EFFECT OF VERMICOMPOST ON GROWTH AND YIELD OF WHEAT UNDER DIFFERENT MOISTURE REGIMES

SANJIDA BINTE SAMAD

REG. NO. : 11- 04500

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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BY

SANJIDA BINTE SAMAD

Reg. No. : 11- 04500

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APPROVED BY:

Prof. Dr. Md. Shahidul Islam	**Prof. Dr. H. M. M. Tariq Hossain**
Supervisor	**Co-Supervisor**

Prof. Dr. Md. Shahidul Islam
Chairman
Examination Committee

CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF VERMICOMPOST ON GROWTH AND YIELD OF WHEAT UNDER DIFFERENT MOISTURE REGIMES**" submitted to the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of Master of Science (MS) in AGRONOMY, embodies the result of a piece of bonafide research work carried out by SANJIDA BINTE SAMAD, Registration No.11- 04500 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: ……………….

Dhaka, Bangladesh

Prof. Dr. Md. Shahidul Islam

Supervisor

Dedicated To

My Beloved Parents

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The Author

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ABSTRACT

A field experiment was carried out at the Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh, during the period from November 2016 to March 2017 to study the effect of vermicompost on growth and yield of wheat under different moisture regimes with the variety, BARI gom 26. The experiment comprised of four levels of irrigation *viz*., I_0 = No irrigation (control), I_1 = Irrigation at18 days after sowing (DAS), I_2 = Irrigation at 18 and 47 days after sowing (DAS) and I_3 = Irrigation at 18, 47 and 76 days after sowing (DAS) and three levels of vermicompost *viz*., V_0 = No vermicompost (control), V_1 = Vermicompost @ 5 t ha^{-1} and V_2 = Vermicompost @ 10 t ha^{-1}. The experiment was laid out in Split Plot Design with three replications. It was found that I_3 and V_2 individually gave the best performance in respect of growth, yield and yield attributes. The treatment combination of I_3V_2 gave the highest plant height (95.47 cm), number of tillers $plant^{-1}$ (4.90), dry weight $plant^{-1}$ (38.70 g), spike length (18.09 cm), number of spikelets $spike^{-1}$ (63.30), number of filled grains $spike^{-1}$ (41.58), grain yield (4.26 t ha^{-1}), straw yield (5.78 t ha^{-1}), biological yield (10.04 t ha^{-1}) and harvest index (42.43%) at harvest. But the highest 1000 seed weight (48.53 g) and lowest number of unfilled grains $spike^{-1}$ (5.13) were found from the treatment combination of I_2V_2.

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ABBREVIATIONS AND ACRONYMS

%	=	Percentage
AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
Ca	=	Calcium
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan’s Multiple Range Test
e.g.	=	exempli gratia (L), for example
et al.,	=	And others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
G	=	Gram (s)
GM	=	Geometric mean
i.e.	=	id est (L), that is
K	=	Potassium
kg	=	Kilogram (s)
L	=	Litre
LSD	=	Least Significant Difference
M.S.	=	Master of Science
m^2	=	Meter squares
mg	=	Miligram
ml	=	MiliLitre
NaOH	=	Sodium hydroxide
No.	=	Number
^oC	=	Degree Celcious
P	=	Phosphorus
SAU	=	Sher-e-Bangla Agricultural University
USA	=	United States of America
var.	=	Variety
WHO	=	World Health Organization
µg	=	Microgram
q	=	Quintal

CHAPTER I

INTRODUCTION

Wheat (*Triticum aestivum*) is one of the leading cereals in the world. It belongs to the family Poaceae and it is the world's most widely cultivated cereal crop which ranks first followed by rice. It is preferable to rice for its higher seed protein content. It ranks first both in acreage and production among the grain crops of the world (FAO, 2008). About one third of the world population lives on wheat grains for their subsistence (FAO, 2007). Wheat grain is rich in food value containing 12% protein, 1.72% fat, 69.60% carbohydrate and 27.20% minerals (BARI, 2006).

In Bangladesh the position of wheat is second in respect of total area of land (0.80 million hectares) and production (2.80 million ton) after rice and the average yield of wheat is only 3.4 t ha^{-1} (BBS, 2015) and it can be increased up to 6.8 t ha^{-1} (RARS, 2002). So, there is an ample opportunity to increase production of wheat per unit area through adoption of modern and improved agronomic practices such as optimum seed rate, timely sowing and judicious application of irrigation, fertilizer and other inputs.

Bangladesh is an overpopulated country. Increasing agricultural production per unit area of land is becoming most important step to cope with the present population growth in Bangladesh. Wheat can be a good supplement of rice and it can play a vital role to feed this vast population.

