GROWTH AND YIELD OF ONION AS INFLUENCED BY VERMICOMPOST AND PLANTING METHODS

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CERTIFICATE

*This is to certify that the thesis entitled "**GROWTH AND YIELD OF ONION AS INFLUENCED BY VERMICOMPOST AND PLANTING METHODS**" submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.)** in **HORTICULTURE**, embodies the results of a piece of bona fide research work carried out by **KHURSHIDA KHATUN** Registration. No**. 12-04760** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

Dated: June '18

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ABSTRACT

The present research was undertaken with the aims to investigate the application of vermicompost and the effect of planting methods on growth and yield of onion in the field condition. The experiment was conducted during the period from October, 2017 to March, 2018 at Horticultural farm of Sher-e-Bangla Agricultural University, Dhaka. The experiment was performed with Randomized Complete Block Design which consists of two factors viz. factor A: Four levels of vermicompost, viz. VC_0 =control, VC_1 = 6 t/ha, VC_2 = 9 t/ha, VC_3 = 12 t/ha and Factor B: Three types of planting method, viz. P_1 = Flat method, P_2 = Furrow method and P_3 = Ridge method. The results demonstrated that morphological parameters and reproductive components as well as yield showed significantly different among the treatments. The highest plant height (54.80 cm), number of leaves plant^{-1} (7.60), bulb length (3.02 cm), bulb diameter (4.47 cm), neck diameter (1.39 cm), root length (7.97 cm), fresh weight of bulb (42.73 g), dry weight of bulb (17.88 %), yield plot^{-1} (769.20 g) and yield (7.12 t/ha) were obtained from treatment combination VC_2P_3 while the lowest was recorded from VC_0P_1. It may be summarized that 9 t/ha vermicompost with ridge method of planting performed the maximum yield compared to other treatments.

LIST OF CONTENTS

LIST OF CONTENTS (Contd.)

LIST OF CONTENTS (Contd.)

LIST OF CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centimeter
DAT	Days after transplanting
^0C	Degree Celsius
et al.	And others
FAO	Food and Agriculture Organization
g	Gram(s)
Ha^{-1}	Per hectare
No.	Number
%	Percent
P	Planting method
SRDI	Soil Resources and Development Institute
VC	Vermicompost
Wt.	Weight

CHAPTER I

INTRODUCTION

Onion (*Allium cepa* L.) is one of the most important spices as well as vegetable crops and it belongs to family Alliaceae (Hanelt, 1990). It is semi-perishable in nature and can be transported to a long distance without much injury. Onion is an indispensable item in every kitchen as condiment and vegetable. Therefore, onion is popularly referred to as "Queen of Kitchen". Onion is liked for its flavour and pungency which is due to the presence of a volatile oil 'allyl propyl disulfide'- an organic compound rich in sulphur.

Central Asia is the primary center of its origin and the Mediterranean is the second center for large type onion (McCullum, 1976). Now, it's growing all over the world. The leading onion growing countries of the world are the China, Netherlands, Korea, Israel, Japan, Turkey, Syria, Iran, Egypt, USA, Lebanon, Austria and India (FAO, 2012). In Bangladesh, it is commercially cultivated in the greater districts of Dhaka, Mymensingh, Rajshahi, Rangpur, Rajbari, Khustia, Khulna, Barisal and Pabna (BBS, 2015). Among the spice crops grown in Bangladesh, onion ranks top in respect of production and area (BBS, 2018). The total production of onion in Bangladesh is about 1866502 metric tons under the total cultivated area of 458969 acres (BBS, 2018). It is most widely grown and popular vegetable crop among the alliums as well as cash crops.

Onion bulb is a rich source of minerals like phosphorus, calcium, and carbohydrates. It also contains protein and vitamin C. It is being used in several ways as fresh, frozen, dehydrated bulbs and green bunching types. Onion has got good medicinal value. It contains several anti-cancerous agents which have shown to prevent cancer in animals. The beneficial compound called 'quercetin' present in onion is a powerful antioxidant. Recently onion is being used by processing industry to a greater extent for preparing dehydrated forms like powder and flakes (Singh, 2015).

Onion contains carbohydrates (11.0 g), proteins (1.2 g), fiber (0.6 g), moisture (86.8 g) and several vitamin like vitamin A (0.012 mg), vitamin C (11 mg), thiamin (0.08 mg), riboflavin (0.01 mg) and niacin (0.2 mg) and also some minerals like phosphorus (39 mg), calcium (27 mg), sodium (1.0 mg), iron (0.7 mg) and potassium (157 mg) per 100 g (Rahman *et al*., 2013).

In recent years, it has been realized that the judicious application of nutrients is essential for higher yield and better quality of onion. Under suitable agro-climatic conditions, nutrient management is the main factor which influences the growth and yield of onion to a great extent. In modern agriculture, fertilizers constitute a major portion of the cost of production of onion. It is possible to produce higher yields of good quality bulbs by judicious application of nutrients.

Onion necessitates the application of inorganic fertilizers for maximum growth and yield. However, inorganic fertilizers application may lead to soil acidity or alkalinity. Chemical fertilizers are very expensive and sometimes unavailable to small-scale farmers. So, there is a great need to increase production as well as productivity to meet our growing demand. Production of any crop can be increased by supplying quality inputs. Nutrition plays an important role on the growth and development of any crop including onion.

It is documented that vermicompost is a rich source of vital macronutrients (N, P, K, Ca and Mg) and micronutrients (Fe, Mo, Zn, and Cu). The chemical analysis of vermicompost reveals that N, P and K content was 0.8, 1.1 and 0.5 percent respectively (Giraddi, 1993). It is scientifically proving as 'miracle growth promoter and also plants protector' from pests and diseases. Vermicompost retains nutrients for a long time and while the conventional compost fails to deliver the required amount of macro and micronutrients including the vital NKP to plants in a shorter time, the vermicompost does (Arancon *et al*., 2004). The process of conversion of organic waste into bio-fertilizer with the help of traditional composting which can be used to minimize the environmental pollution and is a good alternative to restrict the use of chemical fertilizers for sustainable agriculture.

Onion is water sensitive crop and thus the scarcity and lodging of soil water are degrading the quantity and quality of produce. The production of onion in the rabi season is economically beneficial for the farmer, but the water scarcity situations drastically reduced the production of the crop. So the sowing method provides an option to safely produce the onion in rabi season by providing protection from water scarcity in the soil during the crop season.

Onion is a shallow-rooted crop which needs frequent irrigation. It was reported that per unit production can be increased by proper planting methods of cultivation and thus can save 20-34% irrigation water, 16-69% planting cost and ensure less human labour (Hossain *et al*., 2010). Although the demand for onion in Bangladesh is increasing day by day with the rising population, the area under cultivation in not expanding accordingly due to the limitation of land. Total production can be boosted-up by increasing yield as found in the other onion producing countries of the world. But during the last few years, it has been found that the area and total production of onion in Bangladesh remained almost the same. The production per unit area can be increased by adopting improved methods of cultivation. Among the method, transplanting of onion seedling at proper planting method and growing under proper nutrient management (vermicompost) could increase the optimum growth, bulbing and yield of the crop.

Considering the above-stated situations, the present study was undertaken with the following objectives:

1. To determine the appropriate dose of vermicompost for better growth and yield of onion.
2. To find out the appropriate planting method for better growth and yield of onion.
3. To find out the suitable combination of planting method with vermicompost for ensuring higher yield of onion.

CHAPTER II

REVIEW OF LITERATURE

Onion (*Allium cepa* L.) is one of the major bulbous crops of the world and one of the most important commercial vegetable crops grown in Bangladesh. The production of the onion bulb is influenced by many factors, such as planting method, vermicompost, and light duration. Planting method and vermicompost are closely related to growth and yield of onion. Increased use of fertilizer nitrogen is probably the most important single factor that has enabled the crop production to increase significantly in recent years. Vermicompost is a rich source of macro and micronutrients, vitamins, enzymes, growth hormones, and microflora. This organic manure plays a significant role in improving the fertility of topsoil and in boosting the productivity of the crop. There is a need to promote the use of organics in addition to inorganic fertilizers for sustained maintenance of soil fertility.

2.1 Effect of vermicompost

Vermibiotechnology is the best method for application of earthworms in combating the solid waste disposal problem or reducing the pollution effect. It helps in cost-effective and meticulous recycling of agricultural residues and industrial wastes using minimum energy. The process of conversion of organic waste into biofertilizer with the help of traditional composting which can be used to minimize the environmental pollution and is a good alternative to restrict the use of chemical fertilizers for sustainable agriculture.

Patil *et al*. (2013) reported that modern farming practices affect our world, by the way of land degradation, nutrient runoff, soil erosion, water pollution, soil compaction, loss of cultivated biodiversity, habitat destruction, contaminated food and destruction of traditional knowledge systems. These all result in changing climatic conditions of the earth. Farmers are directly getting affected due to these climate changes as it affects crop production. Sudden change in normal weather conditions sometimes results in total crop failure. These ill effects of modern agriculture and climate change can be delineated by adopting organic farming. This paper summarizes the use of biofertilizers and organic fertilizers by the farmers in Sangamner region of Maharashtra as low input Sustainable agricultural technology (LISA). Though the use of chemicals in agriculture is inevitable to meet the growing demand for food in the world, there are opportunities in some areas where organic production can be encouraged to tape the domestic export market. Farmers are now using the biofertilizer, Vermicompost, Poultry manure, Jeevamrit as a source of organic manures in their fields in Sangamner. There is actually a wide variety of biofertilizer that has been evolved through universities and independent research labs, but these are not disseminated to the 100 % farmers. Sustainable use and conservation of natural resources are the key components to face the problem of soil degradation and climate change.

Adhikary (2012) carried out an experiment to catch the imagination of philosophers like Pascal and Thoreau. Yet its role in the nutrition of agricultural fields has attracted the attention of researchers worldwide only in recent decades. Waste management is considered as an integral part of a sustainable society, thereby necessitating diversion of biodegradable fractions of the societal waste from landfill into alternative management processes such as vermicomposting. Earthworms excreta (vermicast) is a nutritive organic fertilizer rich in humus, NPK, micronutrients, beneficial soil microbes; nitrogen-fixing, phosphate solubilizing bacteria, actinomycetes and growth hormones auxins, gibberellins & cytokinins. Both vermicompost& its body liquid (vermiwash) are proven as both growth promoters & protectors for crop plants. We discuss the worms composting technology, its importance, use and some salient results obtained in the globe so far in this review update of vermicompost research.

Hanumannaik *et al*. (2013) carried out an experiment for three years to produce onion organically using farmyard manure, vermicompost, neem cake and sheep manure in comparison with chemical fertilizer at RDF. Plant height, bulb weight and yield per ha were significantly influenced by different treatments. RDF produced tallest plants, while neem cake produced shortest plants. The diameter of the bulb was maximum with vermicompost, while it was least with sheep manure. Vermicompost application resulted in the highest bulb weight and bulb yield. The yield was least with sheep manure. RDF was at third in position in yield. However, the cost: benefit ratio was highest with RDF and least with sheep manure indicating organic farming in onion was not cheaper than farming with RDF.

Meena *et al*. (2015) conducted an experiment during Kharif, 2012 with eighteen treatment combinations including six levels of organic manures (Control, FYM @ 10 t ha^{-1}, vermicompost @ 5 t ha^{-1}, poultry manure @ 5 t ha^{-1}, FYM @ 5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1}, FYM @ 5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1}) and three bio-fertilizer treatments (without inoculation, Azospirillium, Azospirillium + PSB). Results indicated that growth attributes, TSS and nitrogen content in bulb increased significantly with the combined application of FYM @ 5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1}. While phosphorus and sulphur content of bulb significantly increased with the application of FYM @ 5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1}. Bulb inoculation with Azospirillium + PSB significantly increased both growth and quality attributes over other treatments.

Sinha *et al.* (2010) carried out an experiment on earthworms and its excreta (vermicast) promises to usher in the 'Second Green Revolution' by completely replacing the destructive agro- chemicals which did more harm than good to both the farmers and their farmland. Earth-worms restore & improve soil fertility and significantly boost crop productivity. Earthworms excreta (vermicast) is a nutritive 'organic fertilizer' rich in humus, NKP, micronutrients, beneficial soil microbes—'nitrogen fixing & phosphate solubilizing bacteria' & 'actinomycets' and growth hormones 'auxins', 'gibberlins' & 'cytokinins'. Both earthworms and its vermicast & body liquid (vermiwash) are scientifically proving as both 'growth promoters & protectors' for crop plants. In our experiments with corn & wheat crops, tomato and egg-plants it displayed excellent growth performances in terms of height of plants, color & texture of leaves, appearance of flowers & fruits, seed ears etc. as compared to chemical fertilizers and the conventional compost. There is also less incidences of 'pest & disease attack' and 'reduced demand of water' for irrigation in plants grown on vermicompost. Presence of live earthworms in soil also makes significant difference in flower and fruit formation in vegetable crops. Composts work as a 'slow-release fertilizer' whereas chemical fertilizers release their nutrients rather quickly in soil and soon get depleted. Significant amount of 'chemical nitrogen' is lost from soil due to oxidation in sunlight. However, with application of vermicompost the 'organic nitrogen' tends to be released much faster from the excreted 'humus' by worms and those mineralised by them and the net overall efficiency of nitrogen (N) is considerably greater than that of chemical fertilizers. Availability of phosphorus (P) is sometimes much greater. Our study shows that earthworms and vermicompost can promote growth from 50 to 100% over conventional compost & 30 to 40% over chemical fertilizers besides protecting the soil and the agro-ecosystem while producing 'nutritive and tasty food' at a much economical cost (at least 50- 75% less) as compared to the costly chemical fertilizers.

Kumar and Neeraj (2015) conducted an experiment to evaluate the performance of different onion varieties in response to organic condition during the Rabi season of the year 2014-15. The soil was prepared with recommended doses of vermicompost as a soil nutrient. The Pre-harvest effect of the commercial Biobased product namely; *Trichoderma viridae*, Neem, Panchgavya, and Water were studied. It was revealed from the Data, Maximum vegetative growth (Plant height, Number of leaves,) and Bulb growth (Bulb diameter, Bulb weight) was observed in case of Panchgavya treatments. A similar observation was made in the case of neem and *Trichoderma viridae* application as compared to control.

