treatment of (Urea + TSP + MP + MOC). The shortest plant (31.69 cm) and the lowest number of leaves (5.66) were found in the treatment of Poultry dropping. The plants receiving organic (Mustard oil cake) + inorganic (Urea + TSP + MP) fertilizers produced the highest yield (6.26 t ha^{-1}) of garlic while the lowest yield (2.95 t ha^{-1}) was found in the treatment of only poultry dropping. But on the basis of economic analysis, the highest net return and BCR value of Tk. 1,12,999.55 per hectare and 3.19 respectively were obtained from the treatment of (Urea + TSP + MP + cow dung). The yield (5.67 t ha^{-1}) was obtained from the treatment of T_{12} (Urea + TSP + MP+ cow dung).

Naik and Hosamani (2003) conducted an experiment to study the effect of different levels of N, P and K on growth and yield of garlic under rainfed condition. There were twenty-four treatment combinations of fertilizers comprising four levels of N (0, 50, 100 and 150 kg ha^{-1}), three levels of P (0, 40 and 80 kg ha^{-1}) and two levels of K (0 and 60 kg ha^{-1}). They reported that among the fertilizer combinations, 100:40:60 kg NPK ha^{-1} was found to be the optimum dose of fertilizer for increasing plant height, number of leaves per plant, number of bulbs per plot, number of cloves per bulb and bulb yield per hectare.

Das and Mohanty (2001) conducted an experiment to evaluate the effect of plant density (8×8, 10×8, 10×10 and 15×10 cm^2) and N:P:K rates (50:50:50, 75:75:75, 100:100:100 and 125:125:125 kg ha^{-1}) on the yield of garlic cv. Madrasi. Among the fertilizer treatments, N:P:K at 100:100:100 kg ha^{-1} produced the highest bulb yield (153.78 q ha^{-1}), followed by 125:125:125 k ha^{-1}. Combination of 10 × 8 cm^2 spacing and 100:100:100 kg N:P:K· ha^{-1} resulted in the maximum yield of 170.27 q ha^{-1}.

Sardar *et al.* (1999) conducted an experiment to study the effects of applying N (0, 50, 100 or 150 kg ha^{-1}), P (0, 40 or 80 kg ha^{-1}) and K (0 or 60 kg ha^{-1}) on garlic cv. Kanpur Local. They reported that bulb yields were increased as the rate of each macronutrient element applied increased. A fertilizer rate of 100 kg N + 80 kg P + 60 kg K ha^{-1} was recommended for garlic production.

Bull *et al.* (1998) conducted an experiment to observe the relations between resin extractable soil phosphorus and response of vernalized garlic to phosphate fertilization of five soils, with and without organic fertilizer on garlic. They reported that organic fertilizer can substitute for phosphate fertilization in the recommended dosage for spring garlic.

Jalil (1998) carried out an experiment to study the effect of planting time and the paclobutrazol and sulphur fertilizer on the growth, yield and sulphur content of garlic. He used 0, 20, 40 and 80 kg S ha^{-1}. He concluded that, the bulb yield was increased with increasing the level of S. The highest bulb yield (4.33 t ha^{-1}) was obtained from 80 kg S ha^{-1}.

Zhang *et al.* (1998) conducted an experiment on NPK absorption in garlic. The ratio of NPK absorbed by garlic was 1: 0.3: 0.71. The peak of N and K absorption was at the inflation stage of squamose bulbs and the peak of P absorption was during sprout elongation. The recommended optimum dose for application of NPK was 160–350 kg, 120–155 kg and 133.4 kg ha^{-1}. They reported that combination of organic fertilizers with NPK fertilizers increased the yield by 78.4–118.4%.

Hossain (1997) conducted an experiment to study the effect of different levels of nitrogen and potash on the growth and yield of garlic. All parameters namely, plant height, number of levels per plant, leaf length, weight of foliage, pseudo stem and bulb diameter, weight of roots, dry matter contents of foliage, bulb and roots, weight of bulb and yield of bulb varied significantly with the application of nitrogen. A few of these characters namely, leaf length, weight of foliage, bulb diameter, weight of bulb and bulb yield were significantly influenced by potassium levels. The highest bulb yield (8.45 t ha^{-1}) was obtained when the plants were raised with the highest nitrogen level (200 kg ha^{-1}) and the lowest yield (5.61 t ha^{-1}) was recorded in the control. Application of potassium at 120 kg K_2O ha^{-1} showed the highest bulb yield (7.64 t ha^{-1}).

Ashok *et al.* (1996) carried out an experiment with garlic in sandy loam soil supplied with 0, 50, 100 or 150 kg N; 0, 40 or 80 kg P and 0 or 60 kg K ha^{-1} and reported that the highest yield was obtained with 100 kg N + 80 kg P + 60 kg K ha^{-1}.

Bertoni *et al.* (1996) carried out an experiment to study the nutrition of sulphur in garlic cv. Messidrome in a greenhouse pot experiment. Leaf and root sulphur concentration decreased during senescence due to remobilization of organic sulphur from leaves to bulbs during bulbs growth.

Seno *et al*. (1996) studied the effect of four doses of P_2O_5 (control, 150, 300 and 450 kg ha^{-1}) and four doses of chicken manure (control, 4, 8 and 12 t ha^{-1}) on the culture of garlic. The phosphorus, compost and additional nutrients (20 kg N, 90 kg K_2O, 2.2 kg B and 4 kg Zn per ha) were applied. Two foliar applications of nutrients were made with 1% urea at 40 and 60 days after planting. The phosphorus induced linear decrease for the plant length at 30 days and for the production of medium sized bulbs therefore increased the average weight of bulbs. The chicken manure induced a linear increase in the average weight of bulbs.

Verma *et al.* (1996) investigated the effects of N (0, 50, 100 or 150 kg ha^{-1}), P (0, 40 or 80 kg P_2O_5 ha^{-1}) and K (0 or 50 kg K_2O ha^{-1}) on growth and yield of garlic. They reported that specific gravity and dry matter weight of garlic were significantly influenced due to increasing rates of N.

Alam (1995) conducted an experiment to study the effect of paclobutrazol and sulphur fertilizer on growth, yield and sulphur content of garlic. Four levels of sulphur viz., 0, 10, 20 and 40 kg ha^{-1} were applied. He found that sulphur played an appreciable role in yield increase by increasing the number of leaves $plant^{-1}$, plant height, number of cloves $bulb^{-1}$, bulb fresh and dry weight and yield. Sulphur @ 40 kg ha^{-1} was found to be more effective.

Vinay-Singh *et al.* (1995) conducted a two-year field experiment in India on the effect of sulphur sources and levels on yield and uptake of nutrients by garlic cv. white skinned. Sulphur (s) was applied as gypsum, elemental sulphur, sodium sulphate or potassium sulphate at 0, 25, 50 or 100 kg S ha^{-1} during sowing with basal doses of N, P and K. Increased rate of applied S increase the bulb yield and uptake rates and also bulb concentration of NP increased significantly.

Abbas *et al.* (1994) conducted an experiment with a local garlic cultivar where N was applied at 0, 50, 100 or 150 kg ha^{-1} as urea and 0, 30, 60 or 90 kg K_2O ha^{-1} as muriate of potash. Garlic yield was found to be highest with 100 kg N ha^{-1} and 90 kg K_2O ha^{-1}. However, there was no significant interaction between N and K in this respect.

Sarvananan and Nambisan (1994) conducted an experiment on garlic. Garlic crop was given 0, 50, 100 or 150 kg N; 0, 25, 50 or 75 kg P and 0, 25, 50 or 75 kg K ha^{-1} in various combinations. Mean bulb yield was the highest (9750 kg ha^{-1}) with 100 kg N + 75 kg P + 50 kg K ha^{-1}.

Singh *et al.* (1994) carried out an experiment to investigate the effects of N (as urea at 0, 100 or 200 kg N ha^{-1}) on the growth of garlic cv. Amaranle. Plants also received 50 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1}. They observed that vegetative growth and yield (62.07 q ha^{-1}) were the maximum for plants receiving N at the rate of 100 kg ha^{-1}.

Selvaraj *et al.* (1993) conducted a field trial on a local garlic cultivar planted at a spacing of 15 cm × 7.5 cm. They found that the mean uptake of N, P, K and Mg at harvest (calculated from plant nutrient content) was 251.2, 19.03, 298.0 and 2.64 kg ha^{-1}, respectively. They recorded the highest yield of garlic (22.0 t ha^{-1}) with the application of N, K (K_2O) and $MgSO_4$ at 75, 75 and 50 kg ha^{-1}, respectively (in addition to 25 t FYM and 90 kg P_2O_5 ha^{-1}).

Wang *et al.* (1992) worked in China with garlic and found that the optimum N, P and K requirements for higher yield of garlic were 260.27, 60.86 and 369.67

ppm, respectively. They also observed that garlic yield was increased significantly as N, P and K supply was increased.

Eid *et al.* (1991) found that growth parameters and its components of garlic were generally increased with increased K application rate up to 100 kg K_2O/feddan and with micronutrient mixture (Cu, Zn and Fe).

Asandhi (1989) conducted an experiment to determine whether omitting P and K and reducing the N rate to 120 kg·ha^{-1} was possible since the garlic crop is grown after 2 preceding rice crops, which are heavily fertilized. In Indonesia, low land and highland garlic crops are traditionally fertilized with $N:P_2O_5:K_2O$ at the rate of 250:90:150 kg ha^{-1}. The results showed that P and K fertilization was needed and that decreasing the N rates reduced plant growth and garlic yield. The best method of N fertilization was the application of 80 kg N ha^{-1} at 15, 30 and 45 days after planting.

Setty *et al.* (1989) studied the effects of nitrogen, phosphorus and potash on the growth and yield of garlic. Application at three levels each of N (0, 100 and 200 kg ha^{-1}), P_2O_5 (0, 50 and 100 kg ha^{-1}) and K_2O (0, 50 and 100 kg ha^{-1}) were made. Application of N at 200 kg ha^{-1} showed significant increases in plant height, number of leaves, neck thickness, bulb size, number of cloves/bulb and yield. Application of P at 100 kg ha^{-1} increased the number of leaves, bulb size and number of cloves/bulb. Application of K at 100 kg ha^{-1} produced significantly larger bulbs. The largest bulb diameter (3.67 cm) and the highest yield (7.91 t ha^{-1}) were observed with the 100 kg N + 50 kg P_2O_5 + 50 kg K_2O ha^{-1} treatment.

Gudi *et al.* (1988) In a trial conducted in Indonesia observed that application of manure increased fresh yield of garlic. They applied stable manure to garlic at 0 to 10 t ha^{-1} and found that 10 t ha^{-1} stable manure gave the highest yield (12.2 kg/4.5 m^2) compared to control (5.2 kg/4.5m^2).