Among the factors responsible for low grain yield of wheat, lack of irrigation water and plant nutrient, weed competition, insect attack, disease infection etc. are the most important. About 30% of wheat production is lost due to lack of irrigation water and 40% yield loss due to lack of nutrient supply in the country (Karim, and Siddique, 2007). However, optimum irrigation water and nutrient supply can increase yield up to 70% in our country (Ahmed, 2006).

Time of irrigation and its management are very important for successful cultivation of wheat. Supplement irrigation given to wheat, improves the development of grain as well as yield (Singh and Singh, 2005). Irrigation frequency has a significant influence on the growth and yield of wheat.

Wheat is one of the most cultivated cool-season crop originated from the Middle East. It has somewhat longer growing period and minimum heat requirement than the other small grain crops. The irrigation requirements of wheat crop vary with the types of soil and season in which it is grown. The time and amount of irrigation water play an important role in the production of wheat crop in the arid and semiarid.

Determining a suitable irrigation frequency is an important step to optimize winter wheat yield and water use efficiency. Irrigation frequency can affect plant growth in various ways. Decreased irrigation frequency is an important technique used to improve water use efficiency (Shin *et al*., 2012; García-Tejero*et al*., 2011). In winter wheat, increased irrigation frequency results in low evapotranspiration (Li*et al.*, 2013). Han *et al*. (2010) revealed that by irrigating twice in the winter wheat growing season, grain yield could be increased; however, irrigation timing at the end of the growing season could decrease grain yield. Similarly, Li *et al*. (2010) revealed that frequent irrigation late in the winter wheat growing season decreased water use efficiency, and this was mainly due to changes in the vertical distribution of root density. It was also suggested by Li *et al*. (2015) that for winter wheat, a one-time irrigation of 120 mm could produce a reasonable grain yield, and irrigation (60 mm) at both the jointing and heading stages significantly improved grain yield and water use efficiency.

Yield and protein content depend on the weather conditions during the various developmental stages of winter wheat (Johansson *et al*., 2003). Limited water availability and unfavourable moisture distribution during the main wheat growing period can lead to a high variability in yield and in protein content affecting the bread-making quality (Bonfil*et al*., 2004).

Compost produced by traditional processes is generally low in plant nutrient content and the process itself is also slow and time consuming. On the other hand, certain special type of earthworm (*Eisenia foitida*) has the capacity to convert the biodegradable organic waste into higher quality compost at comparatively faster rate (Bhattarai, 2003) than that of the traditional method. Such a compost usually known as “vermicompost” is rich in plant nutrients and contains higher number of microorganisms, which are responsible for decomposition process (Yami *et al*., 2003).

Vermicompost has been recognized as a low cost and environmentally sound process for treatment of many organic wastes. Bevacqua and Mellano (2013) reported that vermicompost treated soils had lower pH and increased levels of organic matter, primary nutrients, and soluble salts. Edwards and Burrows (2010) reported that vermicompost, especially those from animal waste sources, usually contained more mineral elements than commercial plant growth media.

Considering the environmental pollution related to excess use of chemical fertilizer, needs of an alternative approach based on biological origin, safe for use and less expensive generated for the management of nitrogen. Replacement of nitrogen fertilizer in the soil through application of vermicomost can caused reduction in the environmental pollution developed by washing nitrate from the soil. According to Amo-Aghaee *et al*. (2003), this type of organic fertilizers are not only safe for environment but if it applied in higher does, unused nitrogen remained in soil in the form of organic nitrogen and it will eventually return to the plant at the times of its need by process of mineralization. In terms of intangible returns vermicompost not only supplies essential elements to plant but also improves physiochemical and biological properties of soil, thus having promise to marginal and resource poor farmers and this may be a good asset for sustainable agriculture.

Time of irrigation along with application of vermicompost would play a vital role for increasing maximum yield of wheat per unit area. The present study was therefore undertaken with the following objectives:

i. To find out the appropriate irrigation level on wheat in presence of vermicompost.
ii. To find out the optimum doses of vermicompost for the highest growth and yield of wheat.
iii. To identify the best interaction between irrigation levels and vermicompost at which it gives the maximum yield.

CHAPTER II

REVIEW OF LITERATURE

Time of irrigation or irrigation frequencies at different growth stages is a crucial factor for successful wheat production. Vermicompost is also an important organic nutrient source which helps not only on successful crop production but also increase crop productivity and soil fertility. An attempt has been made in this chapter to present a brief review of research in relation to growth and yield of wheat as influenced by time of irrigation and vermicompost. Some of the pertinent findings of the research with time of irrigation and vermicompost on the growth and yield of wheat are reviewed in this chapter.