Yadav *et al*. (2015) carried out an experiment to assess the effect of integrated nutrient management on growth and yield of onion cv. Pusa Madhvi at Horticultural Research Farm, Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University, Lucknow, U.P. India during the year 2013-14. 10 treatments [RDF as control, FYM, Vermicompost, PSB, *Azotobacter*, *Azosprillium*, and combination with nitrogen, phosphorus and potash] were applied with three replications and laid out under

Randomized Block Design. The results showed that the maximum plant height (74.32 cm), bulb diameter (4.60 cm), neck thickness (1.06 cm), bulb length (4.39 cm) and number of leaves (9.88) per plant were recorded under treatment T_{10} - RDF (50%) + Vermicompost (50%) at 90 (DAT). Whereas, the maximum leaf length (62.23 cm) was observed in the treatment T_5 (*Azotobacter* @ 100%). Although, the treatment T_5 showed the maximum bulb weight (175.67 g) but the maximum yield (283 q ha^{-1}) and TSS (12.30 0B) were recorded in T_{10}. Thus, it can be concluded that treatment T_{10} i.e. application of RDF (50%) + Vermicompost (50%) was suitable for better growth and higher production of onion cv. Pusa Madhvi under Lucknow condition having high soil pH of 8.2.

Indira and Singh (2014), a field experiment were conducted during the rabi season of 2008-2009 to study the effect of vermicompost and biofertilizer on yield and quality of rabi onion. The experiment was laid out in the split-plot design with four replications. There were twenty-four treatment combinations comprising of for levels of vermicompost viz. 5, 10, 15, 20 q ha^{-1} , three treatments of Azotobacter (A_1) i.e. Seedling dipping (A_1S_1), seed treatment (A_1S_2) and soil application (A_2S_2) and three treatments of Azospirillum (A_2) i.e. seedling dipping (A_2S_1), seed treatment (A_2S_2) and soil application (A_2S_3). The data revealed that among vermicompost application of 20 q/ha recorded significantly higher high fresh weight of bulb (43.04 g), bulb yield (25 1.20 q/ha), N content (0.918 %), TSS (11.07%) and pungency (6.63 mg / l00g) as compared to control. Among the biofertilizer levels, A_1S_2 recorded significantly maximum bulb yield (23 .51 q/ha) fresh weight of bulb (42.13 q/ha) TSS (10.06 %) and it was on par with A_2S_2. Among the interactions the treatment, 04 A_1S_2 recorded comparatively maximum fresh eight of the bulb (49.14 g) and bulb yield (269.52 q/ha) followed by O4 A_2S_2, 03 A_1S_2 and 03 A_2S_2 which were at par with each other.

Naik and Hosamani (2013) conducted an experiment to investigate the effect of spacing (15 ×10 cm, 15 × 15 cm and 15 × 20 cm) and N levels (0.50. 100 and 150 kg/ha) on the growth and yield of kharif onion under rainfed condition. Narrow spacing of 15 ×10 cm with an application of 150kg N/ha was found optimum for enhancing yield (16.90 t/ha) and other growth and quality parameters including plant height, leaf number per plant, bulb length, bulb diameter, and bulb total soluble solid content. As far as fertilizer treatments were concerned, T4 (50% vermicompost +50% NPK) was proved to be the best fertilizer treatment for most of the traits. It recorded maximum plant height, bulb polar and equatorial diameter and bulb weight. The same treatment also produced the highest bulb yield (353.80 q/ha). Applications of organic inputs in combination with chemical fertilizer were found a better option than the application of organic manure or chemical fertilizer alone. This will not only help to improve the economic return and revenue generation of the farmers but also lower the growing onion market prices in the country.

Dhaker *et al*. (2017), a field experiment was conducted during Rabi season 2016-17 to find out the effect of FYM and Vermi Compost with or without PSB and Azotobactor and rates of organic manures (50% and 100% RND) on yield, quality and economics of onion (Agri Found Dark Red) on clay loam soil. The treatments comprised of organic, inorganic fertilizer and biofertilizers with ten treatments 100% RDF through inorganic, 100% RDF through FYM (N Basis), 100% RDF through vermicompost,50% RDF through Inorganic Fertilizers + 50 % through FYM, 50% RDF through Inorganic Fertilizers + 50 % through vermicompost, 50% RDF through Inorganic Fertilizers + 50 % through FYM + PSB, 50% RDF through Inorganic Fertilizers + 50 % through vermicompost + PSB, 50% RDF through Inorganic Fertilizers + 25 % vermicompost + PSB, 100% RDF through FYM (N Basis) +PSB + Azotobactor and 100% RDF through vermicompost + PSB + Azotobactor. Results revealed that the application of organic manure significantly influenced the diameter of the bulb (cm), bulb weight (g), bulb yield (q/ha), total soluble solid (0B) and allyl propyl content (ppm) with 100% RDF through Vermicompost + PSB + Azotobactor). Application of 100% RDF applied through vermicompost + PSB + Azotobactor (T_{10}) recorded maximum gross returns, net return and cost-benefit ratio of onion crop.

Suresh and Bendegumbal (2007) conducted the field cum laboratory experiments to study the effect of organics and their combination on seed production in onion cv. N-53 at

Agricultural Research Station, Bagalkot. The first season, experiment consisting of RDF (control) @ 125:50:125 kg NPK/ha; RDF @ 125:50:125 kg NPK/ha + PSB @ 5 kg/ha + Azospirillum @ 5 kg/ha; FYM@ 25 t/ha (100%); vermicompost @ 4.2 t/ha (100%); poultry manure @ 4.2 t/ha (100%); FYM @ 12.5 t/ha (50%) + vermicompost @ 2.1 t/ha (50%); vermicompost @ 2.1 t/ha (50%) + poultry manure @ 2.1 t/ha (50%); FYM @ 12.5 t/ha (50%) + poultry manure @ 2.1 t/ha (50%); FYM @ 25 t/ha (100%) + PSB @ 5 kg/ha + Azospirillum @ 5 kg/ha; vermicompost @ 4.2 t/ha (100%) + PSB @ 5 kg/ha + Azospirillum @ 5 kg/ha and poultry manure @ 4.2 t/ha (100%) + PSB @ 5 kg/ha + Azospirillum @ 5 kg/ha. Maximum number of leaves per plant at 30 DAT (7.4), higher bulb length (8.6 cm), higher bulb diameter (22.0 cm), higher bulb weight (133.6 g) and also numerically higher bulb yield (40.01 q/ha) was observed with application of vermicompost @ 4.2 t/ha (100%) alone and vermicompost @ 4.2 t/ha (100%) + PSB @ 5 kg/ha + Azospirillum @ 5 kg/ha. Whereas, lowest bulb yield was obtained in poultry manure @ 4.2 t/ha (22.58 q/ha). Organic onion bulb produced in previous season is used for seed production using same treatments as taken in first experiment. Significantly, maximum number of leaves per plant at 60 DAT in seed crop (13.4), umbel diameter (15.10 cm), seed weight per umbel (5.3 g), seed weight per plant (15.43 g), seed yield per plot and per hectare (16.14 q/ha) respectively and also 1000 seed weight higher (15.43 g) was observed in vermicompost @ 4.2 t/ha (100%) + PSB @ 5 kg/ha + Azospirillum @ 5 kg/ha followed by vermicompost @ 4.2 t/ha (100%). While, minimum seed yield (10.77 q/ha) was obtained with poultry manure 4.2 t/ha (100%) + PSB + Azospirillum. Seed quality parameters did not varied significantly except root length, germination (94.30%), seedling vigour index (1675) was observed in RDF + PSB @ 5 kg/ha + Azospirillum @ 50 kg/ha. The gross returns net returns and B:C ratio were greatly influenced by organics and other combination. However, higher gross returns (Rs. 1, 29,213/ha) and net returns (Rs. 1, 06,543/ha) were recorded in vermicompost @ 4.2 t per ha (100%) + PSB + Azospirillum followed by VC alone and lowest gross returns was seen in FYM @ 12.5 t/ha (50%) + poultry manure @ 2.1 t/ha (50%) (Rs.90, 511/ha).

Rao *et al*. (2017), conducted an experiment to the growth and yield of onion as affected by the application of vermicompost produced from tendu [*Diospyros melanoxylon*] leaf litter was studied in Maharashtra, India, during 2007. The treatments consisted of: 100% N through chemical fertilizer + 50 kg P/ha + 50 kg K/ha (T_1); 100 % N through vermicompost produced by *Eudrilus eugeniae* + 50 kg/ha P + 50 kg K/ha (T_2); 50% N through vermicompost produced by *E. eugeniae* + 50% N through chemical fertilizer + 50 kg P/ha + 50 kg K/ha (T_3); and control (T_4). T_1 increased the total yield by up to 7.25 t/ha after 120 days of treatment (DOT) and plant height by up 30.00% after 30 DOT compared to the control. After 60 DOT, leaf length increased by up to 2.60%. After 90 and 120 DOT, leaf size increased by 23.6 and 15.20%, respectively. T_2 enhanced plant height and increased the yield by up to 8.75 t/ha. Leaf length after 30 DOT increased by up to 50.00%. After 60 DOT, leaf length increased by up to 11.30%. After 90 and 120 DOT, leaf size increased by 36.45 and 53.64%, respectively. T_3 increased the total yield after 120 DOF by up to 9.75 t/ha. Plant height after 30 DOT increased by up to 51.60%. After 60 DOF, leaf length increased by up to 52.6%. After 90 and 120 DOF, leaf size increased by up to 71.4 and 56.65%, respectively.

Reddy and Reddy (2005) conducted an experiment in Andhra Pradesh, India during 1996-98 to determine the effects of different levels of vermicompost (0, 10, 20 and 30 t/ha) and nitrogen fertilizer (0, 50, 100, 150 and 200 kg/ha) on the growth and yield of onion (cv. N-53) and their residual effect on succeeding radish in an onion-radish (cv. Sel-7) cropping system.

Reddy *et al*. (2010) conducted a field experiment was conducted on a sandy loam soil during Kharif (onion) and rabi (radish) seasons of 2007-08 with a view to studying the effect of integrated use of vermicompost (0, 5 and 10 t ha^{-1}) and nitrogen fertilizers (0, 60, 90 and 120 kg N ha-^{1}) on soil dehydrogenase enzyme activity and yield of onion-radish cropping system. Among the different combinations, application of 10 t vermicompost ha^{-1}+120 kg N ha^{-1} recorded significantly highest fresh onion bulb yields (24.45 t ha^{-1}) at harvest. However, this combination was on par with the yield obtained with the application of 10 t vermicompost + 90 kg N ha^{-1} (23.43 t ha^{-1}). The radish crop grown during rabi responded favorably to the residual and cumulative treatments and the highest root yield of 18.45 t ha^{-1} and 23.43 t ha^{-1} was recorded in residual and cumulative treatments with the application of 10 t vermicompost ha^{-1} + 120 kg N ha^{-1}. The soil dehydrogenase enzyme activity at different growth stages of onion and radish revealed that there was an increase in enzyme activities to active growth stages of crops and later showed a decrease. The results showed that integrated application of 10 t vermicompost ha^{-1} + 120 kg N ha^{-1} recorded significantly highest dehydrogenase activity at 30 DAT (170.8 μg of TPF produced g^{-1} soil d^{-1}), 60 DAT (145.9 μg of TPF produced g^{-1} soil d^{-1}), 90 DAT (131.1 μg of TPF produced g^{-1} soil d^{-1}) and at harvest (96.63 μg of TPF produced μg^{-1} soil d^{-1}) of onion. The cumulative and residual effects at different growth stages of radish revealed that the dehydrogenase activity was higher in cumulative treatments than residual treatments.

Kiros *et al*. (2018) studied on the NP fertilizer or organic resources alone may not provide sufficient amounts or may be unsuitable for alleviating specific constraints to crop production. Therefore, a field experiment was conducted at Maitsebri Research Station of Shire-Maitsebri Agricultural Research Center (SMARC) to study the effect of inorganic NP fertilizers and vermicompost on growth, seed yield and yield components of red onion (*Allium cepa* L.) variety during 2016/17 dry season under irrigation. The treatments consisted of five NP fertilizer rates {0, 25, 50, 75 and 100% of recommended NP rates (69 kg N and 92 kg P_2O_5 ha^{-1})} and four rates of vermicompost (0, 2.5, 5.0 and 7.5 t ha^{-1}). The experiment was laid out in a factorial arrangement using a randomized complete block design (RCBD) with three replications. Results of the analysis revealed that the interaction effects on inorganic NP fertilizer and vermicompost significantly ($P<0.05$) affected plant height. Days to bolting, days to 50% flowering, flower stalk diameter and days to maturity were significantly ($P<0.05$) affected by the main effect of NP fertilizer rates and vermicompost. Similarly, numbers of umbels per plant, umbel diameter, number of seeds per umbel and seed weight per umbel were significantly affected by the main effect of NP fertilizer rates and vermicompost. The highest seed yield per hectare (1462.5 kg ha^{-1}) was obtained from the plants grown at 75% of RDF with vermicompost at 2.5 t ha^{-1} which was about 263% higher than seed yield from unfertilized control plot. It can, thus, be concluded that the combined application of 75% of RDF with vermicompost at 2.5 t ha^{-1} can improves growth, seed yield and yield components of Bombay red onion variety in the study area.

An experiment was conducted by Bybordi and Malakouti (2007) in Khosrowshahr and Bonab, Iran, during growing seasons of 2003 and 2004 to evaluate the effects of various sources of organic fertilizers on the yield and quality of Azarshahr variety of red onion. The highest yield (71.1 t/ha) was obtained with the application of vermicompost @ 6 t/ha.

Vedpathak and Chavan (2016) carried out to study the effects of organic and chemical fertilizers on growth and yield characteristics of onion (*Allium Cepa* L) at the outdoor nursery of Solapur University, an an agricultural farm in the district of Solapur, Maharashtra State, India. Plot size 2 m x 1 m ($2m^2$) was prepared for conducting a field experiment. The experiment was arranged in Randomized Block Design (RBD) method with five treatments and three replications. The treatment details consist of vermicompost (T_1) at rate 0.5 kg/plot (@ 0.25 kg/sq. m), NADEP compost (T_2) at rate 1.25 kg/plot (@ 0.625 kg/sq. m), pit compost (T_3) at rate 1.25 kg/plot (@ 0.625 kg/sq. m), recommended dose of chemical fertilizers 100:50:50 kg ha^{-1} (T_4)and Control T_5. The outcomes of field study showed that the highest length of leaves (cm/plant), single bulb weight (gm/plant), bulb yield (Kg/plot) were maximum with the application of a recommended dose of chemical fertilizer as compared to other fertilizer treatments. The application of vermicompost also gave the maximum plant biomass per plant of onion.