Hilman and Noordiyata (1988) conducted an experiment in a rice field at

Ciwidey, Indonesia to study equilibrium of N, P and K fertilization on garlic yield. The results showed that the equilibrium N, P and K fertilization at several levels did not significantly affect bulb diameter, bulb length, number of cloves per bulb or fresh bulb weight. However, the treatments indicated a significant effect on bulb dry matter weight.

Khalaf and Taha (1988) conducted an experiment to study the response of garlic plants grown on calcareous soil to organic manuring and sulphur application. Two experiments were conducted to evaluate the effects of organic manure (0 and 20 m/feddan) and sulphur (0, 250 and 500 kg/feddan) [1 feddan = 0.42 ha] on the growth, plant mineral contents, yield, bulb qualities and bulb volatile oil content of garlic. The treatments were applied during land preparation. They reported that both organic manure and S were significantly favourable for plant growth, total yield and quality as well as N, P and K contents in the plant tissues. The high S rates was more beneficial then the low one.

Borabash and Kochina (1987) worked on mineral fertilization with garlic productivity. They reported that mineral fertilization increased the assimilating leaf area, photosynthetic productivity and yield of garlic. The yields of underground bulbs and of underground bulbs + aerial bulbils at 90:90:90 kg ha^{-1} of N:P_2O_5:K_2O treatments were 6.48 and 7.50 t ha^{-1}, respectively and returns were the highest in this treatment although the 90:90:150 kg ha^{-1} treatment gave the highest yield.

Pereira *et al.* (1987) carried out an experiment on fertilization with garlic. Plants were grown without any fertilization, with NPK or with compost at 10, 20, 30, 40 or 50 t ha^{-1}. The highest yield (7067 kg ha^{-1}) was obtained with 20 t compost ha^{-1}.

Beresniewiez and Nowosiecski (1986) reported that application of 200 kg N, 200 kg P_2O_5, 200 kg K_2O, 20 kg Mg, 5 kg Mn, 5 kg Zn, 10 kg Cu and 1.5 kg

Mo·ha^{-1} gave the highest yields in garlic. Yields were further increased when organic fertilizer (lignite or peat) at 100 M^3 ha^{-1} and Ca at 2 t ha^{-1} were applied at the same time.

Guandi and Asandhi (1986) studied the effect of fertilization on garlic cv. Lumba Hijau planted at 20 × 40 m^2 plots and fertilized with 0, 80, 160 or 240 kg N ha^{-1} as urea or $(NH_4)_2SO_4$ + 120 K_2O ha^{-1} as KCl or K_2SO_4 + 120 kg P_2O_5 ha^{-1} as triple super phosphate. They observed that higher rates of N produced taller plants and longer stem diameter.

Paul and Pandey (1986) conducted an experiment to investigate the effect of different levels of fertilizers on the growth and yield of garlic. Plant growth was significantly increased by the application of 150 kg N, 250 kg P and 75 kg K ha^{-1}. Bulb yield of garlic was significantly increased by 150 kg N, 250 kg P and 75 kg K ha^{-1} (9.49 t ha^{-1} compared with 3.39 t ha^{-1} in control receiving no NPK).

Das *et al.* (1985) conducted an experiment on the effect of fertilization of N:P_2O_5 and/or K_2O at 0–120 : 0–60 : 0–120 kg ha^{-1} on garlic. The average yield of garlic was the highest (6.32 t ha^{-1}) with NPK at 60 : 60 : 120 kg ha^{-1}.

Koltunov (1984) conducted an experiment to study the effect of different fertilizer rates on garlic productivity and storability. They reported that application of FYM at 40 t ha^{-1} + N:P:K at 1:1:2 (N, P_2O_5 and K_2O at 60:60:120 kg ha^{-1}) gave the best yield of garlic suitable for long term storage.

Limat *et al.* (1984) conducted a 2-years trial to observe the effect of organic matter and vermiculite on garlic productivity with the cv. Amaranle of garlic. The plants were grown on soil into which the following were incorporated: green manure (*Crotalaria spectabilis*), FYM [Farm Yard Manure] (30 t ha^{-1}), processed industrial waste (30 t ha^{-1}) or vermiculite (6 t ha^{-1}). Profitability was the maximum with bulbs grown using processed industrial waste followed by FYM.

Nelson (1983) conducted an experiment on garlic fertilization trial. May planted garlic on silt loam soil was supplied with combination of (a) N at 100, 150 or 200 kg ha^{-1} as a basal dressing at 100 days after planting (b) 25 or 325 kg ha^{-1} and (c) 25 or 175 + 150 kg ha^{-1}. Both yield and bulb size of garlic were improved by increasing the basal N rate, increased N side dressing improved bulb size and when combined with the higher P rate it also raised the yield. The different K rates had no effect on yield or bulb size.

Lazzari *et al.* (1978) found that the application of higher nitrogenous fertilizer improved the yield and quality of garlic grown in a loam soil in Argentina.

Minard (1978) conducted an experiment with garlic cloves of 2 sizes (1.0–1.9 g and 2.0–2.9 g) fertilized with N at 0 or 210 kg ha^{-1}, P at 263–1250 kg ha^{-1}, K at 0 or 750 kg ha^{-1} and lime (as ground lime stone) at 5 or 15 t ha^{-1}. The highest yield was obtained from larger bulb size, receiving N and K at high and low rates, respectively.

Bohatyrenko (1975) set up an experiment to study the effects of organic and mineral fertilizers on garlic yield and nutrient removal from the soil. The researcher reported that annual application of FYM @ 40 t ha^{-1} + N, P_2O_5 and K_2O at 120:60:120 kg ha^{-1} gave garlic yields of 132, 76 and 65 centners ha^{-1}, in 1971 (good year), 1972 and (poor year) respectively with control yields of 90, 54 and 46 centners ha^{-1} in UK.

Kusomo and Widiajanto (1973) investigated the effect of fertilization on garlic. The normal fertilizer rate of 240 kg N, 60 kg P_2O_5 and 200 kg K_2O ha^{-1} (control) was compared with 5 other fertilizer treatments. The best of these five was a compound fertilizer, Rustica Blue, supplemented with urea to give 232 kg N, 120 kg P_2O_5 and 170 kg $K_2O \cdot ha^{-1}$, its effects, however, differed little from those of the control.

Pimpin (1970) reported the results of a study conducted with garlic cv. Blanca piacintin where 0, 80 and 160 kg ha^{-1} each of N, P_2O_5 and K_2O were applied in factorial combinations. N and K improved the number and weight of bulbs, but P had negative effects on these parameters.

Devjatova (1969) stated that autumn application of 30 tons of peaty compost ha^{-1} plus NP or NK or NPK at 90 kg ha^{-1} of each nutrient increased yield of garlic crop.

Purewal and Daragan (1961) conducted an experiment on fertilization with garlic. The application of nitrogen increased the weight of individual bulb significantly over control. The highest response was obtained on the weight of individual bulb with 112.27 kg ha^{-1} nitrogen. Phosphorus and potash did not show any significant response.

CHAPTER III

MATERIALS AND METHODS

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

3.1 Description of the experimental site

3.1.1 Location

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

3.1.2 Soil

Soil of the study site was salty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28) with PM 5.8-6.5, ECE-25.28 (Haider *et al*., 1991). The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix II.

3.1.3 Climate

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

3.2 Planting materials

The seeds of garlic CV. BARI Rashun-3 variety was collected from Bangladesh Agricultural Research Institute (BARI), Gazipur.

3.3 Experimental details

3.3.1 Treatments

The experiment consists of single factor. Twelve treatment combinations will be tested in this experiment:

1. T_0 = Control,
2. T_1 = 2 t ha^{-1} vermicompost,
3. T_2 = 4 t ha^{-1} vermicompost,
4. T_3 = 6 t ha^{-1} vermicompost,
5. T_4 = 50% NPKS (RDF),
6. T_5 = 100% NPKS (RDF),
7. T_6 = 2 t ha^{-1} vermicompost + 50% NPKS (RDF),
8. T_7 = 4 t ha^{-1} vermicompost + 50% NPKS (RDF),
9. T_8 = 6 t ha^{-1} vermicompost + 50% NPKS (RDF),
10. T_9 = 2 t ha^{-1} vermicompost + 100% NPKS (RDF),
11. T_{10} = 4 t ha^{-1} vermicompost + 100% NPKS (RDF) and
12. T_{11} = 6 t ha^{-1} vermicompost + 100% NPKS (RDF).

3.3.2 Experimental design

The experiment was laid out in Randomized Complete Block Design (RCBD) with 12 treatment combinations having three replications. First of all, the entire experimental plot was divided into three blocks, each of which was then divided into 36 unit plots. The treatment combinations was assigned randomly to the unit plots of one block. The size of unit plot was 1.0 m × 1.0 m and number of replication 3. Two adjacent unit plots and blocks was separated by 50.0 cm and 50.0 cm, respectively.

3.4 Land preparation

The selected experimental plot was first opened by a power tiller in the month of October, 2019, one month before planting. Several ploughing and cross ploughing with power tiller followed by laddering were done until the desired tilth was achieved for planting the cloves. The corners of the plots were trimmed by spade. The clodes were broken into friable soil and the surface of the soil was leveled. During land preparation weeds and stubbles of the previous crops were collected and removed from the field. Irrigation and drainage channels were prepared around the plots.

3.6 Manuring and fertilization

Urea, Triple Super Phosphate (TSP) and Murate of Potash (MoP), Zypsum were used as the fertilizer source of the nutrient elements N, P, K and S, respectively. A standard dose of Boric acid @ 24 kg ha^{-1} and Zinc Sulphate @ 29 kg ha^{-1} was used in all treatments. The vermicompost was applied after opening the land as per treatment. The total amount of TSP, MoP, Zypsum, Boric acid and Zinc sulphate were applied at the final land preparation as per treatment. Total urea was applied in two installments. The 1^{st} instalments were applied at final land preparation and 2^{nd} installments were applied 25 days after planting as top dressing as per treatment as per treatment. The fertilizer was thoroughly mixed with the soil.

The following doses of manure and fertilizer were used for the present study:

Fertilizer	Doses ha^{-1}	Sources
Vermicompost	2 t	Nature
	4 t	
	6 t	
Urea	217 kg	$CO(NH_2)_2$
TSP	265 kg	$Ca(H_2PO_4)_2$
MoP	333 kg	KCl
Zypsum	110 kg	$CaSO_4.H_2O$
Boric acid	24 kg	H_3BO_3
Zinc sulphate	29 kg	$ZnSO_4.H_2O$

3.7 Planting method of clove

The cloves for planting were selected from large bulbs of garlic. The cloves were separated from bulbs immediately before planting. Planting was done by placing cloves at a depth of 2.5 cm in the soil with the use of a pointed stick. The cloves were inserted vertically with the root plate down making sure that there was a root-soil contact. Selected cloves were planted in each unit plot maintaining spacing of different treatments required. Cloves were also planted around the experimental plot area to check border effect.