2.1 Effect of irrigation

Many research activities have been conducted on the effect of time of irrigation on the growth, yield and yield contributing characters of wheat. Some of the findings of that research were cited below:

Jessica and Robert (2017) conducted an experiment with eight cultivars (subplots) randomly assigned to six water regimes (main plots). Aside from a rainfed check, irrigation treatments were: (i) replenishment of seasonal crop evapotranspiratory water loss via 32 mm per irrigation event (100ET); (ii) only 21 mm replenishment (66ET) per event to simulate season-long deficit; and three treatments in which 100ET replacement was terminated prior to grain fill completion by scheduling final irrigation at respective stages of: (iii) med-milk (100ET.MM), (iv) early milk (100ET.EM), (v) and anthesis (100ET.FL). The latter three treatments simulated end-of-season deficit irrigation. Irrigation treatment yields were similar, except for the lower 100ET.FL yield, indicating that wheat yield response to irrigation will be optimal in this environment as long as at least one irrigation event is supplied during grain fill. The cultivar yield responses to irrigation were similar. Irrigation increased biomass but had no impact on harvest index. Grain test weight (TWT) improved with irrigation. Falling number varied by cultivar and generally decreased with irrigation, but only significantly in 100ET, 66ET, and 100ET.MM. Irrigation improved yield and TWT, particularly during the hot and dry year. Irrigation can be terminated before completion of grain fill with no impact on yield and quality. Identification of adaptive cultivars with reduced irrigation or changing weather is necessary for improved productivity and grain quality.

Bian *et al*. (2016) conducted a study aimed to evaluate the impact of planting pattern and irrigation frequency on grain yield and WUE of winter wheat. The effects of planting patterns and irrigation frequencies were determined on tiller number, grain yield, and WUE. The two planting patterns tested were wide-precision and conventional-cultivation. Each planting pattern had three irrigation regimes. In the study, tiller number was significantly higher in the wide-precision planting pattern than in the conventional-cultivation planting pattern. Additionally, the highest grain yields and WUE were observed when irrigation was applied at the jointing stage (120 mm) or at the jointing and heading stages (60 mm each) in the wide-precision planting pattern. These results could be attributed to higher tiller numbers as well as reduced water consumption due to reduced irrigation frequency. Applying of 60 mm of water at jointing and heading stages resulted in the highest grain yield among the treatments.

Amin *et al*. (2015) conducted a research study to examine the crop responses of maize under two irrigation systems, i.e. raised bed and high-efficiency irrigation system (HEIS; drip irrigation) systems, with three irrigation frequencies and three levels of irrigation water quality. The raised bed irrigation system demonstrated better performance in terms of crop parameters: plant height, biological yield and grain yield for the raised bed system were recorded as 1, 5 and 21%, respectively, higher than the drip irrigation system. Better results were obtained for plots irrigated every 2 or 6 days than for those irrigated every 4 days. Good-quality water raised plant biological yield by 12% and grain yield by 14.85%. The irrigation frequency had a clear-cut effect on total dry matter weight and grain yield was dependent on the quality of the irrigated water. The raised bed with furrow irrigation system produced the highest harvest index for all of the levels of water quality and the highest water use efficiencies were observed for good-quality water.

Shirazi *et al*. (2014) carried out a field experiment to evaluate the effect of irrigation regimes and nitrogen levels on the growth and yield of wheat cv. Kanchan (*Triticum aestivum* L.). The experiment includes two four irrigation regimes and four nitrogen levels. Yield and yield contributing factors were significantly affected by irrigation regimes. Maximum grain yield of 2.27 t ha^{-1} by the application of 200 mm irrigation treatment.

Erekul *et al*. (2012) conducted a study was conducted to determine the suitable irrigation dose (0, 40, 80 and 120 mm) to compensate yield and bread-making quality of four common wheat varieties under the Mediterranean ecological conditions for two years. Grain yields of Pamukova, Sagittario, Fiorino and Golia ranged between 2864 kg ha^{-1} (Golia, 0 mm) and 6021 kg ha-1 (Sagittario, 80 mm). The supplemental irrigation caused the grain yield to increase significantly up to 58%. The highest grain yields could be ensured with a supplemental irrigation of 80 mm. The protein content, sedimentation value and gluten index among the bread making quality parameters have been found to be at the highest levels for all varieties in both trial years when no supplemental irrigation has been applied. Increases of gluten index were observed with supplemental irrigations. Optimum levels of quality characteristics were obtained with 80 mm supplemental irrigation which is also suited to the level of the highest grain yield.