Sharma *et al.* (2009) conducted an experiment to the effect of applying organic manures (vermicompost and farmyard manure) and inorganic fertilizers on yield and nutrient uptake by okra (*Abelmoschus esculentus)* - onion (*Allium cepa*) and nutrient build up in the soil were studied under field conditions. The highest yield of okra was recorded in the treatment comprising 100% recommended NPK + vermicompost @ 10 t ha^{-1}, 11.10 and 11.63 t ha^{-1}

during 2003 and 2004, respectively. Similarly, the maximum yield of onion was observed in plots receiving 100% recommended NPK plus 25 t vermicompost ha^{-1} during both the years i.e. 9.83 and 14.67 t ha^{-1} during 2003-04 and 2004-05, respectively. After completion of the experiment, the highest available NPK content (303, 28.1, 345 kg ha^{-1}, respectively) were recorded in case of the treatment consisting of 10 t vermicompost ha^{-1} to okra and 25 t vermicompost ha^{-1} to the onion along with 100% NPK to these crops. A similar effect was observed on mineral composition and nutrient uptake. Furthermore, the yield of okra obtained at 5 t vermicompost ha^{-1} plus 100% NPK (9.73 and 10.83 t ha^{-1} during 2003 and 2004) was at par with that under 10 t farmyard manure plus 100% NPK (10.03 and 10.46 t ha^{-1} during 2003 and 2004). Similarly, the yield of onion obtained at 12.5 t vermicompost ha^{-1} plus 100% NPK (8.38 and 12.56 t ha^{-1} during 2003-04 and 2004-05) was at par with that under 25 t farmyard manure ha^{-1} plus 100% NPK (8.86 and 12.08 t ha^{-1} during 2003-04 and 2004-05). This demonstrated the superiority of vermicompost over farmyard manure in okra-onion sequence.

2.2 Effect of planting method

Gurjar *et al.* (2017) reported that the effect of planting methods, organic nutrient sources, and bio-fertilizers on bulb yield and quality of kharif onion (*Allium cepa* L). This experiment was conducted at the village- Rawar, near College of Agriculture, Gwalior (M.P.), India during two consecutive years of Kharif seasons in 2013-14 and 2014-15 to evaluate the effect of planting methods, organic nutrient sources, and biofertilizers on quality and economics of Kharif onion in Gwalior conditions. The results of the experiment were revealed that the ridge method of planting resulted in significantly highest protein content (6.34%) over furrow and flat method of planting and maximum TSS (12.52%) was also recorded with ridge method, which was at par with rest of both sowing methods. The interactions were found a not significant response with these parameters. Seedlings inoculated with PSB transplanted on ridges with 25.0 t FYM/ha and PSB 5 kg/ha ($P_3S_2B_1$) accrued the highest net monetary return amounting Rs. 97060/ha followed by $P_3S_2B_2$ (Rs.

93790/ha) and $P_3S_1B_1$ (Rs. 91260/ha) while the highest B: C ratio of 2.65 was obtained with the treatment combination ridge planting with 12.5 t FYM/ha and PSB 5 kg/ha closely followed by $P_3S_1B_2$ (2.58), $P_3S_2B_1$ (2.57) and $P_3S_2B_2$ (2.52).

Ketema *et al*. (2013) Onion dry bulb are commonly established in the field either by direct sowing of seeds to the field or by transplanting seedling from a seedbed or from sets depending on the growing conditions of the specific region. However, the potential of the different methods has not been tested particularly in the potential onion producing areas of Ethiopia. Field experiments were conducted at Melkassa Research Center of Ethiopian Institute of Agricultural Research to investigate the effect of different planting methods on maturity and dry bulb yield of onion in two different seasons in 2008/09. The experiment consisted of three planting methods of onion, namely direct seeding to the field, transplanting of seedlings and planting sets, and three onion cultivars (Adama Red, Bombay Red, and Nasik Red), arranged in factorial split plot design with three replications. Cultivars were assigned to the main plot and planting methods to the sub-plot. Data on days to maturity, dry bulb yield, and bulb weight and bulb diameter were collected. Planting methods and cultivars showed a statistically significant difference ($P<0.01$) both for earliness and dry bulb yield. However, their interaction was not significant. Sets planting resulted in higher yield (39.1 t ha^{-1}) followed by transplants (36.3 t ha^{-1}) and direct seeding (19.5 t ha^{-1}). The cultivar 'Bombay Red' (33.3 t ha^{-1}) gave a significantly higher yield than 'Adama Red' (31.1 t ha^{-1}) and 'Nasik Red' (30.2 t ha^{-1}). Sets matured earlier (94 days) than transplants (104 days) and direct sown (135 days). The overall result indicated that in addition to the current transplanting practice onion establishment from the set may also be a good option for dry bulb production in the Central Rift Valley areas of Ethiopia where earliness and high yield are important parameters considered by onion growers.

Sarker *et al*. (2017) conducted an experiment to the effect of planting method on onion (*Allium cepa* L.) bulb production in Faridpur region of Bangladesh. The present study was undertaken to evaluate the effective planting method for onion production for motivating onion producing farmers in Faridpur region of Bangladesh during rabi season 2014-15 and

2015-16 at spices Research Sub-centre, Faridpur. The number of treatment was four viz., Raised bed + Spices Research Centre (SRC) recommended the practice, Raised bed + Farmer's practice, Flat method + Spices Research Centre (SRC) recommended the practice and Flat method + Farmer's practice. The onion variety BARI Piaz-1 used as planting material. The SRC recommended practice consist of seed sowing at 2nd week of November + seedlings transplanting at the end of December + Spacing (10 cm × 10 cm) + Irrigation (4 times) + weeding (four at 15, 25, 45 and 60 DAT) + Fungicide application with Rovral and Ridomil gold (four spray when disease appears) + Insecticide application (2-3 spray when/before thrips/insect appears) + Fertilizer doses (cow dung 5 ton ha^{-1}, N_{120}, P_{54}, k_{75} and S_{20} kg ha^{-1}. On the other hand farmer's practice consist of seed sowing at last week of November in flat seedbed + seedling transplanting at 3rd week of January + Spacing (10 cm × 7 cm) + Irrigation (2-3 times) + Weeding (2 times) + Fungicide application with Rovral, Score and other type of ineffective fungicide at 5-7 days interval + insecticide application with Confidor after thrips/insect appears + Fertilizer doses (N_{46}, P_{45}, k_{30} and S_{16} kg ha^{-1}. The results of the study revealed that planting method and management practices had a significant impact on yield and yield attributes of onion and among the treatments, the highest yield was found from Raised bed + SRC recommended the practice. Significantly highest yield 14.42 t ha^{-1} in 2014-15 and 12.57 t ha^{-1} in 2015- 16 was recorded from SRC recommended the practice. The lowest yield 8.05 t ha^{-1} in 2014-15 and 7.66 t ha^{-1} in 2015-16 was recorded from Flat method + Farmer's practice. Therefore, the farmers of Faridpur region of Bangladesh are advised to adopt SRC recommended practice with raised bed method for increasing their annual average onion production.

Kanwar and Akbar (2013) conducted an experiment at Research Farm of High Mountain Arid Agriculture Research Institute (SKUAST-K), Stakna, Leh to investigate the impact of three planting methods (Flatbed, Middle of Ridge, Both sides of Ridge) on the performance of four onion varieties in Split-plot design with three replications. The flatbed system produced statistically highest net bulb weight (66.00g), bulb diameter (51.33mm) and yield per ha (440.2 qt). Net bulb weight, diameter, and yield per ha of onion hybrid

Rosy were highest but at par with Local Red and Nasik Red. It can be concluded that planting on flat land is the best method for onion production in cold desert condition

Choudhary *et al*. (2008) field experiments were conducted to study the soil salinity pattern at different locations for furrow- bed, and furrow-ridge irrigated wheat. Results were compared to border irrigation in term of salt movement and their effectiveness on crop yield. Wheat variety "Bhakar 2000" was sown on a plot size of 55.5 m x 7.31 m having loam soil. Traditional flat sowing was accomplished with a row to row distance of 23 cm using seed drill and two rows of wheat planted manually on both 30 cm and 60 cm wide furrow-beds and 45 cm wide furrow-ridges. Four irrigations were applied and soil salinity was estimated both at the time of sowing and harvesting of the wheat. The salt concentration at the sides of the beds increased by 3.2 and 13.6% and at the top-center of beds, it increased by 48.87 and 97.95% as compared to mid-furrow at the time of sowing and harvesting, respectively. It was also observed that the average salt concentration at the ridge-sides increased by 3.35 and 30.43% and at the ridge-top, it increased by 53.63 and 59.67% as compared to mid-furrow at the time of sowing and harvesting for a soil depth of 0-30 cm, respectively. A water saving of 35-45% for furrow-bed and 31- 41% for furrow-ridge were noted compared to flat-border. As regard to grain yields, the furrow-bed and furrow- ridge planting techniques produced 4.09 ton/ha and 4.04 tons/ha compared to flat border i.e., 3.37 tons/ha.

Rasheed et al. (2004) conducted an experiment to study the comparative productivity, nutrient efficiency and economics of maize hybrids was conducted at the University of Agriculture, Faisalabad during 1997 and 1998. The experiment comprised three planting methods 70 cm spaced single rows, 105 cm spaced double-row strips and 70 cm spaced ridges with seven nutrient levels (kg ha^{-1}) viz., 250 N, 250 N + 150 P, 250 N + 150 P + 100 K, 250 N + 150 P + 100 K + 15 S, 250 N + 150 P + 100 K + 15 Mg and 250 N + 150 P + 100 K + 15 S + 15 Mg. Results revealed that the crop sown on ridges increased significantly the grain yield (7.50 t ha^{-1}), stover yield (11-39 t ha^{-1}) and nutrient efficiency (NE) over rest of the two methods which were also statistically different from each other. The crop fertilized @ 250-150-100-15 Kg NPKS ha^{-1} produced significantly more grain yield (8.52 t ha^{-1}), stover yield (12.08 t ha^{-1}) and NE (10.46) than rest of the treatments. Ridge planting gave the maximum net income and BCR.

Kahlon (2017) was studied to investigate the effect of planting methods and irrigation levels on irrigation water productivity and onion (*Allium cepa* L.) yield, a field experiment was conducted on sandy loam soil at the Research Farm of Department of Soil Science, Punjab Agricultural University, Ludhiana during rabi 2011-12. Three planting methods tested include drip irrigated beds, furrow-irrigated beds, and flat flood irrigation. In drip-irrigated beds and furrow irrigated beds three onion rows were planted on 55 cm wide beds at a spacing of 15 cm from row to row. Three levels of irrigation water were tested i.e. IW/PAN-E ratio of 0.3, 0.4 and 0.5 in drip irrigated onions and 1.2, 1.6 and 2.0 in both bed furrow and flat flood methods of irrigation. The results of the experiment indicated that in drip irrigated beds by applying the same quantity and 50 percent of water as of flat flood irrigation, the yield was increased by 43 and 25 percent, respectively. Irrespective of irrigation levels, highest onion yield (32.5 t ha⁻¹) was recorded under drip irrigated beds followed by furrow irrigated beds (28.5 t ha⁻¹) and least under flat flood irrigation method (25.0 t ha⁻¹). The onion yield increases with the increase in irrigation level in all the planting methods. The highest irrigation water productivity was observed under drip irrigated beds (1.26 t ha⁻¹ cm) followed by furrow irrigated beds (0.84 t ha⁻¹ cm) and least under flat flood irrigation (0.48 t ha⁻¹ cm) with equivalent IW/PAN-E ratios. Bigger size onions (40 mm and 50 mm) were observed under drip irrigated beds followed by furrow irrigated beds and smallest size bulbs under flat flood method of irrigation. The results revealed that drip irrigation could successfully be used for onion production with significant water saving and higher production.

Mohammadi *et al*. (2010), onions are generally established either by direct seeding or bare root transplants. Compared to direct seeding, transplanted onions provide for an immediate and complete stand. The effect of transplant age on yield is an issue often broached by growers of horticultural and agronomic crops in an effort to maximize production potential. The experiment was arranged in a randomized complete block (split-plot factorial) with irrigation method as the main plot and three varieties and two planting methods on ridges and flat as a subplot and replicated three times. Results showed that irrigation method only affected bulb weight and leaf sheath length. In the other hand, transplant size had a significant effect on neck thickness, total plant weight, bulb weight, bulb diameter, leaf sheath length, yield, and root weight. Between tested cultivars, Qooli Qesse resulted in the highest yield.

Arian *et al*. (2002), a field trial was conducted for consecutive two years to determine the growth and yielding behaviour of onion in response to essential nutrients (NPK) during 1986-87 and 1987-88 at Sindh Agriculture University, Tandojam. The results described that onion response for plant height bulb diameter, single bulb weight and total marketable bulb yield, to different NPK doses was remarkably significant during both the years. However, NPK dose 90-60-80 kg recorded significantly maximum marketable bulb yield as compared to rest treatments. Onion planted on ridges proved to be better yielding compared to flat planting. It is advisable that for harvesting good marketable bulb yield in onion (Phulkara), the crop should be planted on ridges and fertilized with 90-60-80 kg/ha NPK fertilizers.

Khadrah *et al* (2017), two field experiments were carried out at the Experimental Farm of Sakha Agricultural Research Station, Egypt, during the two winter seasons of 2014/15 and 2015/16. The experiments were conducted to find out the suitable transplanting date (15th December, 1st January, and 15th January), the best planting method (ridges and wide furrows) and to assess three plant densities i.e., 30, 45 and 60 plants/m^2 for vegetative growth, yield and quality of onion under North Delta conditions. The main results showed that the vegetative growth behavior was improved, also yield and its components and quality of onion were increased by transplanting onions on 15th Dec. date in both seasons. Wide furrows planting method resulted in a significant increase in most vegetative growth characteristics, as well as total bulb yield and its components and bulb quality. Increasing plant density up to 45 plants/m^{-2} significantly increased most vegetative growth characteristics, total and marketable bulbs yield/fed and bulb quality in 2014/15 and 2015/16 seasons. Transplanting onions on 15th Dec. in wide furrows planting system significantly recorded the tallest plants, leaf area/plant, total bulbs yield, marketable bulbs yield, and average bulb weight. Onion cultivar transplanted at 15th Dec. with 30 plants/m^{-2} resulted in a markedly increase in plant height, plant fresh and dry weight and leaf area/plant at the three sampling dates in both seasons. While, total and marketable bulbs yield/fed., was increased by transplanted at 15th Dec. with 45 plants/m^{-2}. The highest vegetative growth, total bulbs yield, and bulb quality resulted from onions when were planted with 45 plants/m^{-2} in wide furrows planting method. The economic evaluation showed that the highest gross and net return per fed and net benefit-cost ratio obtained from transplanting onions at 15th Dec. (early date), wide furrows planting method with planting 45 plants/m2. So, this study recommended onion farmers at North Delta of Egypt to transplanting onions at 15th Dec. (early date) in wide furrows planting method with the plant density of 45 plants/m^{-2} to achieve the highest economic yield.

Ahmed and Hassan (1978). Yield data for two seasons indicated that direct seeding was superior over transplanting for all three cultivars. Planting on flat gave a significantly higher yield than planting on ridges. While direct seeding increased the number of large bulbs as compared to transplanting, land preparation method did not have any effect. Direct seeding on both flat and ridges significantly increased percentage doubles for the cultivar "Nasi". Transplanting delayed the maturity of the cultivars "Shendi Red" and "Dongola White Imp". Incidence of bolting was increased by direct seeding on ridges and flat for all three cultivars.