3.8 Intercultural operations

After planting the cloves, the experimental area was kept under careful observation and the following intercultural operations were done.

3.8.1 Gap filling

The unsproutcd cloves were replaced by healthy seedling taken from border plants within two weeks after planting. The damaged plants were also replaced by healthy border plants.

3.8.2 Weeding

Weeding was done regularly to keep the plots free from weeds and to pulverise the soil.

3.8.3 Irrigation

Frequency of watering depended upon the moisture status of the soil. Irrigation was given by a watering can as and when needed. Irrigations were provided in each plot uniformly. Mulching was done after each irrigation at appropriate time by breaking the soil crust.

3.8.4 Plant protection

After complete emergence of the crop, rovral @ 25gm /10 liters of water was applied at an interval of 15 days upto one month before harvesting to control purple leaf blotch disease of garlic.

3.9 Harvesting

The crop was harvested on 03 April, 2014, after attaining maturity, showing the sign of drying out of most of the leaves and softening of the neck of the bulb.

3.10 Collection of data

Ten plants were selected randomly from each unit plot for the collection of data. Data were collected periodically at 30, 60 and 90 DAS (Days after sowing) and at harvest in respect of following characters:

3.10.1 Plant height (cm)

Plant height was measured from ten plants in centimeter (cm) from the ground level to the tip of the longest leaf of the sample plants at 30, 60 and 90 DAS (Days after sowing) and at harvest. The mean was also calculated.

3.10.2 Number of leaves plant^{-1}

The numbers of leaves of 10 sample plants were counted at 30, 60 and 90 DAS (Days after sowing) and at harvest and their average was calculated.

3.10.3 Neck diameter (cm)

Diameter of pseudostem was taken at the neck of 10 randomly selected bulbs at 30, 60, and 90 DAS and their average was calculated.

3.10.4 Bulb diameter (cm)

The diameter at the middle part of the bulb was taken from ten randomly selected plants after harvest with a slide calipers and their mean was recorded in cm.

3.10.5 Clove length (cm)

Clove length was measured from ten plants in centimeter (cm) from the ground level to the end of the clove formation at harvest and the mean was calculated.

3.10.6 Bulb length (cm)

Bulb length was measured from ten plants in centimeter (cm) from the ground level to the end of the clove formation at harvest and the mean was calculated.

3.10.7 Number of cloves bulb^{-1}

After harvest, the numbers of cloves of 10 selected bulbs were counted thoroughly. The mean number of cloves bulb^{-1} was calculated by dividing the total number of cloves counted from ten bulbs by ten.

3.10.8 Fresh weight of bulb (g)

After harvest, the root and top portion were removed keeping only 2.5cm pseudostem with the bulb, the bulb weight of 10 selected plants were taken and their mean was calculated.

3.10.9 Dry weight of bulb (g)

After harvest, the root and top portion were removed keeping only 2.5cm pseudostem with the bulb. Then sliced bulb was dried in the sun kept in oven at 72°C for drying. It took 72 hrs and weight by using a digital electric balance and the weight was expressed in gram.

3.10.10 Fresh clove weight (g)

After harvest, the cloves were removed of garlic plant, the cloves weight of 10 selected plants were taken and their mean was calculated.

3.10.11 Dry clove weight (g)

After harvest, the cloves were removed of garlic plant. Then clove was dried in the sun kept in oven at 72°C for drying. It took 72 hrs and weight by using a digital electric balance and the weight was expressed in gram.

3.10.12 Fresh weight of leaf (g)

After harvest, leaves of 10 selected plants from each plot were collected and weight of leaves were taken by an ordinary balance in gram (g) and their mean was calculated.

3.10.13 Dry weight of leaf (g)

After harvest, leaves of 10 selected plants were weighted. Then leaves was dried in the sun kept in oven at 72°C for drying. It took 72 hrs and weight by using a digital electric balance and the weight was expressed in gram.

3.10.14 Root length (cm)

After harvest, root length was measured from ten plants in centimeter (cm) from the ground level to the end of the bulb formation and the mean was calculated.

3.10.15 Fresh weight of root (g)

After harvest, the roots of garlic plant were separated from the bulbs with a sharp knife. Then fresh weight of roots of 10 selected plants were taken and their meanwas calculated in gram (g).

3.10.16 Yield of bulb plot^{-1} (kg)

Bulb yield per plot was recorded by harvesting all the bulbs in each plot and taking their weight after removing roots and pseudostem keeping only 2.5 cm with the bulb. Yield per plot was expressed in kilogram (kg).

3.10.17 Yield (t ha^{-1})

Yield of bulb per plot was converted into yield per hectare and was expressed in tons.

3.11 Statistical analysis

The collected data from the experiment on yield and yield components were statistically analyzed following experiment in RCBD wherever necessary. The mean for all treatments were calculated and analyses of variance of the parameters under study were performed by F variance test. The significance of the difference among the means of treatment combinations was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez,1984). The means of the parameters were separated by least significant difference (LSD).

CHAPTER IV

RESULTS AND DISCUSSIONS

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

4.1 Plant height (cm)

Plant height was significantly influenced by different nutrients application at different days after sowing (DAS) of garlic (Table 1 and Appendix VI). It was observed that at 30, 60, 90 DAS and at harvest plant height was significantly influenced by different levels of plant nutrient. Plant height was increased within 30 DAS to 90 DAS. At 30 and 60 DAS, the longest plant (22.60 cm and 36.30 cm) was achieved from T_{10} (4.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment, which was statistically similar to T_{11} (22.07 cm and 35.60 cm) treatment whereas, the shortest plant (19.53 cm and 28.53 cm) was observed from T_0 (control) treatment which was statistically identical to T_1 (19.87 cm) at 30 DAS and similar to T_2 (20.20 cm) at 30 DAS treatment. At 90 DAS and harvest, the longest plant (49.90 cm and 37.10 cm) was achieved from T_{11} (6.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment, which was statistically similar to T_{10} (36.20 cm) at harvest treatment and the shortest plant (39.33 and 32.30 cm, respectively) was observed from T_0 (control) treatment which was statistically similar to T_1 (40.80 cm at 90 DAS) treatment. This promoted increased nutrient uptake by the garlic crop in goat manure-based vermi-compost treated soils which facilitated increased plant growth hence taller garlic plants. Similar results were found from the findings of Farooqui *et al.* (2009). Hence it may be inferred that the increase in plant height may be due to the favorable influence and balanced absorption of nutrients, increased role of photosynthesis, reduced transpiration and stimulation of root system. Harun-or Rashid (1998) was observed that plant height was significantly influence by different plant nutrient application to garlic crop field. Hore *et al.* (2014) also reported that plant height increased from 53.98 cm to 69.14 cm with increasing level of nitrogen from 50 kg ha^{-1} to 200 kg ha^{-1} and thereby decreased. Diriba-Shiferaw *et al.* (2013) also found similar results that application of different compound fertilizers significantly influenced garlic plant height at all successive growth stages of 30, 60, 90 and 120 days after planting. Fanaei *et al.* (2014) reported significant difference in plant height for different garlic germplasm. Bagali *et al.* (2012) reported that significantly higher plant height over lower levels of vermi-compost was recorded in response to application of vermi-compost at the rate of 6 t ha^{-1}. The result of this study are agreements with the Mandloi *et al.* (2008), Ali *et al.* (1998), Gunadi *et al.* (1996) and Naidu *et al.* (2000) in garlic crop.

Table 1. Effect of different nutrient on plant height of garlic at different data recording intervals

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	Harvest
T_0	19.53 g	28.53 g	39.33 h	32.30 e
T_1	19.87 g	31.73 f	40.80 gh	33.63 d
T_2	20.20 fg	32.80 e	41.23 g	34.47 cd
T_3	20.93 d-f	33.27 de	44.10 ef	35.43 bc
T_4	20.73 ef	34.03 cd	44.07 ef	35.17 bc
T_5	21.20 c-e	34.03 cd	43.30 f	34.83 cd
T_6	21.67 b-d	34.73 bc	45.30 de	35.03 bc
T_7	21.77 bc	34.90 bc	47.27 bc	35.50 bc
T_8	21.80 bc	35.23 b	47.23 bc	35.43 bc
T_9	21.73 bc	34.20 cd	46.10 cd	34.90 c
T_{10}	22.60 a	36.30 a	48.17 b	36.20 ab
T_{11}	22.07 ab	35.60 ab	49.90 a	37.10 a
LSD (0.05)	**0.3700**	**0.9760**	**0.8552**	**0.6019**
CV (%)	**2.06**	**1.71**	**2.26**	**2.03**

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

Here, T_0 = Control, T_1 = 2.0 t ha^{-1} vermi-compost, T_2 = 4.0 t ha^{-1} vermi-compost, T_3 = 6.0 t ha^{-1} vermi-compost, T_4 = 50% NPKS (RDF), T_5 = 100% NPKS (RDF), T_6 = 2.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_7 = 4.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_8 = 6.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_9 = 2.0 t ha^{-1} vermi-compost + 100% NPKS (RDF), T_{10} = 4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) and T_{11} = 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF).

4.2 Number of leaves plant^{-1}

There was significant difference in the number of leaves plant^{-1} of garlic due to different plant nutrient application at different days after sowing (DAS) (Table 2 and Appendix V). It was observed that at 30, 60, 90 DAS and at harvest, number of leaves plant^{-1} was significantly influenced by different levels of plant nutrient application. At 30 and 60 DAS, the highest number of leaves plant^{-1} (4.53) and (5.93) was achieved from T_{10} (4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment, which was statistically similar to T_{11} (4.37) and (5.73) treatment whereas, the lowest number of leaves plant^{-1} (3.17) and (4.23) was observed from T_0 (control) treatment which was statistically similar to T_1 (3.37) and T_2 (3.40) treatment at 30 DAS. At 90 DAS and harvest, the highest number of leaves plant^{-1} (6.60) and (5.87) was achieved from T_{11} (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment and the lowest number of leaves plant^{-1} (5.05) and (4.02) was observed from T_0 (control) treatment which was statistically similar to T_2 (4.30) and T_1 (4.32) treatment at harvest. From the results of the present study indicated that optimum levels of vermi-compost and NPKS combination might have induced better growing condition, perhaps due to supply of adequate plant nutrients which ultimately led to the production of more leaves plant^{-1}. The result obtained from the present was supported by Farooqui *et al.* (2009), Setty *et al.* (1989), Vachhani and Patel (1993), Alam (1995) and Jana and Kabir (1990) in respect of number of leaves per plant. Bagali *et al.* (2012) reported that significantly higher number of leaves per plant, leaf area per plant and leaf area index over lower levels of vermi-compost was recorded in response to application of vermi-compost at the rate of 6 t ha^{-1}.

Table 2. Effect of different nutrient on number of leaves plant^{-1} of garlic at different data recording intervals

Treatment	Number of leaves plant^{-1}			
	30 DAS	60 DAS	90 DAS	Harvest
T_0	3.17 g	4.23 h	5.05 e	4.02 f
T_1	3.37 fg	4.53 g	5.47 d	4.32 e
T_2	3.40 fg	4.80 f	5.67 cd	4.30 ef
T_3	3.53 ef	5.07 e	5.80 b-d	4.73 cd
T_4	3.80 de	5.33 d	5.60 cd	4.33 e
T_5	3.87 cd	5.40 cd	5.80 b-d	4.53 de
T_6	3.90 cd	5.57 bc	6.00 bc	4.40 e
T_7	4.13 bc	5.70 b	5.95 bc	5.30 b
T_8	3.90 cd	5.67 b	5.87 b-d	5.00 c
T_9	3.73 de	5.60 bc	5.67 cd	4.93 c
T_{10}	4.53 a	5.93 a	6.13 b	5.33 b
T_{11}	4.37 ab	5.73 ab	6.60 a	5.87 a
LSD (0.05)	**0.1390**	**0.1028**	**0.2037**	**0.1420**
CV (%)	**4.31**	**2.29**	**4.15**	**3.53**

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

Here, T_0 = Control, T_1 = 2.0 t ha^{-1} vermi-compost, T_2 = 4.0 t ha^{-1} vermi-compost, T_3 = 6.0 t ha^{-1} vermi-compost, T_4 = 50% NPKS (RDF), T_5 = 100% NPKS (RDF), T_6 = 2.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_7 = 4.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_8 = 6.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_9 = 2.0 t ha^{-1} vermi-compost + 100% NPKS (RDF), T_{10} = 4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) and T_{11} = 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF).

4.3 Neck diameter (cm)

Application of different nutrients had significant effect of neck diameter of garlic at different days after sowing (DAS) (Table 3 and Appendix VI). It was observed that at 30 DAS, there was no significant effect on neck diameter among the treatments but in case of 60 and 90 DAS, neck diameter was significantly influenced by different levels plant nutrients application. At 30 DAS, the numarically maximum neck diameter (0.36 cm) was observed from T_{11} (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment and the numarically minimum (0.26 cm) was observed from T_0 (control) treatment. At 60 and 90 DAS, the maximum neck diameter (0.55 cm and 0.67 cm) was recorded from T_{11} (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment which was statistically similar to T_{10} (0.53 cm) at 60 DAS and the minimum (0.42 and 0.52 cm) was recorded from T_0 (control) treatment which was statistically similar to T_1 (0.45 cm and 0.53 cm) treatment. These result indicated that the different levels of vermi-compost with NPKS fertilizers combinedly supplied plant nutrients and provided better growing conditions which helped for getting proper vegetative growth as well as maximum neck diameter. Farooqui *et al.* (2009) and Setty *et al.* (1989) also observed that different plant nutrients significantly affect neck diameter of garlic during cropping season.

Table 3. Effect of different nutrients on neck diameter (cm) of garlic at different data recording intervals

Treatment	Neck diameter (cm)		
	30 DAS	**60 DAS**	**90 DAS**
T_0	0.26	0.42 f	0.52 h
T_1	0.27	0.44 ef	0.53 gh
T_2	0.28	0.45 ef	0.53 gh
T_3	0.28	0.47 de	0.54 fg
T_4	0.29	0.49 cd	0.54 fg
T_5	0.30	0.49 cd	0.56 ef
T_6	0.30	0.50 b-d	0.57 e
T_7	0.32	0.51 bc	0.62 d
T_8	0.33	0.52 ab	0.64 bc
T_9	0.31	0.50 bc	0.62 cd
T_{10}	0.34	0.53 ab	0.65 b
T_{11}	0.36	0.55 a	0.67 a
LSD (0.05)	**NS**	**0.0165**	**0.0103**
CV (%)	**5.38**	**3.99**	**2.10**

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

Here, T_0 = Control, T_1 = 2.0 t ha^{-1} vermi-compost, T_2 = 4.0 t ha^{-1} vermi-compost, T_3 = 6.0 t ha^{-1} vermi-compost, T_4 = 50% NPKS (RDF), T_5 = 100% NPKS (RDF), T_6 = 2.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_7 = 4.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_8 = 6.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_9 = 2.0 t ha^{-1} vermi-compost + 100% NPKS (RDF), T_{10} = 4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) and T_{11} = 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF).

4.4 Bulb diameter (cm)

Different levels of nutrient application showed significant variation for bulb diameter of garlic (Table 4 and Appendix VII). It was found that the highest bulb diameter of garlic (3.32 cm) was recorded from T_{11} (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment which was statistically similar to T_{10} (3.15 cm) treatment, where the lowest bulb diameter of garlic (2.11 cm) treatment was recorded from T_0 (control) treatment, which was statistically identical (2.13 cm) with T_1 (vermi-compost 2.0 t ha^{-1}) treatment. The probable reason for maximum diameter of bulb is may be due to the application of RDF which enhanced the activity of some microbial population in vermi-compost along with NPK nutrient resulting in increase to the diameter of bulb. The results of this study are agreements with the Bhatia and Pandey (1997) and Yadav (2003) in garlic crop. Different levels of plant nutrient application showed significant influence on bulb diameter and it was supported by the findings of Farooqui *et al.* (2009), Setty *et al.* (1989), Francois (1991) and Varu *et al.* (1997). The result was in conformity with the findings of Nasiruddin *et al.* (1993) that reported the application of both potassium and sulfur either individually or in combined increased bulb diameter, bulb weight and bulb yield. This might be due to the fact that organic manure (MOC) kept the soil loose and both manure and fertilizers supplied adequate plant nutrients for better vegetative growth of garlic plants and ultimately increased bulb diameter. Varu *et al.* (1997) obtained the highest bulb diameter from organic + inorganic fertilizers.

4.5 Clove length (cm)

Effect of different nutrients application showed significant variation on clove length of garlic (Table 4 and Appendix VII). Increased trend was found with increased nutrient levels. The longest clove of garlic (3.44 cm) was recorded from T_{11} (6.0 t ha^{-1} vermicompost + 100% NPKS (RDF) treatment which was statistically identical (3.36 cm) with T_{10} (4.0 t ha^{-1} vermicompost + 100% NPKS (RDF) treatment. On the other hand, the shortest clove of garlic (2.53 cm) was recorded from T_0 (control) treatment.

Table 4. Effect of different nutrients on clove and bulb parameters of garlic

Treatment	Bulb diameter (cm)	Clove length (cm)	Bulb length (cm)
T_0	2.11 g	2.53 f	1.65 g
T_1	2.13 g	2.65 e	1.81 f
T_2	2.35 f	2.72 e	1.88 f
T_3	2.39 f	2.87 d	1.90 ef
T_4	2.44 ef	2.95 cd	1.99 de
T_5	2.63 de	2.93 cd	2.03 cd
T_6	2.65 d	2.97 cd	2.01 d
T_7	2.94 c	3.01 c	2.07 cd
T_8	3.01 bc	3.14 b	2.25 b
T_9	2.93 c	2.98 c	2.13 c
T_{10}	3.15 ab	3.36 a	2.28 b
T_{11}	3.32 a	3.44 a	2.43 a
LSD (0.05)	**0.1020**	**0.0510**	**0.0508**
CV (%)	**4.51**	**2.04**	**2.95**

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

Here, T_0 = Control, T_1 = 2.0 t ha^{-1} vermi-compost, T_2 = 4.0 t ha^{-1} vermi-compost, T_3 = 6.0 t ha^{-1} vermi-compost, T_4 = 50% NPKS (RDF), T_5 = 100% NPKS (RDF), T_6 = 2.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_7 = 4.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_8 = 6.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_9 = 2.0 t ha^{-1} vermi-compost + 100% NPKS (RDF), T_{10} = 4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) and T_{11} = 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF).

4.6 Bulb length (cm)

Effect of different nutrients application showed significant variation on bulb length of garlic (Table 4 and Appendix VII). Increased trend was found with increased nutrient levels. The highest bulb length of garlic (2.43 cm) was recorded from T_{11} (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment whereas, the lowest bulb length of garlic (1.65 cm) was recorded from T_0 (control) treatment. Setty *et al*. (1989) and Pande and Mundra (1971) observed that different nutrients had significant effect on bulb size.

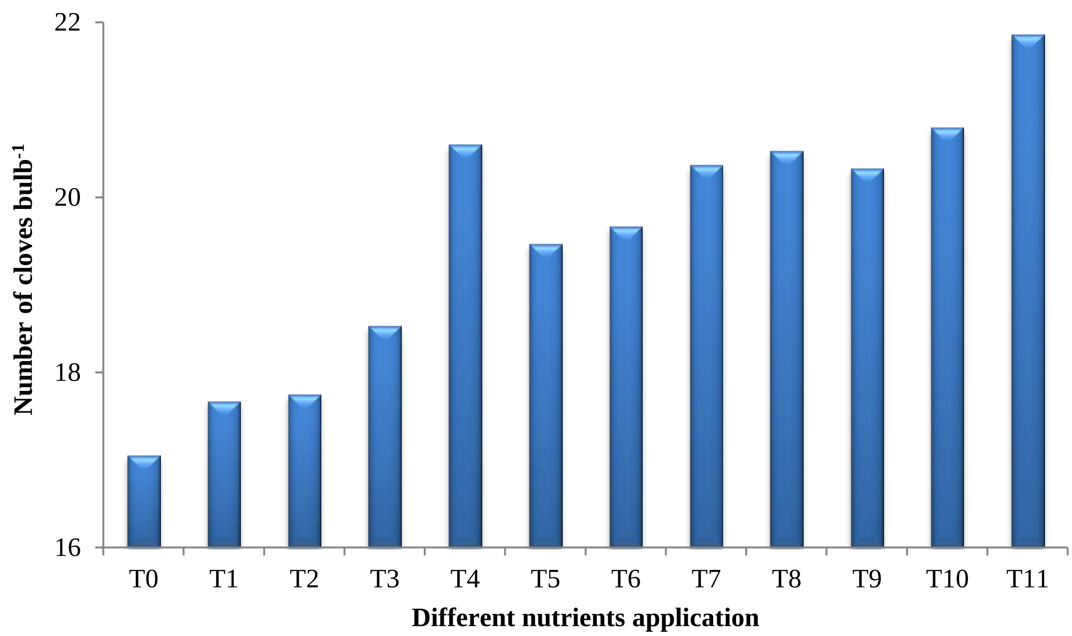

Fig. 1. Effect of different nutrients application on number of cloves/bulb of garlic (LSD value = 0.3619)

Here, T_0 = Control, T_1 = 2.0 t ha^{-1} vermi-compost, T_2 = 4.0 t ha^{-1} vermi-compost, T_3 = 6.0 t ha^{-1} vermi-compost, T_4 = 50% NPKS (RDF), T_5 = 100% NPKS (RDF), T_6 = 2.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_7 = 4.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_8 = 6.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_9 = 2.0 t ha^{-1} vermi-compost + 100% NPKS (RDF), T_{10} = 4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) and T_{11} = 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF).