Ahmed *et al.* (2017), the rapid increase in population and consumption, urged upon the agronomists to develop a comprehensive site-specific agro-technology to boost up production per unit area and quality of daily dietary onion crop in salt-affected soils by improving some basic components of the prevailing onion production technology in Pakistan. In this perspective, a detailed and systematic series of field studies were undertaken for three consecutive years (2013 - 2015) at Soil Salinity Research Institute, Pindi Bhattian, Pakistan to evaluate different nitrogen levels and the cost-effective planting technique for onion production under salt affected conditions. The experiment was laid out in a split plot arrangement using a randomized complete block design having three replications. Two planting methods, ridge and bed planting and 4 nitrogen levels, 1- recommended dose (RD) of N (90 kg ha^{-1}), 2 -75 % N of RD (67.5 kg ha^{-1}), 3 -125 % N of RD (112.5 kg ha^{-1}), 4 - 150 % N of RD (135 kg ha^{-1}) were used. Planting methods were kept in main plots and nitrogen levels in subplots keeping sub-plot size of 4 m x 6 m. Measurements included were: plant height, number of leaves/plants/m^{-2}, bulb diameter, bulb mass, total bulb yield, number of flowers/umbel, seed mass/plant and 1000-seed mass. Results showed that maximum onion yield and yield attributes were recorded with nitrogen application at a rate of 150 & 125 of RD in ridge planting. However, nitrogen application at the rate of 125 of RD in ridge planting recorded higher economic returns over all the other treatments and is recommended as a most cost-effective technique for onion production under salt-affected soil as compared to other treatments.

Bakht *et al.* (2011), field experiment was conducted at KPK Agricultural University, Peshawar, Pakistan to find out the effect of planting methods on the yield and yield components of maize varieties. Analysis of the data revealed that planting methods had a significant effect on days to tasseling, days to silking, plant height, number of plants ha^{-1} at harvest, thousand grain weight, grain yield, biological yield, fresh weed biomass m^{-2} and non-significant effect on days to emergence, emergence m^{-2}, number of cobs $plant^{-1}$, grains ear^{-1}, harvest index and dry weed biomass m^{-2}. Similarly, the effect of varieties was also significant on all parameters except fresh and dry weed biomass m^{-2}. Maximum emergence m^{-2}, days to tasseling, days to silking, plant height, number of plants ha^{-1} at harvest, grains ear^{-1}, thousand-grain weight, grain yield, and biological yield were recorded in ridge planting method. Similarly, Jalal sown on ridges took maximum days to emergence, emergence m^{-2}, plant height, number of cobs $plant^{-1}$, grains ear^{-1}, thousand-grain weight, grain yield, biological yield, fresh weed biomass, and dry weed biomass.

Abdullah *et al*. (2007) An experiment to study the impact of planting methods and herbicides on weed biomass and some agronomic traits of maize hybrid P-3025 was conducted at Agricultural Research Farm, NWFP Agricultural University, Peshawar during summer 2006. The crop was sown on April 22, 2006, in RCB design with split plot arrangement, replicated four times. The treatments included planting methods (Ridge, Broadcast & Flat sowing) in main-plots and herbicides (pendimethalin @0.75, s-metolachlor @ 1.92 and 2,4-D @ 0.80 kg a.i ha^{-1}) and a weedy check assigned to the sub-plots. Each subplot measured 5 x 3 m^2. The data were recorded on fresh and dry weed biomass (gm^{-2}), plant height (cm), number of leaves $plant^{-1}$, leaf area (cm^2) and biological yield (t ha-1). For planting methods, significant differences were noted for fresh and dry weed biomass (gm^2), plant height (cm), leaf area (cm^2) and biological yield (t ha^{-1}). For herbicides, significant differences were depicted for fresh and dry weed biomass (gm^{-2}), plant height (cm), leaf area (cm^2) and biological yield (t ha^{-1}). For interaction, significant differences were deciphered for fresh weed biomass (gm^{-2}), dry weed biomass (gm^{-2}), plant height (cm), leaf area (cm^2) and biological yield (t ha^{-1}). Maximum plant height (209.43, 213.41 & 218.75 cm), leaf area (346.79, 349 & 382.18 cm^2) and biological yield (10.45, 10.68 & 13.03 t ha^{-1}), while minimum values were observed for fresh weed biomass (265.68 gm^{-2}, 169.50 gm^{-2} & 147.75 gm^{-2}) and dry weed biomass (53.13 gm^{-2}, 33.90 gm^{-2} & 29.55 gm^{-2}) in Ridge planting. Dual gold 960 EC (s-metolachlor) and their interaction, respectively. Similarly, maximum values were recorded for fresh weed biomass (306.00 gm^{-2}, 414.08 gm^{-2} & 443.75 gm^{-2}) and dry weed biomass (61.20 gm^{-2}, 82.81 gm^{-2}, 88.75 gm^{-2}) while, minimum values were obtained for plant height (192.68 cm, 180.58 cm & 176.25 cm) and biological yield (6.87 t ha^{-1}, 5.00 t ha^{-1} & 4.40 t ha^{-1}) in broadcast sowing, weedy check and their interaction respectively.

Arif *et al*. (2001), an experiment was conducted at the Agricultural Research. Farm of NWFP Agricultural University, Peshawar during Spring, 1999 to study the response of maize varieties to different planting methods. The experiment was laid out in RCB design with split plot arrangement and four replications. Planting methods studied were ridge planting, furrow planting, line planting, and broadcast planting. Varieties included in the experiment were Hybrid-922, Sarhad White and Sweet corn. Urea and DAP were used as sources of a basal dose of fertilizers at the rate of 200: 100 N: P kg NP per hectare. Planting methods, varieties and their interaction significantly affected all the parameters studied except for emergence per m^{-2} which was only significantly affected by varieties. Number of cobs per plant (1.03), cob length (20.32 cm), number of grains per cob (451.83), grain weight per cob (128.9 g), biological yield (53.91 kg/plot) and grain yield (4629.62 kg/ha) had maximum values in ridge planting. Maximum cob length (25.07 cm), number of grains per cob (614.14), grain weight per cob (217.26 g), biological yield per plot (73.82 kg) and grain yield/ha (6791.66 kg) were noted in Hybrid-922.

Nawaz *et al.* (2017), Rapid increase in population and consumption, urged upon the agronomists to develop a comprehensive site-specific agro-technology to boost up production per unit area and quality of daily dietary onion crop in salt-affected soils by improving some basic components of the prevailing onion production technology in Pakistan. In this perspective, a detailed and systematic series of field studies were undertaken for three consecutive years (2013 - 2015) at Soil Salinity Research Institute, Pindi Bhattian, Pakistan to evaluate different nitrogen levels and the cost-effective planting technique for onion production under salt affected conditions. The experiment was laid out in a split plot arrangement using a randomized complete block design having three replications. Two planting methods, ridge and bed planting and 4 nitrogen levels, 1- recommended dose (RD) of N (90 kg ha^{-1}), 2 -75 % N of RD (67.5 kg ha^{-1}), 3 -125 % N of RD (112.5 kg ha^{-1}), 4 - 150 % N of RD (135 kg ha^{-1}) were used. Planting methods were kept in main plots and nitrogen levels in subplots keeping sub-plot size of 4 m x 6 m. Measurements included were: plant height, number of leaves/plants/m^{-2}, bulb diameter, bulb mass, total bulb yield, number of flowers/umbel, seed mass/plant and 1000-seed mass. Results showed that maximum onion yield and yield attributes were recorded with nitrogen application at a rate of 150 & 125 of RD in ridge planting. However, nitrogen application at the rate of 125 of RD in ridge planting recorded higher economic returns over all the other treatments and is recommended as a most cost-effective technique for onion production under salt affected soil as compared to other treatments.

Amin *et al*. (2006) a field experiment was conducted to evaluate the effect of planting methods, seed density and nitrogen phosphorus (NP) fertilizer levels on emergence m/sup -2/ growth and grain yield of sweet corn. The fertilizer and interaction of fertilizer x seed density had a significant negative effect with the increasing level while seed density had a positive effect with increased density on emergence per m/sup 2/. Increased seed density significantly reduced plant growth which increased with the application of higher fertilizer dose. The grain yield was improved by ridge planting methods, increased seed density and increased fertilizer levels. The highest grain yield (3,553.50 kg ha/sup-1/) of sweet corn plants was recorded in ridge planting method with highest NP fertilizer level of 300:150 kg ha/sup 1/ and 4 seeds hill/sup -1/. The lowest grain yield (3,493.75 kg ha/sup -1/) of sweet corn was observed in flat sowing planting method with 120:75 NP level and 2 seeds hill/sup -1/ seed density. The ridge planting rank first then furrow and flat planting methods on the basis of grain yield per hectare. The sweet corn plant yield was high with 4 seeds hill/sup -1/ compared with 2 seeds hill/sup -1.

Liu and Yong (2008) was conducted a conference through field experiments, effects of ridge-furrow tillage with different surface configurations and crop planted in-furrow, on the efficiency for rainwater harvesting and crop production, were evaluating to determine the optimal surface configuration of ridge-furrow tillage. Two parameters of ridge heights (H_R) and ridge-furrow ratios ($R_{H/W}$, the ratio between H_R and furrow width, W_F) were defined to determine the configuration of ridge-furrow tillage. The results indicate that relative to conventional field tillage (CT), ridge-furrow tillage increased volumetric soil water content of the plow layer (0-30 cm) and crop yields. And the practice with 25 cm H_R (ridge height) and 1/24 $R_{H/W}$ (ratio between H_R and furrow width) was the most optimal configuration of ridge-furrow tillage for rainfed agriculture in the semiarid region.

Memon *et al.* (2017) this review paper reveals that plastic mulching is beneficiary in every aspect of irrigation and it is a process, which produces good quality of food and vegetables. Different types of mulching methods and materials are used worldwide according to the requirements of crop and climatic condition, Similarly, Grass clipping, straw, newspaper, dry leaves, bark clippings, sawdust, and compos were included in the organic mulching materials, while the other types of material i.e. gravel, plastic and landscape fabric used in the inorganic mulching, but plastic is one of the best materials, which are the most used materials in the world, especially black polyethylene type of plastic with the positive results in production and also available in the market with low price. Moreover, Ridge Furrows Plastic Mulching (RFPM) method based on the ridges cover with a plastic sheet to enhance soil water infiltration and water availability to the crop helps to improve soil biodiversity and environmental benefits. The effectiveness of RFPM systems is reflected in increased crop yields (20%-180%) compared with that of the conventional-flat planting. We strongly suggest that RFPM systems are the innovative approach for increasing crop water availability, improving soil productivity, and enhancing food security for arid and semiarid rain-fed areas. This study also indicates that RFPM systems with plastic mulching, indigenous to China and India and now spreading around the world, and proved an important or innovative water-saving tool and can get higher Water Use Efficiency (WUE) for increasing crop yields and securing food supply in arid and semiarid regions of the world. Further research should be carried out to evaluate and define the optimum use of this system in the development of long-term sustainable systems for the rain-fed and semi-arid area of agriculture.

Rasheed *et al.* (2004) an experiment to study the comparative productivity, nutrient efficiency and economics of maize hybrids was conducted at the University of Agriculture, Faisalabad during 1997 and 1998. The experiment comprised three planting methods 70 cm spaced single rows, 105 cm spaced double-row strips and 70 cm spaced ridges with seven nutrient levels (kg ha^{-1}) viz., 250 N, 250 N + 150 P, 250 N + 150 P + 100 K, 250 N + 150 P + 100 K + 15 S, 250 N + 150 P + 100 K + 15 Mg and 250 N + 150 P + 100 K + 15 S + 15 Mg. Results revealed that the crop sown on ridges increased significantly the grain yield (7.50 t ha^{-1}), stover yield (11-39 t ha^{-1}) and nutrient efficiency (NE) over rest of the two methods which were also statistically different from each other. The crop fertilized @250-150-100-15 Kg NPKS ha^{-1} produced significantly more grain yield (8.52 t ha^{-1}), stover yield (12.08 t ha^{-1}) and NE (10.46) than rest of the treatments. Ridge planting gave the maximum net income and BCR.

CHAPTER III

MATERIALS AND METHOD

This chapter describes the materials and methods which were used in the field to conduct the experiment entitled "growth and yield of onion influenced by vermicompost and planting methods" during the period from October 2017 to March 2018. It comprises a short description of experimental site, soil, and climate, variety, growing of the crops, experimental design and treatments, and collection of data presented under the following headings.

3.1. Experimental site

The study was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. Geographically the experimental area is located at $23^0$41 N latitude and $90^0$22 E longitudes at the elevation of 8.2 m above the sea level (FAO, 1988).

3.2. Characteristics of soil

The soil of the experimental field was silty loam in texture. The soil of the experimental area belongs to the Madhupur Tract (UNDP, 1988) under the AEZ No. 28. Soil sample of the experimental plot was collected from a depth of 0-30 cm before conducting the experiment and analyzed in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix I.

3.3. Climate and weather

The climate of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979). Details of the meteorological data during the period of the experiment were collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix II.

3.4. Planting material

The “Taherpuri” cultivar of onion was used in the experiment. The seeds of the cultivar were collected from government approved market ‘Siddique Bazar’, Dhaka.

3.5. Seedbed preparation

The land which was selected for raising seedlings was fine textured and well drained. The land was opened and drying for 10 days. Seedbed was prepared on 19 October 2017 for raising seedlings of onion and the size of the seedbed was 3m×1m. For making seedbed, the soil was well ploughed to loose friable and dried masses to an obtained good tilth. Weeds, stubbles and dead roots were removed from the seedbed. The soil was treated by Sevin 50WP @ 5kg/ha to protect the young plants from the attack of mole crickets, ants and cutworm. Onion seeds were soaked overnight (12 hours) in water and allowed to sprout in a piece of moist cloth keeping in sun shade for one day.

3.6. Seed treatment

Seeds were treated by Vitavax-200 @ 5g/1kg seeds to protect some seed-borne diseases.

3.7. Seed Sowing

The date of the seed sowing was 19 October 2017. Seeds were sown on the seedbed to get 35 days old seedlings. Seeds were sown at a depth of 0.6 cm and covered with a fine layer of soil followed by light watering by water can. The young seedlings were exposed to dew by night and mild sunshine in the morning and evening. Shade was given over the seedbed to retain soil moisture and to save the seedlings from direct sun and rain.

3.8. Raising of seedlings

Light watering and weeding were done several times. No chemical fertilizers were applied for rising of seedlings. When the seedlings of the seedbeds attained a height of about 10 cm, the thinning operation was done. Healthy and 35 days old seedlings were transplanted into the experimental field on 25 November 2017.

3.9. Treatment of the experiment

The experiment consisted of two factors viz., vermicompost and planting method.