4.7 Number of cloves bulb^{-1}

Different levels of nutrients application showed significant variation for number of cloves bulb^{-1} of garlic (Figure 1 and Appendix VII). Observed result showed that the maximum number of cloves bulb^{-1} of garlic (21.25) was recorded from T_{11} (6.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment. On the other hand, the minimum number of cloves bulb^{-1} of garlic (17.11) was recorded from T_0 (control) treatment. According to Fanaei *et al.* (2014) number of clove bulb^{-1} may be important trait in increasing bulb yield that should be considered in breeding of local varieties. Application of RDF and vermi-compost, nutrient resulting in increase of cloves number per bulb. The results of this study in agreements with the Yadav (2003), Reddy *et al.* (2000), Ali *et al.* (1998) and Verma *et al.* (1996) in garlic crop. Manish *et al.* (2017) reported that number of cloves per bulb of garlic were significantly affected with varying levels of S application. Similar result was found from the findings of Farooqui *et al.* (2009), Naik and Hosamani (2003), Setty *et al.* (1989) and Hilman and Noordiyata (1988).

4.8 Fresh weight of bulb (g)

Fresh weight bulb plant^{-1} was significantly influenced due to different levels of nutrients application (Figure 2 and Appendix VII). Fresh bulb weight was increased with increasing plant nutrients. Results showed that the maximum fresh weight of bulb (35.11 g) was recorded from T_{11} (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment whereas, the minimum fresh weight of bulb (18.52 g) was recorded from T_0 (control) treatment. From the above results, it was noted that vermi-compost and NPKS fertilizers when combinedly used the nutrients become available to plants and much bulb formation was occurred. The available soil nutrients supported proper vegetative growth by producing succulent bulb with more protoplasm in the cells in comparison to less available nutrient in garlic. The results found from the findings of Farooqui *et al.* (2009), Gudi *et al.* (1988), Pande and Mundra (1971), Hilman and Noordiyata (1988), Alam (1995) and Maurya and Lai (1975) were similar with the present study. Bulb development in garlic depend on an increase in total soluble carbohydrate in photosynthetic activity of the leaves which depend on light and nutrition (Arguleo *et al.*, 2007). Kakar *et al.* (2002) reported that increasing nitrogen level upto 100 kg resulted in the maximum single bulb weight (42.60 g) of garlic. The result was in conformity with the findings of Nasiruddin *et al.* (1993) that reported the application of both potassium and sulfur either individually or in combined increased fresh bulb weight of gralic. The reason for maximum fresh weight of bulb due to the RDF and Vermi-compost application in the soil enhances the biochemical potential of soil and consequently effect plant production. The results of this study are agreements with the Suther (2009), Jahangir *et al.* (2005) and Abdel *et al.* (2002) in garlic crop.

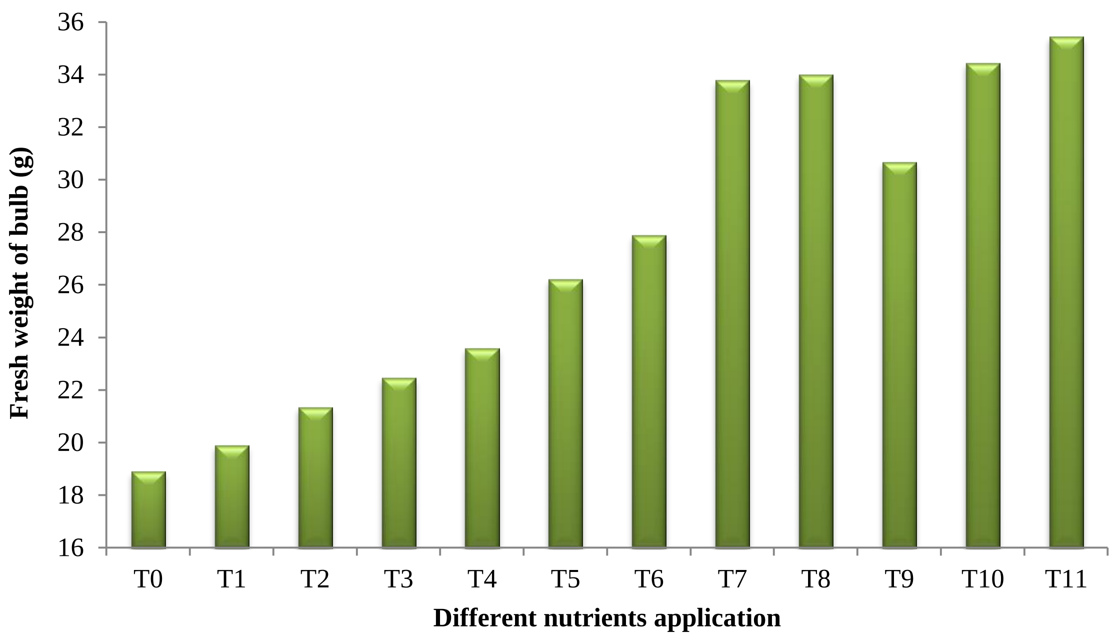

Fig. 2. Effect of different nutrients application on fresh weight of bulb(g) of garlic (LSD value = 0.4632)

Here, T_0 = Control, T_1 = 2.0 t ha^{-1} vermi-compost, T_2 = 4.0 t ha^{-1} vermi-compost, T_3 = 6.0 t ha^{-1} vermi-compost, T_4 = 50% NPKS (RDF), T_5 = 100% NPKS (RDF), T_6 = 2.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_7 = 4.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_8 = 6.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_9 = 2.0 t ha^{-1} vermi-compost + 100% NPKS (RDF), T_{10} = 4.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) and T_{11} = 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF).

4.9 Dry weight of bulb (g)

The different nutrients application had significant influence on the dry weight of bulb of garlic (Table 5 and Appendix VII). The maximum dry weight of bulb was obtained from the treatment of 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) (4.95 g) which was followed by the treatment of 4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) (4.53 g) and 6.0 t ha^{-1} vermi-compost + 50% NPKS (RDF) (4.40 g). On the other hand, the minimum dry weight of bulb was obtained from the treatment of control (2.03 g) which was statistically similar with the treatment of 2.0 t ha^{-1} vermi-compost (2.25 g). Such effect of vermi-compost and NPKS fertilizers application may be attributed to the provision of favourable soil condition and supply of required nutrients for better growth and development which gave maximum dry weight. Manish *et al.* (2017) showed that the dry weight of bulb of garlic were significantly affected with varying levels of S application. This result is supported by Juan *et al.* (2006) who showed that vermi-compost increased the bulb dry weight due to the accumulation of non-structural carbohydrates whose distribution patterns change, thus favouring the metabolism of fructan precursors and accumulating as scorodose.

4.10 Fresh clove weight (g)

Fresh clove weight $plant^{-1}$ was significantly influenced due to different levels of nutrients application (Table 5 and Appendix VII). Results observed that the highest fresh clove weight (6.93 g) was recorded from T_{11} (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment which was statistically similar with T_{10} (6.68 g) and T_8 (6.37 g) treatment whereas, the lowest fresh clove weight (3.04 g) was recorded from T_0 (control) treatment which was statistically similar with T_1 (3.48 g) and T_2 (3.70 g) treatment. The results found from the findings of Farooqui *et al.* (2009), Gudi *et al.* (1988), Pande and Mundra (1971), Hilman and Noordiyata (1988), Alam (1995) and Maurya and Lai (1975) were similar with the present study.

Table 5. Effect of different nutrients on clove and bulb weight of garlic

Treatment	Dry weight of bulb (g)	Fresh clove weight (g)	Dry clove weight (g)
T_0	2.03 g	3.04 h	1.43 i
T_1	2.25 fg	3.48 gh	1.45 hi
T_2	2.39 f	3.70 g	1.50 gh
T_3	2.54 f	4.24 f	1.55 fg
T_4	2.94 e	4.68 f	1.57 fg
T_5	3.31 d	5.18 e	1.60 ef
T_6	3.63 d	5.61 de	1.64 de
T_7	4.16 c	6.04 cd	1.68 cd
T_8	4.40 bc	6.37 bc	1.74 bc
T_9	4.09 c	5.97 cd	1.66 d
T_{10}	4.53 b	6.68 ab	1.75 b
T_{11}	4.95 a	6.93 a	1.89 a
LSD (0.05)	**0.1713**	**0.2250**	**0.0329**
CV (%)	**5.89**	**5.15**	**2.39**

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

Here, T_0 = Control, T_1 = 2.0 t ha^{-1} vermi-compost, T_2 = 4.0 t ha^{-1} vermi-compost, T_3 = 6.0 t ha^{-1} vermi-compost, T_4 = 50% NPKS (RDF), T_5 = 100% NPKS (RDF), T_6 = 2.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_7 = 4.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_8 = 6.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_9 = 2.0 t ha^{-1} vermi-compost + 100% NPKS (RDF), T_{10} = 4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) and T_{11} = 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF).

4.11 Dry clove weight (g)

The different nutrients application had significant influence on the dry clove weight of garlic (Table 5 and Appendix VII). The maximum dry clove weight was obtained from the treatment of 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) (1.89 g). On the other hand, the minimum dry clove weight was obtained from the treatment of control (1.43 g) which was statistically similar with the treatment of 2.0 t ha^{-1} vermi-compost (1.45 g). Such effect of vermi-compost and NPKS fertilizers application may be attributed to the provision of favourable soil condition and supply of required nutrients for better growth and development which gave maximum dry weight.

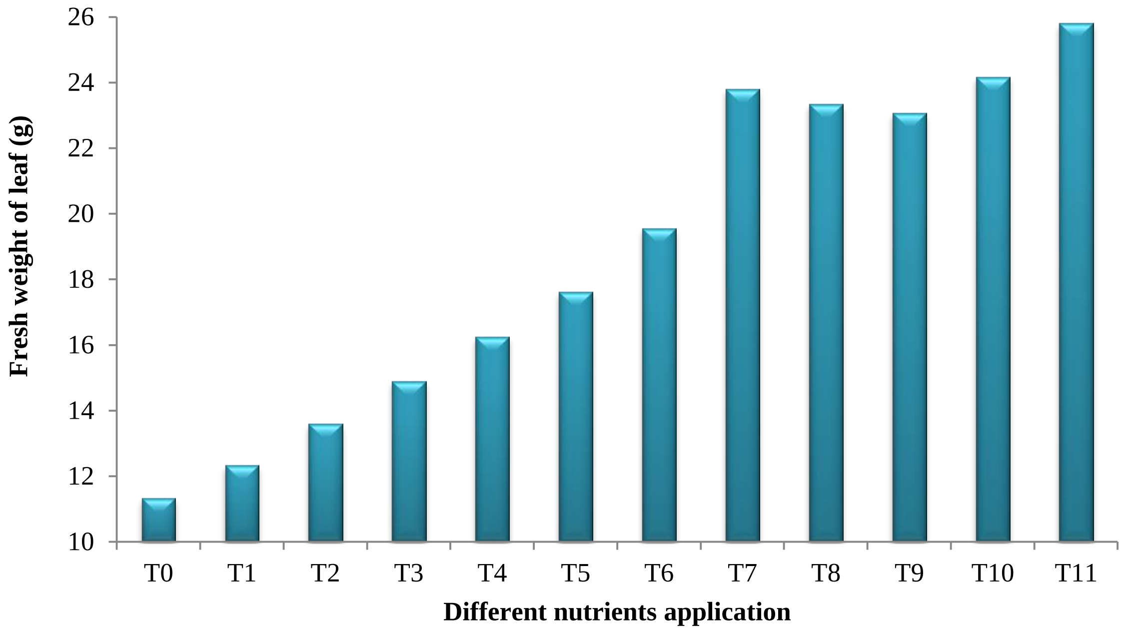

Fig. 3. Effect of different nutrients application on fresh weight of leaf (g) of garlic (LSD value = 1.4658)

Here, T_0 = Control, T_1 = 2.0 t ha^{-1} vermi-compost, T_2 = 4.0 t ha^{-1} vermi-compost, T_3 = 6.0 t ha^{-1} vermi-compost, T_4 = 50% NPKS (RDF), T_5 = 100% NPKS (RDF), T_6 = 2.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_7 = 4.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_8 = 6.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_9 = 2.0 t ha^{-1} vermi-compost + 100% NPKS (RDF), T_{10} = 4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) and T_{11} = 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF).

4.12 Fresh weight of leaf (g)

A significant variation was observed on the fresh weight of leaves plant-1 due to different nutrients application (Figure 3 and Appendix VIII). The maximum fresh weight of leaves plant^{-1} (25.31 g) was recorded from the treatment of 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) while the minimum was recorded from the treatment of control (11.08 g). The highest plant height along with maximum number of leaves plant^{-1} in T_{11} treatment (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF)) contributed to gave the highest weight of leaves due to better nutrient supply at the growing stage of the plants. Kakar *et al.* (2002) and Jan *et al.* (2009) also reported that nitrogen fertilization is necessary for ensuring successful vegetative growth of garlic.

4.13 Dry weight of leaf (g)

Different nutrients applications showed significant variation in respect of dry weight of leaves (Table 6 and Appendix VIII). The maximum dry weight of leaves (3.31 g) was obtained from 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) (T_{11}) treatment which was followed (g) by T_{10} (3.21 g) and T_8 (3.07 g) treatment. But the minimum (1.11 g) dry weight of leaves plant^{-1} was recorded from the treatment of control which was statistically identical with T_1 (1.15 g) treatment. The higher dry weight of leaves plant^{-1} was obtained due to availability of more nutrients in the soil in all stages of plant resulting of plant higher vegetative growth. Fenwik and Hanley (1985) reported that, in garlic, the fructan polysaccharide is the scorode which accounts for 8% of garlic leaves dry matter.

Table 6. Effect of different nutrient on leaf and root parameters of garlic

Treatment	Dry weight of leaf (g)	Root length (cm)	Fresh weight of root (g)
T_0	1.11 i	10.40 h	0.48 g
T_1	1.15 i	11.47 gh	0.49 g
T_2	1.41 h	12.74 fg	0.56 f
T_3	1.63 g	13.84 f	0.58 f
T_4	1.93 f	15.48 e	0.61 ef
T_5	2.38 e	16.35 e	0.67 de
T_6	2.64 d	18.11 d	0.72 d
T_7	3.05 c	20.16 bc	0.86 bc
T_8	3.07 bc	21.17 bc	0.88 bc
T_9	2.99 c	19.97 c	0.84 c
T_{10}	3.21 ab	22.70 a	0.96 a
T_{11}	3.31 a	21.57 ab	0.92 ab
LSD (0.05)	**0.0779**	**0.7373**	**0.0316**
CV (%)	**3.96**	**5.12**	**5.23**

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

Here, T_0 = Control, T_1 = 2.0 t ha^{-1} vermi-compost, T_2 = 4.0 t ha^{-1} vermi-compost, T_3 = 6.0 t ha^{-1} vermi-compost, T_4 = 50% NPKS (RDF), T_5 = 100% NPKS (RDF), T_6 = 2.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_7 = 4.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_8 = 6.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_9 = 2.0 t ha^{-1} vermi-compost + 100% NPKS (RDF), T_{10} = 4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) and T_{11} = 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF).

4.14 Root length (cm)

Effect of different nutrients application showed significant variation on root length of garlic (Table 6 and Appendix VIII). Increased trend was found with increased nutrient levels. The longest root of garlic (22.70 cm) was recorded from T_{10} (4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment which was statistically similar (21.57 cm) with T_{11} (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment. On the other hand, the shortest root of garlic (10.40 cm) was recorded from T_0 (control) treatment which was statistically similar (11.47 cm) with T_1 (2.0 t ha^{-1} vermi-compost) treatment.

4.15 Fresh weight of root (g)

The fresh weight of roots $plant^{-1}$ significantly differed with different nutrients application (Table 6 and Appendix VIII). The maximum fresh weight of roots $plant^{-1}$ (0.96 g) was recorded from the treatment of 4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) (T_{10}) which was statistically similar with T_{11} (0.92 g) treatment whereas, the minimum fresh weight of roots $plant^{-1}$ (0.48 g) was recorded from the control T_0(control) treatment which was statistically similar with T_{11} (0.49 g) treatment.

4.16 Yield of bulb $plot^{-1}$ (kg)

Yield per plot of garlic was significantly affected by different levels of nutrients application (Table 7 and Appendix IX). Higher application of plant nutrients gave higher bulb yield per plot. Results specified that the highest yield per plot of garlic (1.45 kg) was recorded from T_{11} (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment where, the lowest yield per plot of garlic (0.54 kg) was recorded from T_0 (control) treatment. 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) gave the highest yield and it was probably due to the fact that combination of organic and inorganic fertilizers improved physical condition of the soil for better growth as well as supplied sufficient plant nutrients in all stages of plant growth. This result is in agreement with the findings of Mallanagouda *et al.* (1995), Kropisz (1992) and Vinay *et al.* (1995).

Table 7. Effect of different nutrient on yield of garlic

Treatment	Yield plot^{-1} (kg)
T_0	0.54 j
T_1	0.66 i
T_2	0.74 h
T_3	0.87 f
T_4	0.77 g
T_5	0.85 f
T_6	0.92 e
T_7	1.05 d
T_8	1.22 c
T_9	1.06 d
T_{10}	1.25 b
T_{11}	1.45 a
LSD (0.05)	0.0170
CV (%)	0.60

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

Here, T_0 = Control, T_1 = 2.0 t ha^{-1} vermi-compost, T_2 = 4.0 t ha^{-1} vermi-compost, T_3 = 6.0 t ha^{-1} vermi-compost, T_4 = 50% NPKS (RDF), T_5 = 100% NPKS (RDF), T_6 = 2.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_7 = 4.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_8 = 6.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_9 = 2.0 t ha^{-1} vermi-compost + 100% NPKS (RDF), T_{10} = 4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) and T_{11} = 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF).

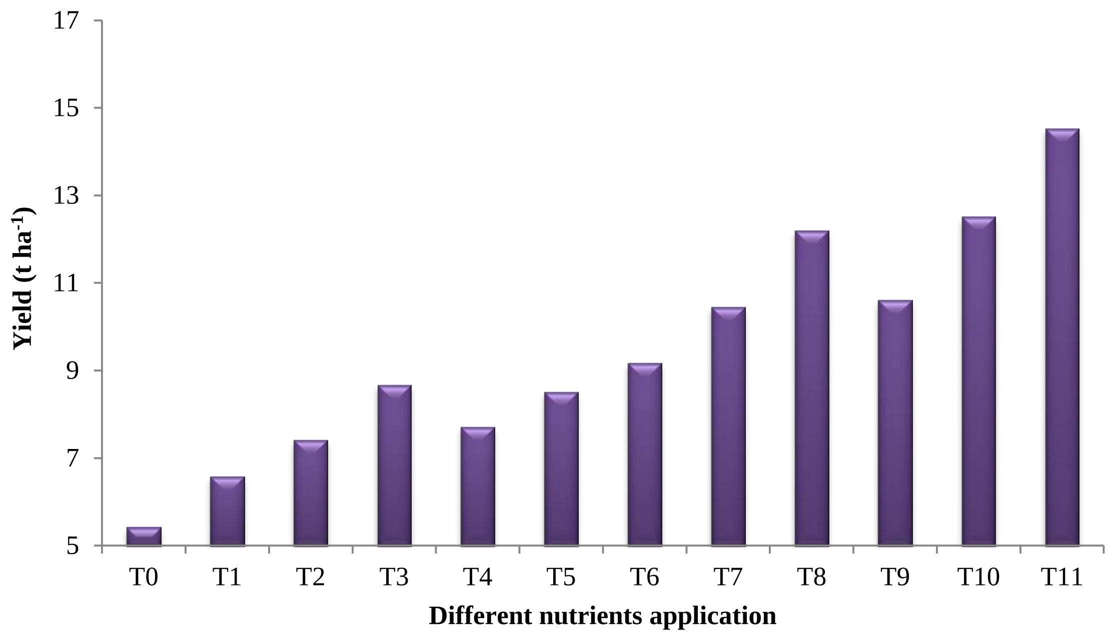

Fig. 4. Effect of different nutrients application on yield (t ha^{-1}) of garlic (LSD value = 0.1696)

Here, T_0 = Control, T_1 = 2.0 t ha^{-1} vermi-compost, T_2 = 4.0 t ha^{-1} vermi-compost, T_3 = 6.0 t ha^{-1} vermi-compost, T_4 = 50% NPKS (RDF), T_5 = 100% NPKS (RDF), T_6 = 2.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_7 = 4.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_8 = 6.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_9 = 2.0 t ha^{-1} vermi-compost + 100% NPKS (RDF), T_{10} = 4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) and T_{11} = 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF).