Factor A: Different levels of vermicompost such as,

1. **V_0** : Control
2. **V_1** : 6 t/ha
3. **V_2** : 9 t/ha
4. **V_3** :12 t/ha

Factor B: Different planting methods, viz.

1. **P_1:** Flat method
2. **P_2**: Furrow method
3. **P_3**: Ridge method

There were 12 treatment combination such as P_1V_0, P_1V_1, P_1V_2, P_1V_3, P_2V_0, P_2V_1, P_2V_2, P_2V_3, P_3V_0, P_3V_1, P_3V_2, and P_3V_3.

3.10. Design and layout of the experiment

The two-factorial experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was divided into three equal blocks. Each block was divided into 12 plots where 12 treatments combination were distributed randomly. There were 36 unit plots altogether in the experiment. The size of each plot was 1.2 m × 0.9 m. Two adjacent unit plots and blocks were separated by 50 cm.

3.11. Land preparation

The plot selected for conducting the experiment was opened in the 4th week of November 2017 with a power tiller and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil was obtained for transplanting of the seedling. In order to avoid water logging due to rainfall during the study period, drainage channels were made around the land. The soil was treated with Sevin 50 WP @ 5kg/ha when the plot was finally ploughed to protect the young seedlings from the attack of cutworm.

3.11.1. Application of fertilizer and manure

BARI recommendation doses of Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MP) are 200 Kg ha^{-1}, 125Kg ha^{-1}, and MP-180 Kg ha^{-1} respectively. But in the present study, no chemical fertilizer was used. The only vermicompost was used for proper nutrient supply. In addition, vermicompost was used regarding different doses as per treatment.

3.11.2. Planting methods

Three types of planting methods; viz., flat method, ridge method, and furrow method were used.

3.11.3. Transplanting

The seedbed was watered before uprooting the seedlings to minimize the damage of roots. 35 days old healthy seedlings were transplanted at the spacing of 30 cm × 15 cm in the experimental plots on 25 November 2017. The uprooting of seedlings was done in the afternoon very carefully so that seedlings were not injured. Light irrigation was given immediately after transplanting around each seedling for their better establishment.

3.12. Intercultural operations

After transplanting of seedlings, intercultural operations were done whenever required for getting better growth and development of the plants. So the crop was always kept under careful observation.

3.12.1 Gap filling

Very few seedlings were damaged after transplanting and new seedlings from the same stock were replaced these.

3.12.2 Weeding and earthing up

Weeding was done three to four times after transplanting to keep the crop free from weeds and mulching was provided by breaking the crust of the soil for easy aeration and to conserve soil moisture, when needed especially after irrigation.

3.12.3 Irrigation

Irrigation was given by watering can be and or hose pump when needed. First irrigation was given just after transplanting. During this time, care was taken so that irrigated water could not pass from one plot to another. During irrigation, the soil was made saturated with water. After rainfall excess water was drained out when necessary.

3.12.4. Plant protection

The preventive measure was taken against soil-borne insects. Furadan 3G @ 20kg/ha was applied for the prevention of cutworm. After the pesticide application, no insect infestation was found in the field. Few days after transplanting some plants were attacked by purple blotch disease caused by *Alternaria porri*. It was controlled by spraying Rovral 50 WP @ 2g/ L of water at 7 days interval.

3.12.5. Removal of scape

The flower stalk was removed whenever appeared in plants. This was done daily by keen inspection and this discourages bolting.

3.12.6. Harvest

The maturity of the crop was determined by the appearance of the yellowish color of the leaves, falling off the stems on the ground and finally drying of leaves. Onions were lifted with the help of hand and care was taken so that no bulb was injured during lifting. The tops were removed by cutting off the pseudostem keeping 2.5 cm with the bulb. Harvesting was done on 27 March 2018.

3.13. Collection of data

Ten plants were randomly selected from each plot to record data in such a way that the border effect was avoided. The following data was recorded from the sample plants during the study period.

Data were collected on the following parameters

1. Plant height (cm)
2. Number of leaves per plant
3. Bulb length (cm)
4. Bulb diameter (cm)
5. Neck diameter (cm)
6. Root length (cm)
7. Fresh weight of bulb per plant (g)
8. Dry weight of bulb per plant (g)
9. Yield per plot (g)
10. Yield per ha (t/ha)

3.14 Data collection procedure

3.14.1 Plant height

The heights of the randomly selected ten plants were measured with a meter scale from the ground level to the top of the tallest leaf after 30 days of transplanting and then 15 days interval up to 60 days of transplanting and the mean height was expressed in cm.

3.14.2 Number of leaves per plant

A total number of leaves per 10 plants was counted after 30 days after transplanting and then 15 days interval up to 60 days of transplanting and the average number of leaves per plant was recorded.

3.14.3 Length of the bulb (cm)

After harvesting the length of the bulb was measured with a scale from the neck to the bottom of the bulb of ten randomly selected plants from each plot and their average was taken in centimeter.

3.13.4 Bulb diameter

After harvesting the diameter of the bulb was measured at the middle portion of ten randomly selected plants from each plot and their mean value was taken in centimeter.

3.14.5 Neck diameter

Neck diameter was measured at the neck of ten randomly selected plants with a slide caliper after harvesting and the average mean was calculated and expressed in centimeter.

3.14.6 Root length

After harvesting the length of the root was measured with a scale of ten randomly selected plants from each plot and their average was taken in centimeter.

3.14.7 Fresh weight of bulb per plant

Fresh bulb of 10 individual plants was taken and weighted after harvest and their average weight was calculated and expressed in gram (g).

3.14.8 Dry matter content of bulb (%)

To determine the dry matter content of bulbs, 100 g of bulb was randomly collected from harvested bulb of each plot. The bulbs were sliced with a sharp knife. The fresh sample was dried under scorching sunlight and kept in an oven at 700^{0}C for 72 hours until constant weight. Finally dry weight was taken with an electric balance and dry matter percentage was calculated by the following formula.

$$\text{Dry matter (\%)} = \frac{\text{Dry weight of bulb}}{\text{Fresh weight of bulb}} \times 100$$

3.14.9 Yield per plot

All the leaves along with pseudostem were removed keeping only 2.5 cm neck. The weight of the bulb was taken by an electric balance in gram (g) from each unit plot separately. An electric balance was used to take the weight of bulb per plot. It was measured by totaling the bulb yield of each unit plot separately harvest and was recorded in gram (g).

3.14.10 Yield per hectare

The yield of bulb per plot was converted into ton per hectare to get the yield of onion.

3.15 Statistical analysis

The data collected on various parameters were statistically analyzed using SPSS software (Version 20.00) to find out the statistical significance of the treatment effect. The mean values of all the treatments were calculated and analyses of variance for all the characters were performed by the F-test. The significance of the difference among the treatments and combinations of means was estimated by DMRT (Duncan's Multiple Range Test) at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of different planting methods and vermicompost on the growth and yield of onion. The results obtained from the study have been presented, discussed and compared in this chapter through tables, figures, and appendices. The analyses of variance (ANOVA) of data in respect of all the parameters have been shown in Appendix III-XIV. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following subheadings.

4.1 Plant height

Plant height is an important parameter which reflects the vegetative growth of the plant. The plant height was significantly influenced by different levels of vermicompost (Figure 1 and Appendix III, IV, V). It was found that there was a significant effect on plant height among the treatments at 30, 45 and 60 days after transplanting (DAT). At 30 DAT, the tallest plant (29.47 cm) was measured from VC_2 which was statistically similar to that of VC_3 and the shortest (24.28 cm) was recorded from the control treatment (VC_0). At 45 DAT, the tallest plant height (39.30 cm) was recorded from VC_2 which was statistically similar to that of VC_3 and the shortest (30.96 cm) was measured from VC_0. At 60 DAT, the tallest plant height (52.09 cm) was recorded from VC_2 which was statistically similar to that of VC_3 and the shortest (43.67 cm) was recorded from VC_0 treatment. It was revealed that the plant height increased with the increase in days after transplanting (DAT) i.e., 30, 45 and 60 DAT and also revealed that the plant height increased with different levels of vermicompost application as well. The result might be due to the fact that vermicompost enhances the vegetative growth of onion. The present findings are agreed with the findings of Yadav *et al.* (2015) and Meena *et al*. (2015).

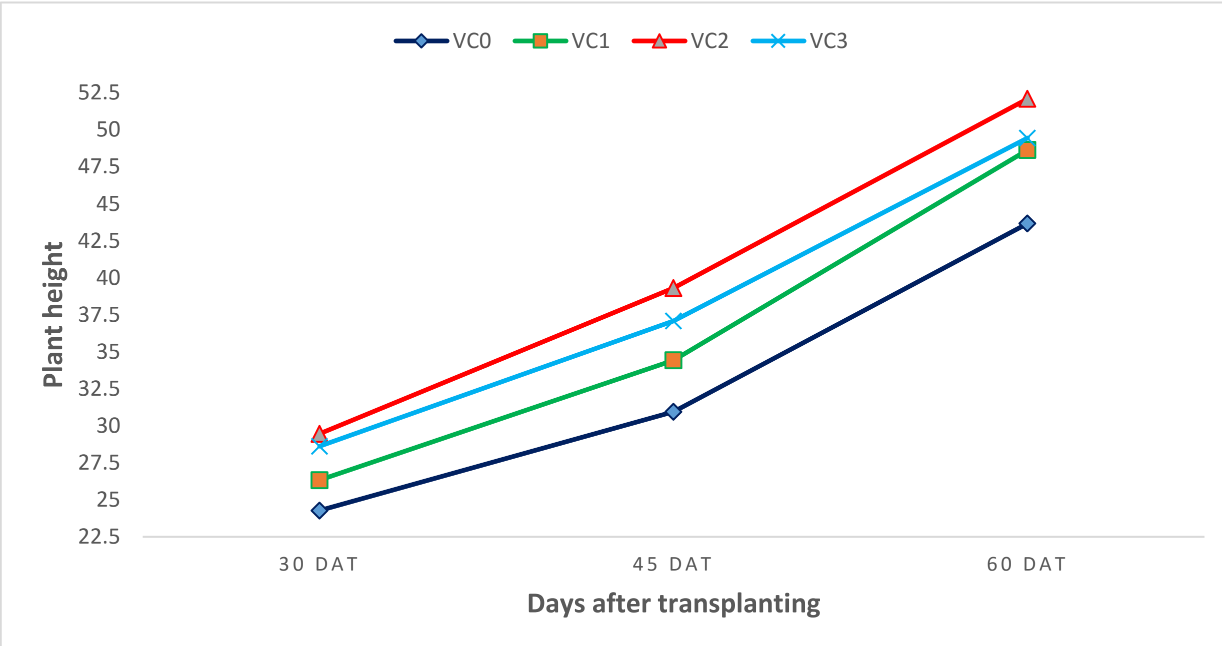

Figure 1. Effect of vermicompost on plant height of onion

DAT: Days after transplanting; VC_0: control, VC_1: 6 ton/ha, VC_2: 9 ton/ha, VC_3: 12 ton/ha;

Different planting method statistically influenced on plant height of Taherpuri at different days after transplanting (DAT) (Fig. 2 and Appendix III, IV, V). At 30 DAT, the tallest plant (28.63 cm) was measured from P_3 which was statistically similar to that of P_2 and the shortest (25.63 cm) was recorded from P_1. At 45 DAT, the tallest plant height (36.78 cm) was recorded from P_3 which was statistically similar to that of P_2 and the shortest (34.50cm) was measured from P_1. At 60 DAT, the tallest plant height (50.05 cm) was recorded from P_3 which was statistically similar to that of P_2 and the shortest (47.10 cm) was recorded from P_1 treatment. The variation in plant height as influenced by planting method was perhaps due to proper utilization of nutrients, moisture, and light.

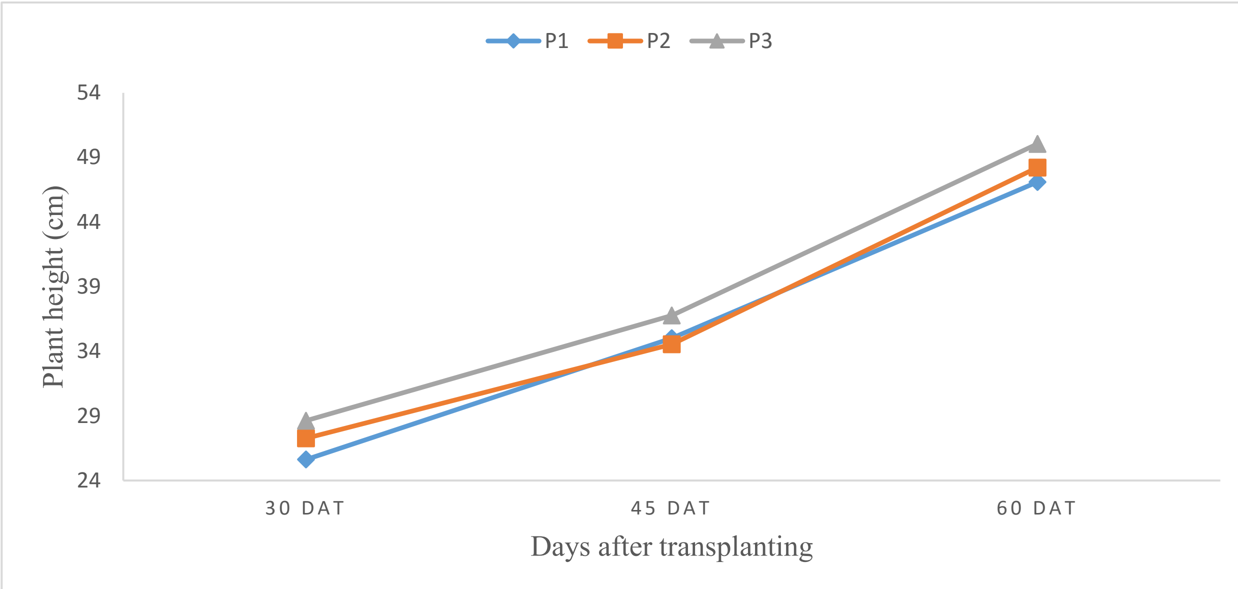

Figure 2. Effect of planting method on plant height of onion

DAT: Days after transplanting; P_1: Flat method, P_2: Furrow method, P_3: Ridge method.

The combined effect of different planting method and vermicompost showed positively significant variation all dates of observation (Table 1 and Appendix III-V). At 30 DAT, the tallest plant (31.67 cm) was measured from VC_2P_3 combination which was statistically similar to VC_2P_2 and the shortest (22.83 cm) was recorded from VC_0P_1 combination. At 45 DAT, the tallest plant height (40.40 cm) was recorded from VC_2P_3 combination which was statistically similar to VC_3P_3 and the shortest (29.33 cm) was measured from VC_0P_1 combination. At 60 DAT, the tallest plant height (54.80 cm) was recorded from VC_2P_3 which was statistically similar to VC_3P_3 and the shortest (42.27 cm) was recorded from VC_0P_1 combination.