4.17 Yield (t ha^{-1})

Different levels of nutrients application showed significant variation on yield (t ha^{-1}) of garlic (Figure 4 and Appendix IX). Results represented that the maximum yield of garlic (14.53 t ha^{-1}) was recorded from T_{11} (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF)) treatment. Again, the minimum yield of garlic (5.43 t ha^{-1}) was recorded from T_0 (control) treatment. The results obtained from the present study was similar with the findings of Farooqui *et al.* (2009), Limat *et al.* (1984), Setty *et al.* (1989) and Agrawal *et al.* (1981). The plant received more nutrients when raised with the combination of vermi-compost and NPKS fertilizers. Bogatirenko (1995) and Koltunov (1984) found the highest yield of garlic when grown with the combination of organic and inorganic fertilizers. Balanced fertilizers are the basis for more production and nutrient needs of crops is according to their physiological requirements and expected yields (Ryan, 2008). Bulb crops are a heavy feeder, requiring optimum supplies of nitrogen, phosphorus, potassium and sulphur and other nutrients which can adversely affect the growth, yield and quality of bulbs under sub-optimal levels in the soil (Gubb and Tavis, 2002). The application of RDF and vermi-compost and micro nutrients setting are affected the soil ability and balancing nutrient supply to the plant increase with the bulb yield with the study are agreement with the findings of Yadav (2003), Patil *et al.* (2007), Sharma (1988), Singh *et al.* (1994) and Jahangir *et al.* (2005) in garlic crop. Increased yield may be due to role of S in improving uptake of nutrient by root system, increased chlorophyll content, photosynthesis activity and protein content in crop plants. Similar results were also reported by Verma *et al*. (2013) and Chaudhary *et al*. (2014). The increase in bulb yield with application of vermi-compost were in conformity with the earlier findings of Suthar (2009), Shashidhar *et al*. (2009), Rodriguez *et al*. (2012) and Verma *et al*. (2013).

4.18 Cost benefit analysis

4.18.1 Gross income

In the combination of vermi-compost and fertilizer management practices maximum gross income (Tk. 5,81,200.00) was obtained from the treatment combination of T_{11} (6.0 $t{\cdot}ha^{-1}$ vermi-compost + 100% NPKS (RDF) and the second highest gross income (Tk. 5,00,400.00) was obtained from the treatment combination of T_{10} (4.0 $t{\cdot}ha^{-1}$ vermi-compost + 100% NPKS (RDF). The lowest gross income (Tk. 2,17,200.00) was obtained in the combination of control conditions i.e. no vermi-compost and no fertilizer application (Table 8).

4.18.2 Net income

Different treatment combination gives different types of net income. In combination of vermi-compost and fertilizer management practices highest net income (Tk. 3,54,694.00) was obtained from the treatment combination of T_{11} (6.0 t·ha^{-1} vermi-compost + 100% NPKS (RDF)) and the second highest net income (Tk. 3,01,969.00) was obtained in T_{10} (4.0 t·ha^{-1} vermi-compost + 100% NPKS (RDF)). The lowest net income (Tk. 1,05,229.00) was obtained in the combination of control conditions (T_0) in this trial (Table 8).

Table 8. Cost and return of garlic cultivation as influenced by different nutrient application

Treatments	Cost of production (Tk.)	Yield (t ha^{-1})	Gross income (Tk.)	Net income (Tk.)	Benefit Cost Ratio (BCR)
T_0	111971	5.43	217200	105229	1.94
T_1	137886	6.58	263200	125314	1.91
T_2	165961	7.41	296400	130439	1.79
T_3	191876	8.67	346800	154924	1.81
T_4	123887	7.71	308400	184513	2.49
T_5	137962	8.51	340400	202438	2.47
T_6	154121	9.17	366800	212679	2.38
T_7	181116	10.45	418000	236884	2.31
T_8	208111	12.2	488000	279889	2.34
T_9	170356	10.61	424400	254044	2.49
T_{10}	198431	12.51	500400	301969	2.52
T_{11}	226506	14.53	581200	354694	2.57

Here, T_0 = Control, T_1 = 2.0 t ha^{-1} vermi-compost, T_2 = 4.0 t ha^{-1} vermi-compost, T_3 = 6.0 t ha^{-1} vermi-compost, T_4 = 50% NPKS (RDF), T_5 = 100% NPKS (RDF), T_6 = 2.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_7 = 4.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_8 = 6.0 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_9 = 2.0 t ha^{-1} vermi-compost + 100% NPKS (RDF), T_{10} = 4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) and T_{11} = 6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF).

4.18.3 Benefit cost ratio

In combination of vermi-compost and fertilizer management practices the highest benefit cost ratio (2.57) was attained from the treatment combination of T_{11} (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF)) and the closest benefit cost ratio (2.52) was acquired in T_{10} (4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF)). On the other hand, the lowest benefit cost ratio (1.94) was obtained in the combination of control conditions (T_0) (Table 8).

CHAPTER V

SUMMARY AND CONCLUSIONS

The present research work was conducted at the horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during October 2019 to July 2020 to study the effect of different levels of vermi-compost and macro nutrients on the growth and yield of garlic. Garlic variety 'BARI Rashun-3' was used as planting material in this study. The experiment consists of single factor. Twelve treatment combinations were tested in this experiment: T_0 = Control, T_1 = 2 t ha^{-1} vermi-compost, T_2 = 4 t ha^{-1} vermi-compost, T_3 = 6 t ha^{-1} vermi-compost, T_4 = 50% NPKS (RDF), T_5 = 100% NPKS (RDF), T_6 = 2 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_7 = 4 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_8 = 6 t ha^{-1} vermi-compost + 50% NPKS (RDF), T_9 = 2 t ha^{-1} vermi-compost + 100% NPKS (RDF), T_{10} = 4.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) and T_{11} = 6.00 t ha^{-1} vermi-compost + 100% NPKS (RDF). The experiment was laid out in Randomized Complete Block Design (RCBD) with 12 treatment combinations having three replications. Total 36 unit-plots were made for the experiment with 12 treatments. Each plot was of required size. Data on different growth and yield parameter of garlic were recorded and significant variation was recorded for different treatments.

Plant height was significantly influenced by different nutrients application at different days after sowing (DAS) of garlic. At 30 and 60 DAS, the tallest plant (22.60 and 36.30 cm, respectively) was achieved from T_{10} (4.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment, whereas, the shortest plant (19.53 and 28.53 cm, respectively) was observed from T_0 (control) treatment. At 90 DAS and harvest, the tallest plant (49.90 and 37.10 cm, respectively) was achieved from T_{11} (6.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment, and the shortest plant (39.33 and 32.30 cm, respectively) was observed from T_0 (control) treatment.

There was significant difference in the number of leaves plant^{-1} of garlic. At 30 and 60 DAS, the highest number of leaves plant^{-1} (4.53 and 5.93, respectively) was achieved from T_{10} (4.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment, whereas, the lowest number of leaves plant^{-1} (3.17 and 4.23, respectively) was observed from T_0 (control) treatment. At 90 DAS and at harvest, the highest number of leaves plant^{-1} (6.60 and 5.87, respectively) was achieved from T_{11} (6.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment and the lowest number of leaves plant^{-1} (5.05 and 4.02, respectively) was observed from T_0 (control) treatment. Application of different nutrients had significant effect on neck diameter of garlic. It was observed that at 30 DAS, there was no significant effect on neck diameter among the treatments but in case of 60 and 90 DAS, neck diameter was significantly influenced by different levels plant nutrients application. At 30 DAS, the numerically maximum neck diameter (0.36 cm) was observed from T_{11} (6.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment and the numerically minimum (0.26 cm) was observed from T_0 (control) treatment. At 60 and 90 DAS, the maximum neck diameter (0.55 and 0.67 cm, respectively) was recorded from T_{11} (6.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment and the minimum (0.42 and 0.52 cm, respectively) was recorded from T_0 (control) treatment. The highest bulb diameter of garlic (3.32 cm), the longest clove of garlic (3.44 cm), the highest bulb length of garlic (2.43 cm), the maximum number of cloves bulb^{-1} of garlic (21.25), the maximum fresh weight of bulb (35.11 g), the maximum dry weight of bulb (4.95 g), the highest fresh clove weight (6.93 g), the maximum dry clove weight (1.89 g), the maximum fresh weight of leaves plant^{-1} (25.31 g) and the maximum dry weight of leaves (3.31 g) was recorded from T_{11} (6.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment. On the other hand, the lowest bulb diameter of garlic (2.11 cm), the shortest clove of garlic (2.53 cm), the lowest bulb length of garlic (1.65 cm), the minimum number of cloves bulb^{-1} of garlic (17.11), the minimum fresh weight of bulb (18.52 g), the minimum dry weight of bulb (2.03 g), the lowest fresh clove weight (3.04 g), the minimum dry clove weight (1.43 g), the minimum fresh weight of leaves plant^{-1} (11.08 g) and the minimum dry weight of leaves plant^{-1} (1.11 g) was obtained from T_0 (control) treatment. The longest root of garlic (22.70 cm) and the maximum fresh weight of roots plant^{-1} (0.96 g) was recorded from T_{10} (4.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment. On the other hand, the shortest root of garlic (10.40 cm) and the minimum fresh weight of roots plant^{-1} (0.48 g) was recorded from T_0 (control) treatment. The highest yield plot^{-1} of garlic (1.06 kg) and the maximum yield of garlic (10.73 t ha^{-1}) was recorded from T_{11} (6.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) treatment whereas, the lowest yield plot^{-1} of garlic (0.57 kg) and the minimum yield of garlic (5.83 t ha^{-1}) was recorded from T_0 (control) treatment.

In the combination of vermi-compost and fertilizer management practices maximum gross income (Tk. 5,81,200.00) was obtained from the treatment combination of T_{11} (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF) and the second highest gross income (Tk. 5,00,400.00) was obtained from the treatment combination of T_{10} (4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF). In combination of vermi-compost and fertilizer management practices the highest net income (Tk. 3,54,694.00) was obtained from the treatment combination of T_{11} (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF)) and the second highest net income (Tk. 3,01,969.00) was obtained in T_{10} (4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF)). The highest benefit cost ratio (2.57) was attained from the treatment combination of T_{11} (6.0 t ha^{-1} vermi-compost + 100% NPKS (RDF)) and the closest benefit cost ratio (2.52) was acquired in T_{10} (4.0 t ha^{-1} vermi-compost + 100% NPKS (RDF)). On the other hand, the lowest benefit cost ratio (1.94) was obtained in the combination of control conditions (T_0) (Table 8).

Conclusion

i. The effect of different levels of vermi-compost and essential macronutrients was found to be significant on growth, yield contributing and yield parameters of garlic.

ii. Application of 6.00 t ha^{-1} vermi-compost + 100% NPKS (RDF) was recorded to be more suitable practice for getting higher amount and quality of bulb yield of garlic.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh

Appendix II. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from September, 2019 to August, 2020

Month	Air temperature (^{0}C)		R. H. (%)	Total rainfall (mm)
	Maximum	Minimum		
September, 2019	39.47	29.94	87	77
October, 2019	37.89	25.49	81	37
November, 2019	31.82	14.04	78	24
December, 2019	23.40	10.50	75	5
January, 2020	20.18	7.04	72	0
February, 2020	18.20	9.70	74	15
March, 2020	34.70	22.94	82	78
April, 2020	36.28	29.68	86	125
May, 2020	38.95	33.40	89	155
June, 2020	37.55	32.93	92	183
July,2020	35.91	32.57	91	173
August, 2020	34.65	30.75	88	136

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

Appendix III. Characteristics of experimental fields soil was analyzed by Soil Resources Development Institute (SRDI), Farmgate, Dhaka

A. Morphological characteristics of the experimental field

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

B. Physical properties of the initial soil

Characteristics	Value
%Sand	27
%Silt	43
%Clay	30

C. Chemical properties of the initial soil

Characteristics	Value
Textural class	Silty-clay
PH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (mel 1 00 g soil)	0.10
Available S (ppm)	45

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

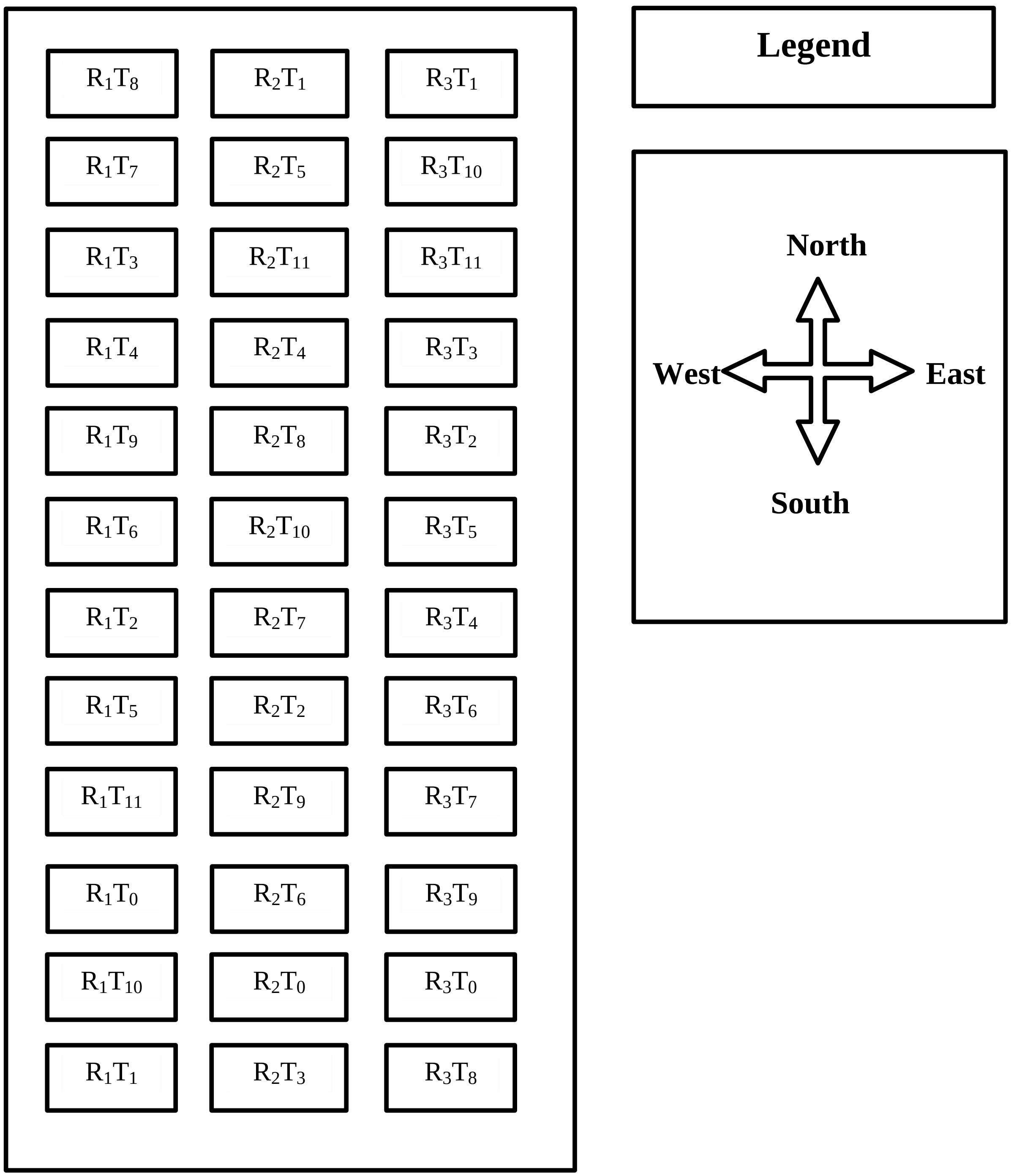

Fig. Layout of experiment plot

Appendix IV. Mean square value of plant height from Analysis of variance (ANOVA)

Source of variation	Degree of freedom	Mean square value of Plant height (cm)			
		30 DAS	60 DAS	90 DAS	At Harvest
Replication	2	1.92583	2.9186	4.9975	0.24333
Different nutrients	11	2.65402**	12.8682**	30.8509**	4.35861**
Error	22	0.19098	0.3322	1.0202	0.50545

** = Significant at 0.01 level of probability and

NS = Non-significant

Appendix V. Mean square value of number of leaves from Analysis of variance (ANOVA)

Source of variation	Degree of freedom	Mean square value of Number of leaves			
		30 DAS	60 DAS	90 DAS	At Harvest
Replication	2	0.04000	0.00444	0.19000	0.00551
Different nutrients	11	0.49583**	0.84131**	0.42742**	0.88880**
Error	22	0.02697	0.01475	0.05788	0.02815

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

Appendix VI. Mean square value of neck diameter from Analysis of variance (ANOVA)

Source of variation	Degree of freedom	Mean square value of Neck diameter (cm)		
		30 DAS	60 DAS	90 DAS
Replication	2	0.03747	0.03453	0.1296
Different nutrients	11	0.02774^{NS}	0.04542**	0.8706**
Error	22	0.0464	0.03787	0.148

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

Appendix VII. Mean square value of bulb and clove parameters from Analysis of variance (ANOVA)

Source of variation	Degree of freedom	Mean square value of							
		Bulb diameter	Clove length (cm)	Bulb length (cm)	Fresh weight of bulb (gm)	Dry wt. of bulb (gm)	Fresh clove wt. (gm)	Dry clove wt. (gm)	Clove no/bulb
Replication	2	0.13901	0.00614	0.01087	2.618	0.1742	0.28	0.02353	0.41868
Different nutrients	11	0.47741**	0.21094**	0.14029**	113.264**	2.9896**	5.20**	0.05289**	6.63560**
Error	22	0.01451	0.00364	0.00360	0.550	0.0409	0.0706	0.00151	0.24983

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

Appendix VIII. Mean square value of garlic leaf and root parameters from Analysis of variance (ANOVA)

Source of variation	Degree of freedom	Mean square value of			
		Fresh wt. of leaf	Dry weight of leaf (gm)	Root length (cm)	Fresh weight of root (gm)
Replication	2	2.6514	0.00127	2.9704	0.00747
Different nutrients	11	79.1666**	2.11280**	53.4081**	0.08804**
Error	22	0.4297	0.00846	0.7584	0.00139

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

Appendix IX. Mean square value of garlic yield from Analysis of variance (ANOVA)

Source of variation	Degree of freedom	Mean square value of	
		Yield per plot (kg)	Yield per ha (ton)
Replication	2	0.00240	0.23988
Different nutrients	11	0.09817**	9.81693**
Error	22	0.00038	0.03840

** = Significant at 0.01 level of probability and

NS = Non-significant

Appendix X. Production cost of garlic per hectare

A. Input cost (Tk/ha)

Treatment	Labor cost	Ploughing cost	cost of seed	Cost of irrigation	Cost of manure and fertilizers							Insecticide/ pesticide	Sub-total (A)
					Vermi-compost	Cow-dung	Urea	TSP	MOP	Gypsum	Boric Acid		
T_0	18000	8000	36000	5000	0	15000	0	0	0	0	3360	2500	87860
T_1	18000	8000	36000	5000	24000	15000	0	0	0	0	3360	2500	111860
T_2	20000	8000	36000	5000	48000	15000	0	0	0	0	3360	2500	137860
T_3	20000	8000	36000	5000	72000	15000	0	0	0	0	3360	2500	161860
T_4	18000	8000	36000	5000	0	15000	1736	3204	4995	1100	3360	2500	98895
T_5	20000	8000	36000	5000	0	15000	3472	6408	9990	2200	3360	2500	111930
T_6	22000	8000	36000	5000	24000	15000	1736	3204	4995	1100	3360	2500	126895
T_7	23000	8000	36000	5000	48000	15000	1736	3204	4995	1100	3360	2500	151895
T_8	24000	8000	36000	5000	72000	15000	1736	3204	4995	1100	3360	2500	176895
T_9	26000	8000	36000	5000	24000	15000	3472	6408	9990	2200	3360	2500	141930
T_{10}	28000	8000	36000	5000	48000	15000	3472	6408	9990	2200	3360	2500	167930
T_{11}	30000	8000	36000	5000	72000	15000	3472	6408	9990	2200	3360	2500	193930

T_0 = Control
T_1 = 2.0 t ha^{-1} Vermicompost
T_2 = 4.0 t ha^{-1} Vermicompost
T_3 = 6.0 t ha^{-1} Vermicompost
T_4= 50% NPKS (RDF)
T_5 = 100% NPKS (RDF)
T_6 = 2.0 t·ha^{-1} Vermicompost +50% NPKS (RDF)
T_7 = 4.0 t ha^{-1} Vermicompost + 50% NPKS (RDF)
T_8 = 6.0 t ha^{-1} Vermicompost + 50% NPKS (RDF)
T_9 = 2.0 t ha^{-1} Vermicompost + 100% NPKS (RDF)
T_{10}= 4.0 t ha^{-1} Vermicompost + 100% NPKS (RDF)
T_{11}= 6.0 t ha^{-1} Vermicompost +100% NPKS (RDF)

Labor cost =400 TK/day
Ploughing (4 times) =2000 TK
Seed rate =300 kg/h

Urea=16 tk/kg
TSP=24 tk/kg
MOP=30 tk/kg
Gypsum=20tk/kg
Boric acid=140 tk/kg

B. Overhead cost (Tk/ha)

Treatment combination	Cost of lease of land (Tk.8% of value of land cost/4 months)	Miscellaneous cost (Tk. 7% of the input cost)	Interest on running capital for 6 months (Tk. 14% of cost/year)	Sub-total (Tk.) (B)	Total cost of production (Tk./ha) [Input cost (A) + overhead cost (B)
T_0	15000	6150	2961	24111	111971
T_1	15000	7830	3196	26026	137886
T_2	15000	9650	3451	28101	165961
T_3	15000	11330	3686	30016	191876
T_4	15000	6923	3069	24992	123887
T_5	15000	7835	3197	26032	137962
T_6	15000	8883	3344	27226	154121
T_7	15000	10633	3589	29221	181116
T_8	15000	12383	3834	31216	208111
T_9	15000	9935	3491	28426	170356
T_{10}	15000	11755	3746	30501	198431
T_{11}	15000	13575	4001	32576	226506