Table 1. Combine effect of vermicompost and planting method on plant height

Treatments	Plant height (cm) at		
	30 DAT	45 DAT	60 DAT
VC_0P_1	22.83 f	29.33 e	42.27 e
VC_0P_2	24.73 ef	30.60 de	44.13 de
VC_0P_3	25.27 def	32.93 cde	44.60 cde
VC_1P_1	24.73 def	35.93 abc	48.13 bcd
VC_1P_2	26.27 cde	33.27 bcde	49.03 bc
VC_1P_3	28.00 bcd	34.07 bcd	48.73 bcd
VC_2P_1	26.73 cde	38.73 a	49.73 b
VC_2P_2	30.00 ab	38.77 a	51.73 ab
VC_2P_3	31.67 a	40.40 a	54.80 a
VC_3P_1	28.20 bc	34.00 bcd	48.27 bcd
VC_3P_2	28.07 bcd	37.53 ab	48.00 bcd
VC_3P_3	29.60 ab	39.73 a	52.07 ab
SE (±)	0.46	0.68	0.67
Significance level	0.000	0.000	0.000

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by DMRT.
DAT: Days after transplanting; VC_0: control, VC_1: 6 t/ha, VC_2: 9 t/ha, VC_3: 12 t/ha; P_1: Flat method, P_2: Furrow method, P_3: Ridge method.

4.2 Number of leaves plant^{-1}

Good foliage indicates higher growth, development, and productivity of the plant. In the present study, the number of leaves per plant was found to be significantly influenced by vermicompost (Figure 3 and Appendix VI-VIII). At 30 DAT, the maximum number of leaves plant^{-1} of onion (4.05) was measured from VC_2 which was statistically similar to that of VC_3 and the minimum number of leaves plant^{-1} of onion (2.75) was recorded from the control treatment (VC_0). At 45 DAT, the maximum number of leaves plant^{-1} of onion (5.24) was recorded from VC_2 which was statistically similar to that of VC_3 and the minimum number of leaves plant^{-1} of onion (4.04) was measured from VC_0. At 60 DAT, the maximum number of leaves plant^{-1} of onion (6.93) was recorded from VC_2 which was statistically similar to that of VC_3 and the minimum number of leaves plant^{-1} of onion (5.2) was recorded from VC_0 treatment.

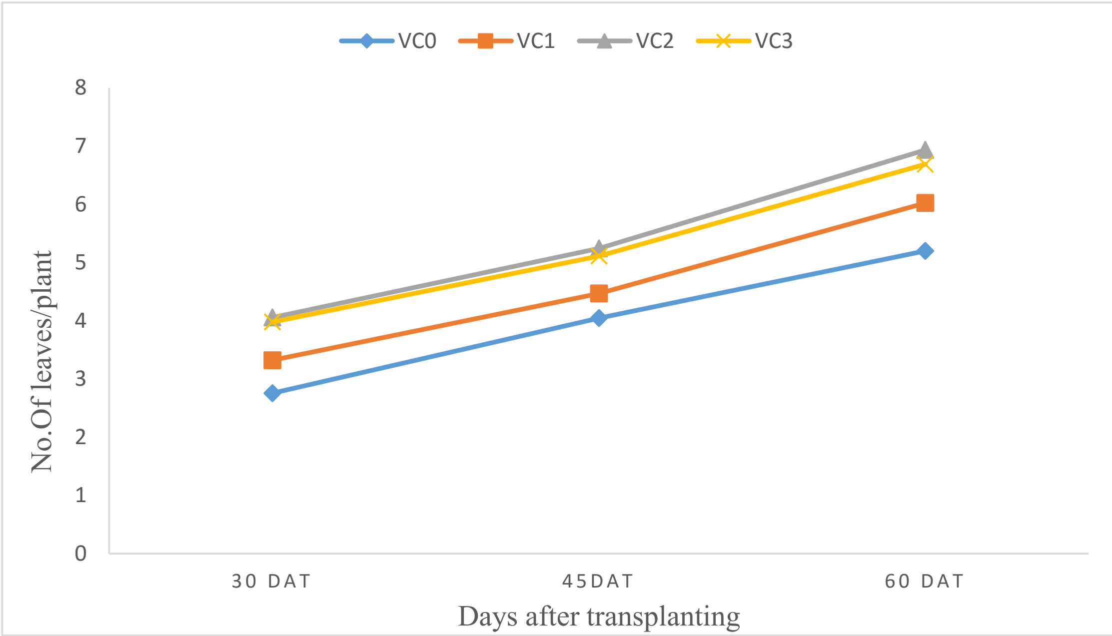

Figure 3. Effect of vermicompost on number of leaves plant^{-1} of onion

DAT: Days after transplanting; VC_0: control, VC_1: 6 ton/ha, VC_2: 9 ton/ha, VC_3: 12 ton/ha.

The experiment was significantly influenced for the variation of different planting method on a number of leaves plant $^{-1}$ of Taherpuri at different days after transplanting (DAT) (Fig.4 and Appendix VI, VII, VIII). At 30 DAT, the maximum number of leaves plant^{-1} of onion (3.80) was measured from P_3 which was statistically similar to that of P_2 and the minimum number of leaves plant^{-1} of onion (3.25) was recorded from P_1. At 45 DAT, the maximum number of leaves plant^{-1} of onion (4.87) was recorded from P_3 which was statistically similar to that of P_2 and the minimum number of leaves plant^{-1} of onion (4.57) was measured from P_1. At 60 DAT, the maximum number of leaves plant^{-1} of onion (6.51) was recorded from P_3 which was statistically similar to that of P_2 and the minimum number of leaves plant^{-1} of onion (5.93) was recorded from P_1 treatment. The variation in a number of leaves plant $^{-1}$ as influenced by planting method was perhaps due to proper utilization of nutrients, moisture, and light. Gurjar *et al*. (2017) found that better growth of leaves/plant as an effective nutrient sink of the bulb, which eventually translated into higher yield.

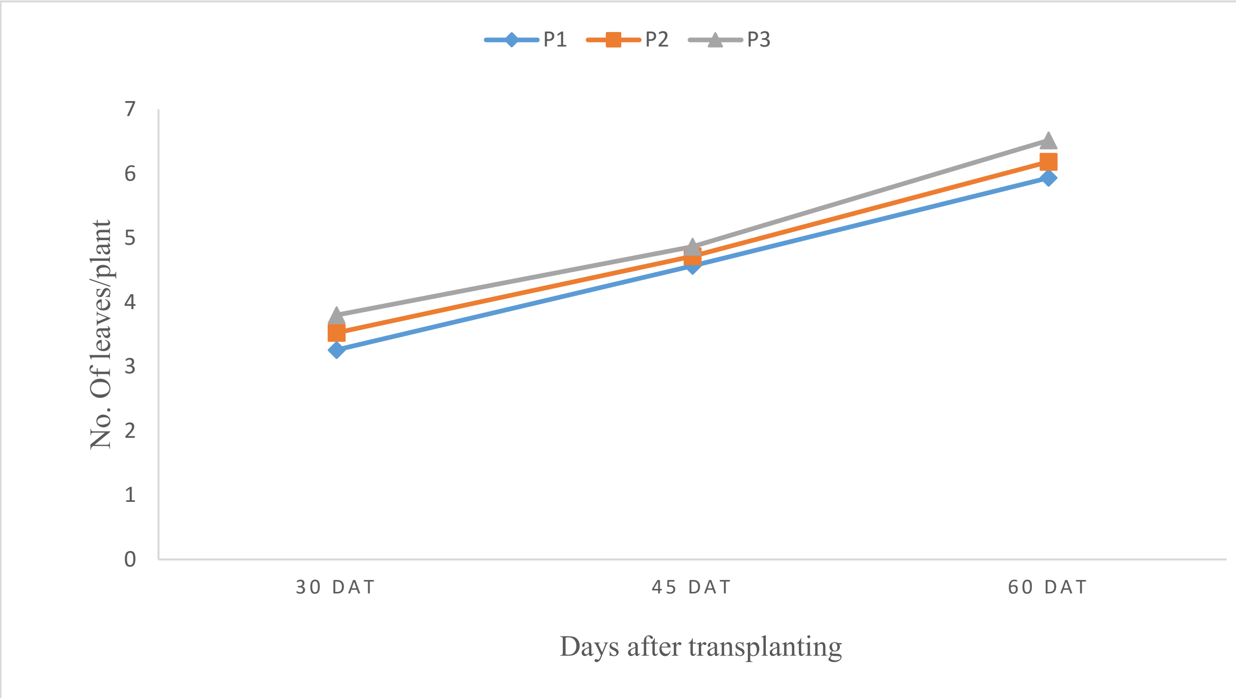

Figure 4. Effect of planting method on the number of leaves of plant^{-1} of onion

DAT: Days after transplanting; P_1: Flat method, P_2: Furrow method, $P_{3:}$ Ridge method.

The combined effect of different planting method and vermicompost showed positively significant variation at all dates of observation (Table 2 and Appendix VI, VII, VIII). At 30 DAT, the maximum number of leaves plant^{-1} of onion (4.6) was found from VC_2P_3 combination which was statistically to VC_3P_3 and the minimum number of leaves plant^{-1} of onion (2.53) was recorded from VC_0P_1 combination. At 45 DAT, the maximum number of leaves plant^{-1} of onion (5.53) was recorded from VC_2P_3 combination which was statistically VC_2P_2 and the minimum number of leaves plant^{-1} of onion (3.87) was measured from VC_0P_1 combination. At 60 DAT, the maximum number of leaves plant^{-1} of onion (7.6) was recorded from VC_2P_3 which was statistically to VC_3P_3 and the minimum number of leaves plant^{-1} of onion (4.87) was recorded from VC_0P_1 combination.

Table 2. Combined effect of vermicompost and planting method on the number of leaves per plant of onion

Treatments	Number of leaves at		
	30 DAT	45 DAT	60 DAT
VC_0P_1	2.53 g	3.87 e	4.87 f
VC_0P_2	2.80 fg	4.00 de	5.27 ef
VC_0P_3	2.93 efg	4.27 cd	5.47 def
VC_1P_1	3.13 def	4.47 c	6.07 bcde
VC_1P_2	3.33 de	4.47 c	5.93 cde
VC_1P_3	3.50 cd	4.47 c	6.07 bcde
VC_2P_1	3.50 cd	4.93 b	6.33 bcd
VC_2P_2	4.07 b	5.27 ab	6.86 ab
VC_2P_3	4.60 a	5.53 a	7.60 a
VC_3P_1	3.87 bc	5.00 b	6.47 bc
VC_3P_2	3.90 bc	5.13 b	6.67 bc
VC_3P_3	4.17 b	5.20 ab	6.93 ab
SE (±)	0.104	0.091	0.14
Significance level	0.000	0.000	0.000

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by DMRT.
DAT: Days after transplanting; VC_0: control, VC_1: 6 t/ha, VC_2: 9 t/ha, VC_3: 12 t/ha; P_1: Flat method, P_2: Furrow method, P_3: Ridge method.

4.3 Bulb length

With the application of vermicompost, bulb length showed positively significant variation (Table 3 and Appendix IX). The highest bulb length of onion was recorded in the treatment VC_2 (2.89 cm) which was statistically similar to VC_3 and the lowest bulb length of onion was recorded in the treatment VC_0 (2.46 cm). The result might be due to the fact that vermicompost enhances the development of onion.

Bulb length was significantly influenced by planting method (Table 3 and Appendix IX). The highest length of bulb of onion (2.8 cm) was produced from P_3 treatment, which was statistically similar to P_2 treatment and the lowest bulb length (2.61 cm) was recorded from P_1 treatment. Comparable findings are also stated by (Arif *et al*., 2001 and Rasheed *et al*., 2004) that ridge planting gave better results than other sowing methods.

In case of combined effect of vermicompost and planting method was also found to be significant on bulb length of onion (Table 4 and Appendix IX). The longest bulb length (3.02 cm) was recorded from VC_2P_3 treatment which was statistically to VC_3P_3. On the other hand, the shortest bulb length (2.37 cm) was observed in VC_0P_1 treatment compared to other treatment.

4.4 Bulb diameter

Significant variation was found in bulb diameter due to different rates of vermicompost (Table 3 and Appendix X). Results revealed that the highest bulb diameter (4.25 cm) was recorded from VC_2 followed by VC_3 (4.17 cm) where the lowest bulb diameter (3.62 cm) was recorded from VC_0 = control. Similar result was found from Yadav *et al*. (2015) and they showed that the maximum bulb diameter (4.60 cm), was recorded under treatment T10 - RDF (50%) + Vermicompost (50). This may be due to application of organic manures which provide major and micro nutrients resulted in increased the photosynthetic activity, chlorophyll formation, nitrogen metabolism and auxin contents in the plants which ultimately improving the diameter of bulb

Planting method had a significant effect on bulb diameter of onion (Table 3 and Appendix X). Data showed that the highest bulb diameter (4.12 cm) was recorded from P_3 followed by P_2 (4.02 cm) where the lowest bulb diameter (3.79 cm) was recorded from P_1 = control. Current findings corroborate the report of Bakht *et al.* (2011) who suggested that ridge planting rendered better growth conditions and improved nutrient absorption capacity.

The combined effect of different planting method and vermicompost showed positively significant variation all dates of observation (Table 4 and Appendix X). Data showed that the highest bulb diameter was found 4.47 cm in VC_2P_3 combination which was statistically to VC_3P_3 and the lowest bulb diameter was recorded 3.45 cm in VC_0P_1 combination compared to other combination.

Table.3 Effect of vermicompost and planting method on bulb length and bulb diameter of onion

Treatments	Bulb Length (cm)	Diameter of Onion (cm)
Effect of Vermicompost		
VC_0	2.46 c	3.62 b
VC_1	2.68 b	3.84 b
VC_2	2.89 a	4.25 a
VC_3	2.83 a	4.17 a
SE (±)	0.035	0.057
Significance level	0.000	0.000
Effect of planting method		
P_1	2.61 b	3.79 b
P_2	2.74 ab	4.02 ab
P_3	2.8 a	4.12 a
SE (±)	0.035	0.057
Significance level	0.067	0.050

(Means in the column followed by a different letter(s) differed significantly by DMRT at 5% level of significance). Here, VC_0: control, VC_1: 6 ton/ha, VC_2: 9 ton/ha, VC_3: 12 ton/ha; P_1: Flat method, P_2: Furrow method, $P_{3:}$ Ridge method.

Table.4 Combined effect of vermicompost and planting method on bulb length and bulb diameter of onion

Treatments	Bulb Length (cm)	Bulb diameter (cm)
VC_0P_1	2.37 f	3.45 d
VC_0P_2	2.51 ef	3.67 cd
VC_0P_3	2.50 ef	3.75 cd
VC_1P_1	2.58 de	3.80 cd
VC_1P_2	2.72 bcd	3.84 c
VC_1P_3	2.75 bcd	3.88 c
VC_2P_1	2.77 bcd	4.01 bc
VC_2P_2	2.88 abc	4.28 ab
VC_2P_3	3.02 a	4.47 a
VC_3P_1	2.69 cde	3.89 c
VC_3P_2	2.87 abc	4.26 ab
VC_3P_3	2.93 ab	4.36 ab
SE (±)	0.035	0.057
Significance level	0.000	0.000

(Means in the column followed by a different letter(s) differed significantly by DMRT at 5% level of significance)

Here, VC_0: control, VC_1: 6 ton/ha, VC_2: 9 ton/ha, VC_3: 12 ton/ha; P_1: Flat method, P_2: Furrow method, $P_{3:}$ Ridge method.

4.5 Neck diameter

Significant variation was observed in neck diameter among the vermicompost treatments (Table 5 and Appendix XI). At harvesting, the maximum neck diameter (1.17 cm) was obtained from VC_2 treatment, whereas the minimum neck diameter (0.91 cm) was recorded from control VC_0 treatment. These results indicate that vermicompost supplied plant nutrients and provide better growing conditions, which helped for getting proper vegetative growth as well as maximum neck diameter of onion.

Planting method had a significant effect on neck diameter of onion (Table 5 and Appendix XI). At harvesting, the maximum neck diameter (1.16 cm) was obtained from P_3 treatment which was statistically similar to P_2, whereas the minimum neck diameter (0.96 cm) was recorded from P_1 treatment.

The neck diameter was significantly influenced by the combinations of vermicompost and planting method (Table 6 and Appendix XI). The maximum neck diameter (1.39 cm) was obtained from VC_2P_3 treatment combination, whereas the minimum neck diameter (0.85 cm) was recorded from VC_0P_1 treatment combination compared to other combination

4.6 Root length

Vermicompost effects on root length significantly under the present study. It was evident that different levels of vermicompost showed different root length (Table 5 and Appendix XII). The highest root length (6.99 cm) was indicated with the treatment of VC_2 which was statistically similar to VC_3. On the other hand, the lowest root length (5.03 cm) was recorded from VC_0 treatment.

Effect of planting method on onion showed positively significant difference for the root length (Table 5 and Appendix XII). The highest root length (6.69 cm) was observed with the treatment of P_3. On the other hand, the lowest root length (5.6 cm) was recorded from P_1 treatment.

Table.5 Effect of vermicompost and planting method on neck diameter and root length of onion

Treatments	Neck diameter (cm)	Root length (cm)
Effect of Vermicompost		
VC_0	0.91 b	5.03 b
VC_1	0.98 b	5.66 b
VC_2	1.17 a	6.99 a
VC_3	1.12 a	6.76 a
SE (±)	0.02	0.18
Significance level	0.000	0.000
Effect of planting method		
P_1	0.96 b	5.6 b
P_2	1.03 b	6.04 ab
P_3	1.16 a	6.69 a
SE (±)	0.027	00.18
Significance level	0.008	0.047

(Means in the column followed by a different letter(s) differed significantly by DMRT at 5% level of significance). Here, VC_0: control, VC_1: 6 ton/ha, VC_2: 9 ton/ha, VC_3: 12 ton/ha; P_1: Flat method, P_2: Furrow method, P_3: Ridge method.

Table.6 Combined effect of vermicompost and planting method on neck diameter and root length of onion

Treatments	Neck diameter (cm)	Root length (cm)
VC_0P_1	0.85 f	4.88 e
VC_0P_2	0.92 ef	5.17 de
VC_0P_3	0.96 cdef	5.05 de
VC_1P_1	0.95 def	5.43 cde
VC_1P_2	0.98 cdef	5.49 cde
VC_1P_3	1.02 cdef	6.04 bcd
VC_2P_1	1.03 cde	5.96 bcde
VC_2P_2	1.10 bcd	7.04 ab
VC_2P_3	1.39 a	7.97 a
VC_3P_1	1.01 cdef	6.14 bcd
VC_3P_2	1.12 bc	6.44 bc
VC_3P_3	1.25 ab	7.70 a
SE (±)	0.03	0.18
Significance level	0.000	0.000

(Means in the column followed by a different letter(s) differed significantly by DMRT at 5% level of significance).

Here, VC_0: control, VC_1: 6 ton/ha, VC_2: 9 ton/ha, VC_3: 12 ton/ha; P_1: Flat method, P_2: Furrow method, P_3: Ridge method.

This might be due to the fact that ridge planting provided good soil conditions for proper root development, reduced lodging and ensured efficient use of irrigation water and nutrients for proper growth and development. These results agree with those reported by Rasheed *et al*., (2004), Liu & Young (2008), Amin *et al.,* (2006) and Abdullah *et al.,* (2007). They concluded that maximum grain yield was recorded in ridge planting.

The combined effect of different planting method and vermicompost showed significant effect for root length (Table 6 and Appendix XII). Data showed that the highest root length was found 7.97 cm in VC_2P_3 combination and the lowest root length was recorded 4.88 cm in VC_0P_1 combination compared to other combination

4.7. Fresh weight of bulb per plant

Fresh weight of bulb showed significant variation for different rates of vermicompost (Table 7 and Appendix XIII). Results explained that the maximum fresh bulb weight (36.47 g) was recorded from VC_2 treatment, whereas the minimum bulb weight (22.07 g) was recorded from control VC_0 treatment. Similar result was also observed by Hanumannaik et al., (2013) and they observed that vermicompost application resulted in highest bulb weight and bulb yield.

The findings showed the significant variation for different planting method on fresh weight of bulb per onion plant (Table 7 and Appendix XIII). Data showed that the maximum fresh bulb weight (34.7 g) was recorded from P_3 treatment, whereas the minimum bulb weight (26.92 g) was recorded from P_1 treatment.

There was a significant variation due to different planting method and vermicompost on fresh weight of bulb per onion plant (Table 8 and Appendix XIII). The findings showed that the highest fresh weight of bulb per plant (42.73 g) was found in VC_2P_3 followed by VC_3P_3. Conversely the lowest fresh weight of bulb per plant (19.07 g) was recorded from VC_0P_1 treatment.

4.8 Dry matter content of bulb

Results showed that the dry matter content of bulb varied significantly due to different rates of vermicompost (Table 7 and Appendix XIV). Results explained that the highest dry weight of bulb (16.86 %) was recorded from VC_2 =9 t ha^{-1} treatment followed by VC_3 = 12 t ha^{-1} treatment, where the lowest dry weight of bulb (14.09 %) was recorded from VC_0 treatment. Similar result was also observed by Hanumannaik *et al.*, (2013) and Yadav *et al.,* (2015).

Effect of planting method on onion showed positively significant difference for dry weight of bulb (Table 7 and Appendix XIV). The highest dry weight of bulb (16.05 %) was recorded from P_3 treatment while the lowest dry weight of bulb (15.05 %) was recorded from P_1 treatment.

The combined effect of different planting method and vermicompost showed significant effect for dry weight of bulb (Table 8 and Appendix XIV). Data showed that the highest dry weight of bulb (17.88 %) was recorded from VC_2P_3 combination and the lowest dry weight of bulb (13.75 %) was recorded from VC_0P_1 combination compared to other combination.

4.9 Yield per plot

The bulb weight of onion per plot was also found to be significantly influenced by different different rates of vermicompost (Table 7 and Appendix XV). The maximum yield per plot (656.40 g) was recorded from VC_2 treatment, which was closely followed by (634.4 g) VC_3 treatment. On the other hand, the minimum yield per plot (397.20 g) was observed in control VC_0 treatment.

The findings showed there was a significant variation due to different planting method on yield per plot of onion (Table 7 and Appendix XV). Data showed that the maximum yield

Table.7 Effect of vermicompost and planting method on fresh weight of bulb per plant, dry matter content of bulb and Yield per plot of onion

Treatments	Fresh weight of bulb per plant (g)	Dry matter content of bulb (%)	Yield per plot (g)
Effect of Vermicompost			
VC_0	22.07 c	14.09 c	397.20 c
VC_1	29.16 b	15.19 b	524.80 b
VC_2	36.47 a	16.86 ab	656.40 a
VC_3	34.73 a	16.09 a	625.20 a
SE (±)	1.28	0.27	23.05
Significance level	0.000	0.001	0.000
Effect of planting method			
P_1	26.92 b	15.05 a	484.50 b
P_2	30.20 ab	15.58 a	543.60 ab
P_3	34.70 a	16.05 a	624.60 a
SE (±)	1.28	0.27	23.05
Significance level	0.040	0.339	0.040

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly at 5% level of probability analyzed by DMRT.
Here, VC_0: control, VC_1: 6 t/ha, VC_2: 9 t/ha, VC_3: 12 t/ha; P_1: Flat method, P_2: Furrow method, P_3: Ridge method.

per plot (624.60 g) was recorded from P_3 treatment, whereas the minimum yield per plot (484.50 g) was recorded from P_1 treatment. Similar result was also observed by Gurjar *et al.*, (2017) and they observed that planting methods effects on bulb yield and quality of onion.

The combined effect of different planting method and vermicompost showed significant effect on yield per plot (Table 8 and Appendix XV). Data showed that the maximum yield per plot (769.2 g) was recorded from VC_2P_3 treatment combination, whereas the minimum yield per plot (343.2 g) was recorded from VC_0P_1 combination compared to other combination.

Table.8 Combined effect of vermicompost and planting method on fresh weight of bulb per plant, dry matter content of bulb, yield per plot and yield (t/ ha) of onion

Treatments	Fresh weight of bulb (g)	Dry matter content of bulb (%)	Yield per plot (g)	Yield (t/ ha)
VC_0P_1	19.07 f	13.75 c	343.20 f	3.18 f
VC_0P_2	22.33 df	14.13 c	402.00 df	3.72 df
VC_0P_3	24.80 cdf	14.39 bc	446.40 cdf	4.13 cdf
VC_1P_1	27.53 cd	14.94 bc	495.60 cd	4.59 cd
VC_1P_2	29.80 bcd	15.11 bc	536.40 bcd	4.97 bcd
VC_1P_3	30.13 bcd	15.53 abc	542.40 bcd	5.02 bcd
VC_2P_1	30.73 bc	15.75 abc	553.20 bc	5.12 bc
VC_2P_2	35.93 ab	16.97 ab	646.80 a	5.98 ab
VC_2P_3	42.73 a	17.88 a	769.20 a	7.12 a
VC_3P_1	30.33 bcd	15.77 abc	546.00 bcd	5.05 bcd
VC_3P_2	32.73 bc	16.12 abc	589.20 bc	5.45 bc
VC_3P_3	41.13 a	16.40 abc	740.40 a	6.85 a
SE (±)	1.28	0.27	23.05	0.21
Significance level	0.000	0.055	0.000	0.000

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by DMRT.
Here, VC_0: control, VC_1: 6 t/ha, VC_2: 9 t/ha, VC_3: 12 t/ha; P_1: Flat method, P_2: Furrow method, P_3: Ridge method.

4.10 Yield (t/ ha)

The bulb weight per hectare was found to be significantly influenced by vermicompost (Fig. 5 and Appendix XVI). Result explained that the maximum yield (6.07 t/ha) was recorded from VC_2 =9 t/ha treatment, which was closely followed by VC_3 =12 t/ha treatment. On the other hand, the minimum yield (3.67 t/ha) was observed in control VC_0 treatment. Similar result was also observed by Hanumannaik *et al.* (2013) and they observed that vermicompost application resulted in highest bulb weight and bulb yield. Supported result was also found by Yadav et al. (2015).

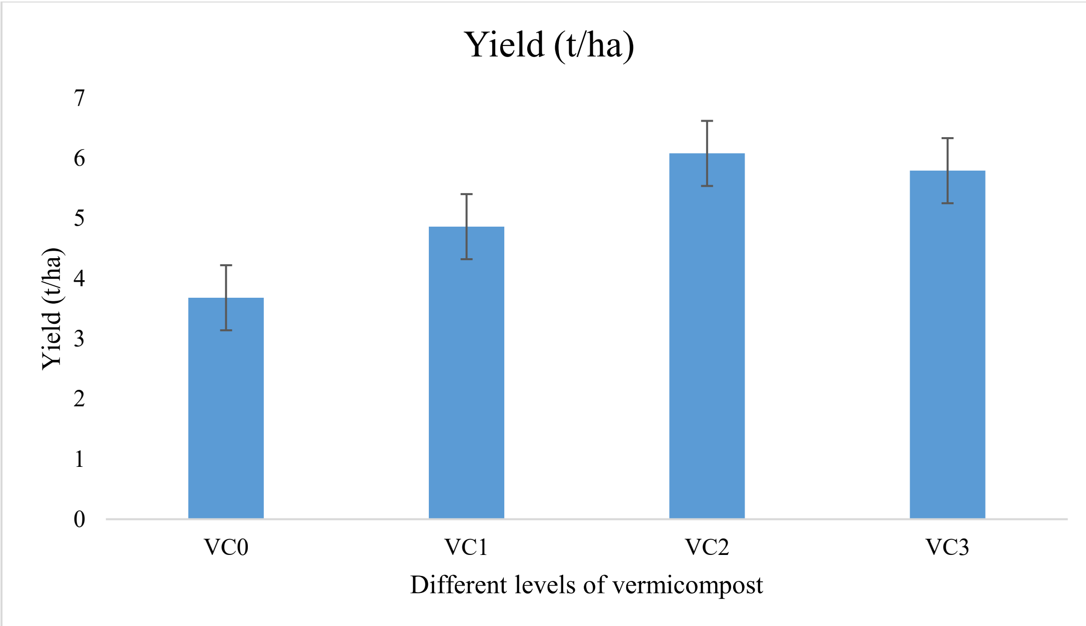

Fig. 5: Effect of vermicompost on yield (t/ha) of onion

VC_0: control, VC_1: 6 ton/ha, VC_2: 9 ton/ha, VC_3: 12 ton/ha;

The findings showed the significant variation for different planting method on yield (t/ha) of onion (Table 10 and Appendix XVI). Bulb yield per hectare differed significantly due to method of planting. Seedlings transplanted on ridges resulted in significantly highest bulb yield over those transplanted in furrow and flat soils. Data showed that the maximum yield (5.78 t/ha) was recorded from P_3 treatment, whereas the minimum yield (4.48 t/ha) was recorded from P_1 treatment. The similar results was also found in the work of Arian *et al*. (2002) also confirmed the findings of Choudhary *et al*. (2008) that bigger bulb yield in ridge planting might also be due to the more favorable soil conditions created by ridges.

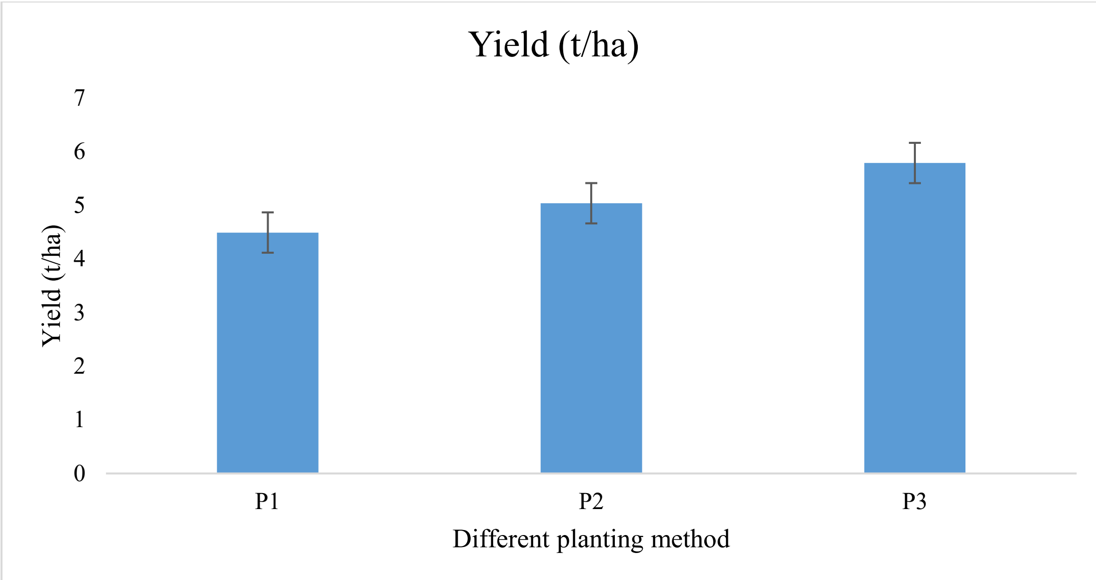

Fig. 6: Effect of planting method on yield (t/ha) of onion

P_1: Flat method, P_2: Furrow method, P_3: Ridge method.

The combined effect of different planting method and vermicompost showed significant effect on yield (t/ha) (Table 11 and Appendix XVI). Data showed that the maximum yield (7.12 t/ha) was recorded from VC_2P_3 treatment combination, whereas the minimum yield per plot (3.18 t/ha) was recorded from VC_0P_1 combination compared to other combination.

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted at Horticultural Farm in Sher-e-Bangla Agricultural University, Dhaka- 1207, Bangladesh, to study the growth and yield of onion influenced by vermicompost and different planting methods. The experiment was carried out during the winter season (October, 2017 to March, 2018). The experiment consisted of two factors, Factor A: Four levels of vermicompost, viz. VC_0 =control, VC_1 = 6 t/ha, VC_2 = 9 t/ha, VC_3 = 12 t/ha and Factor B: Three types of planting method, viz. P_1 = Flat method, P_2 = Furrow method and P_3 = Ridge method. There were 12 treatment combinations. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

Due to the use of vermicompost, the highest plant height (29.47 cm, 39.30 cm and 52.09 cm at 30, 45 and 60 DAT respectively) was recorded from VC_2 treatment and the lowest (24.28 cm, 30.96 cm and 43.67 cm at 30, 45 and 60 DAT respectively) was measured from VC_0. The maximum number of leaves plant^{-1} of onion (4.05, 5.24 and 6.93 at 30, 45 and 60 DAT respectively) was measured from VC_2 while the minimum number (2.75, 4.04 and 5.2 respectively) was recorded from VC_0 treatment. The highest bulb length was recorded in VC_2 (2.89 cm) while the lowest length was recorded in VC_0 (2.46 cm). The highest bulb diameter (4.25 cm) was recorded from VC_2 and the lowest (3.62 cm) was recorded from VC_0 = control. At harvesting, the maximum neck diameter (1.17 cm) was obtained from VC_2 and the minimum neck diameter (0.91 cm) was recorded from control VC_0 treatment. The highest root length (6.99 cm) was observed from treatment VC_2 and the lowest root length (5.03 cm) was recorded from VC_0. The maximum fresh bulb weight (36.47 g) was recorded from VC_2 treatment and the minimum bulb weight (22.07 g) was recorded from VC_0 treatment. The highest dry weight of bulb (16.86 %) was recorded from $VC_{2,}$ where the lowest dry weight of bulb (14.09 %) was recorded from VC_0 treatment. The maximum yield per plot (656.40 g) was recorded from VC_2 and the minimum yield per plot (397.20 g) was observed in control VC_0 treatment. The maximum yield (6.07 t/ha) was recorded from VC_2 treatment and the minimum yield (3.67 t/ha) was observed in VC_0 treatment.

Due to the effect of planting methods, the tallest plant (28.63 cm, 36.78 cm and 50.05 cm at 30, 45 and 60 DAT respectively) was measured from P_3 and the shortest (25.63 cm, 25.63 cm and 47.10 cm at 30, 45 and 60 DAT respectively) was recorded from P_1. The maximum number of leaves plant^{-1} of onion (3.80, 4.87 and 6.51 at 30, 45 and 60 DAT respectively) was measured from P_3 and the minimum number (3.25, 4.57 and 5.93 at 30, 45 and 60 DAT respectively) was recorded from P_1. The highest length of bulb (2.8 cm) was produced from P_3 and the lowest length (2.61 cm) was recorded from P_1 treatment. The highest bulb diameter (4.12 cm) was recorded from P_3 where the lowest bulb diameter (3.79 cm) was recorded from P_1. The maximum neck diameter (1.16 cm) was obtained from P_3 treatment and the minimum neck diameter (0.96 cm) was recorded from P_1 treatment. The highest root length (6.69 cm) was observed with the treatment of P_3 and the lowest (5.6 cm) was recorded from P_1 treatment. The maximum fresh bulb weight (34.7 g) was recorded from P_3 treatment and the minimum bulb weight (26.92 g) was recorded from P_1 treatment. The highest dry weight of bulb (16.05 %) was recorded from P_3 treatment while the lowest (15.05 %) was recorded from P_1 treatment. The maximum yield per plot (624.60 g) was recorded from P_3 treatment, whereas the minimum (484.50 g) was recorded from P_1 treatment. The maximum yield (5.78 t/ha) was recorded from P_3 treatment, whereas the minimum yield (4.48 t/ha) was recorded from P_1 treatment.

Due to interaction effect of vermicompost and planting method, the tallest plant (31.67 cm, 40.40 cm and 54.80 cm at 30, 45 and 60 DAT respectively) was measured from VC_2P_3 combination and the shortest (22.83 cm, 29.33 cm and 42.27 at 30, 45 and 60 DAT respectively) was recorded from VC_0P_1 combination. The maximum number of leaves plant^{-1} of onion (4.6, 5.53 and 7.6 at 30, 45 and 60 DAT respectively) was found from VC_2P_3 and the minimum number (2.53, 3.87 and 4.87 at 30, 45 and 60 DAT respectively) was recorded from VC_0P_1 combination. The longest bulb length (3.02 cm) was recorded from VC_2P_3 treatment and the shortest bulb length (2.37 cm) was observed in VC_0P_1. The highest bulb diameter was found 4.47 cm in VC_2P_3 combination and the lowest was recorded 3.45 cm in VC_0P_1 combination. The maximum neck diameter (1.39 cm) was obtained from VC_2P_3 treatment combination, whereas the minimum (0.85 cm) was recorded from VC_0P_1 combination. The highest root length was found 7.97 cm in VC_2P_3 combination and the lowest root length was recorded 4.88 cm in VC_0P_1 combination. The highest fresh weight of bulb per plant (42.73 g) was found in VC_2P_3, Conversely, the lowest weight (19.07 g) was recorded from VC_0P_1 treatment. The highest dry weight of bulb (17.88 %) was recorded from VC_2P_3 combination and the lowest dry weight of bulb (13.75 %) was recorded from VC_0P_1 combination. The maximum yield per plot (769.2 g) was recorded from VC_2P_3 treatment combination, whereas the minimum yield (343.2 g) was recorded from VC_0P_1. The maximum yield (7.12 t/ha) was recorded from VC_2P_3 treatment combination and the minimum yield (3.18 t/ha) was recorded from VC_0P_1 combination.

The present research work was carried out at Horticultural Farm of Sher-e-Bangla Agricultural University and one season only. Considering the present study following recommendation may be suggested:

I. The application of vermicompost showed the best vegetative growth and yield of onion, which may also improve the soil health and save the use of costly chemical fertilizers.
II. Ridge method gave the best results for both growth and yield of onion.
III. It is concluded that the combination of vermicompost and ridge planting methods is suitable for onion cultivation.
IV. Further investigation is needed in different Agro-Ecological Zones (AEZ) of Bangladesh to justify the result for economic returns.
V. After consecutive trial, best result could be proposed for commercial cultivation in all over the country.

The results indicate that 9 t/ha vermicompost with ridge planting method may be used for better production of onion.

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APPENDIX

Appendix I. Physical characteristics and chemical composition of soil of the experimental plot

Soil characteristics	Analytical results
Agrological Zone	Madhupur Tract
pH	6.00-6.63
Organic mater	0.84
Total N (%)	0.46
Available phosphorus	21 ppm
Exchangeable K	0.41 meq / 100g soil

Source: Soil resource and development institute (SRDI), Dhaka

Appendix II. Monthly recorded the average air temperature, rainfall, relative humidity and sunshine of the experimental site during the period from October 2017 to March 2018.

Month	Air temperature		Relative humidity (%)	Total rainfall (mm)	Sunshine (hr)
October, 2017	31.6	23.8	78	172.3	5.2
November, 2017	29.6	19.2	77	34.4	5.7
December, 2017	26.4	14.1	69	12.8	5.5
January, 2018	25.4	12.7	68	7.7	5.6
February, 2018	28.1	15.5	68	28.9	5.5
March, 2018	32.5	20.4	64	65.8	5.2

Source: Bangladesh Meteorological Department (Climate & Weather Division) Agargoan, Dhaka – 1212.

Appendix III. Analysis of variance of plant height at 30 DAT

Source of variation	DF	SS	MS	F value	Significance level
Factor A (Vermicompost)	3	148.036	49.345	12.772	0.000
Factor B (Planting method)	2	54.452	27.226	4.136	0.025
Interaction A × B	11	215.994	19.636	8.465	0.000

Appendix IV. Analysis of variance of plant height at 45DAT

Source of variation	DF	SS	MS	F value	Significance level
Factor A (Vermicompost)	3	348.881	116.294	16.469	0.000
Factor B (Planting method)	2	34.162	17.081	1.043	0.364
Interaction A × B	11	435.768	39.615	6.836	0.000

Appendix V. Analysis of variance of plant height at 60 DAT

Source of variation	DF	SS	MS	F value	Significance level
Factor A (Vermicompost)	3	334.296	111.432	16.011	0.000
Factor B (Planting method)	2	53.195	26.598	1.742	0.191
Interaction A × B	11	414.828	37.712	6.366	0.000

Appendix VI. Analysis of variance of number of leaves at 30 DAT

Source of variation	DF	SS	MS	F value	Significance level
Factor A (Vermicompost)	3	10.077	3.359	29.403	0.000
Factor B (Planting method)	2	1.761	0.880	2.426	0.104
Interaction A × B	11	12.506	1.137	22.243	0.000

Appendix VII. Analysis of variance of number of leaves at 45 DAT

Source of variation	DF	SS	MS	F value	Significance level
Factor A (Vermicompost)	3	8.537	2.846	46.144	0.000
Factor B (Planting method)	2	0.540	0.270	0.894	0.419
Interaction A × B	11	9.390	0.854	18.292	0.000

Appendix VIII. Analysis of variance of number of leaves at 60 DAT

Source of variation	DF	SS	MS	F value	Significance level
Factor A (Vermicompost)	3	16.271	5.424	20.171	0.000
Factor B (Planting method)	2	2.056	1.028	1.486	0.241
Interaction A × B	11	19.622	1.784	8.150	0.000

Appendix IX. Analysis of variance of Bulb Length

Source of variation	DF	SS	MS	F value	Significance level
Factor A (Vermicompost)	3	0.994	0.331	18.407	0.000
Factor B (Planting method)	2	0.237	0.119	2.935	0.067
Interaction A × B	11	1.256	0.114	8.723	0.000

Appendix X. Analysis of variance of Bulb diameter

Source of variation	DF	SS	MS	F value	Significance level
Factor A (Vermicompost)	3	2.336	0.779	14.296	0.000
Factor B (Planting method)	2	0.678	0.339	3.290	0.050
Interaction A × B	11	3.177	0.289	7.683	0.000

Appendix XI. Analysis of variance of Neck diameter

Source of variation	DF	SS	MS	F value	Significance level
Factor A (Vermicompost)	3	0.400	0.133	8.039	0.000
Factor B (Planting method)	2	0.237	0.119	5.645	0.008
Interaction A × B	11	0.738	0.067	8.401	0.000

Appendix XII. Analysis of variance of Root length

Source of variation	DF	SS	MS	F value	Significance level
Factor A (Vermicompost)	3	23.038	7.679	12.718	0.000
Factor B (Planting method)	2	7.188	3.594	3.372	0.047
Interaction A × B	11	34.030	3.094	8.912	0.000

Appendix XIII. Analysis of variance of fresh weight of bulb

Source of variation	DF	SS	MS	F value	Significance level
Factor A (Vermicompost)	3	1137.657	379.219	13.058	0.000
Factor B (Planting method)	2	366.442	183.221	3.555	0.040
Interaction A × B	11	1609.532	146.321	7.676	0.000

Appendix XIV. Analysis of variance of dry weight of bulb

Source of variation	DF	SS	MS	F value	Significance level
Factor A (Vermicompost)	3	38.513	12.838	7.318	0.001
Factor B (Planting method)	2	6.008	3.004	1.118	0.339
Interaction A × B	11	47.171	4.288	2.168	0.055

Appendix XV. Analysis of variance of yield per plot

Source of variation	DF	SS	MS	F value	Significance level
Factor A (Vermicompost)	3	368600.760	122866.920	13.058	0.000
Factor B (Planting method)	2	118727.280	59363.640	3.555	0.040
Interaction A × B	11	521488.440	47408.040	7.676	0.000

Appendix XVI. Analysis of variance of yield (t/ha)

Source of variation	DF	SS	MS	F value	Significance level
Factor A (Vermicompost)	3	31.564	10.521	13.081	0.000
Factor B (Planting method)	2	10.158	5.079	3.555	0.040
Interaction A × B	11	44.646	4.059	7.696	0.000

Plate 1: Raising of seedling of onion on seedbed

Plate 2: Pictorial representation of the experimental field

a

c

b

d

Plate 3: a) Gap filling, b) drying of bulbs, c) intercultural operation and

d) harvested onion

a

b

c

Plate 4: a) Flat method, b) furrow method and c) ridge method