Al-Tahar *et al*. (2011) conducted two consecutive winter seasons (2008/09-2009/10) experiment to study the effect of skipping one irrigation during different developmental stages on growth, yield, yield components and water use efficiency of wheat (*Triticum aestivum* L.). Condor cultivar was grown under six irrigation treatments at developmental growth stage, in which one-irrigation was skipped at some of growth stages (seedling W_1, tillering W_2, booting W_3, dough W_4 and repining stage W_5) and irrigation without skipping with intervals of 10 days as control WS. The results showed there were highly significant differences in all tested parameters due to skipping irrigation except plant/m^2 in both seasons, and plant height and dry matter accumulation in 45 days reading (booting stage) in the second seasons. Irrigation every 10 days throughout (control) gave higher values (few different with seedling and repining stages) than the other sensitive stages. Although, the resulted showed highly significant effect on the studied parameters biomass, straw and grain yield, harvest index, water use efficiency and protein content. In general irrigation every 10 days with slightly different at skipping on seedling and repining stages gave the highest protein content, grain and straw yield and field water use efficiency. Skipping irrigation during tillering and booting stage must be avoided.

Kong *et al.*, (2002) carried out an experiment in India to study the effect of irrigation on the yield of wheat and water use efficiency under limited irrigation. The irrigation treatments designed were: no irrigation (control); 30 mm of irrigation norm at elongation and booting stage; 45 mm at elongation and booting stage; 30 mm at filling stage; 45 mm at filling stage; 30 mm at elongation and 30 mm at filling stage; and 45 mm at elongation and booting stages and 45 mm at the filling stage. Irrigation increased the average yield of wheat by 13.0-39.6% and the water use efficiency by 7.0-18.0%. The physiological properties and yield compositions of winter wheat could be also improved. In a year with enough precipitation, the volume of supplementary irrigation satisfying the maximum water use efficiency of the crop was 45 mm, and the highest volume of water needed for irrigation ranged from 30 to 45 mm. The number of ears of winter wheat could be increased by irrigation during the elongation and booting stages and the water use efficiency could also be improved. Irrigation at filling stage improved the 1000-grain weight and water use efficiency of wheat. It is concluded that the best time for limited irrigation is the elongation and booting stages.

Khan *et al*. (2007) conducted an experiment to study the effect of different irrigation schedules on water use and yield of wheat. Experiments were conducted with one wheat variety, four irrigation intervals i.e. three weeks (W_3), four weeks (W_4), five weeks (W_5) and six weeks (W_6) and two pan levels i.e. equal to pan evaporation (P_1) and half of the pan evaporation (P_2) using randomized complete block design. The average seasonal evapotranspiration of wheat were 518, 439, 496 and 478 mm and crop coefficients were 1.02, 0.87, 0.96 and 0.94, for W_3, W_4, W_5 and W_6, respectively. Results of yield and its components indicated that there was significant effect of irrigation intervals on grain yield, number of grain per spike, grain weight per spike, number of tillers per plant and visual lodging percentage. Maximum yield was obtained when plots were irrigated after five weeks interval. Same was the case with number of grains per spike and grain weight per spike. But in case of number of tillers and lodging percentage, the result showed that more moisture favours greater number of tillers and lodging percentage. The highest water use efficiency (8.01 kg $ha^{-1}mm^{-1}$) was obtained when crop was irrigated after five weeks interval. It is concluded that for maximum yield of wheat the crop may be irrigated after five weeks interval.

Ali and Amin (2007) conducted a study during rabi season to determine the effect of irrigation frequencies on the yield and yield attributes of the wheat cultivar Shatabdi. Irrigation treatments were given as: no irrigation, control (T_0); one irrigation at 21 DAS (T_1); two irrigations at 21 and 45 DAS (T_2); three irrigations at 21, 45 and 60 DAS (T_3); and four irrigation at 21, 45, 60 and 75 DAS (T_4). Significant effects were observed on plant height, number of effective tillers per hill, spike length, number of spikelets per spike, filled grains per spike due to different levels of irrigation. Two irrigations at 21 and 45 DAS significantly enhanced the growth, yield attributes and yield of wheat over the other treatments.

Results also showed that grain yield, straw yield and harvest index were significantly higher at T_2 compared to the other treatments of the study.

Ju-Hui (2006) studied the impacts of single irrigation at different stage on wheat yield components. Results indicate that single irrigation at different stage has different contribution to wheat yield components. Irrigation at floret differentiation stage can increase the number of ears greatly, irrigation at quadrant stage significantly enhanced grains number per ear. Irrigation at heading stage increased 1000 grain weight. 1000 Grain weight was the key factor determining yield under water saving cultivation, the next was the number of grains per unit area. Sink was enlarged and the total grain number of population was increased by irrigation at pistil-stamen differentiation stage. Irrigated after pistil-stamen differentiation stage, the effect of enlarging sink is reduced gradually and the contribution of strengthening source is increased. The irrigation at heading stage has the most grain number of population. Population was with small source and big sink while irrigation is at pistil- stamen differentiation stage and with big source and small sink while irrigation is at heading stage. The relationship of source and sink has relative good balance while irrigation at quadrant stage with highest level of grain yield.

Sun and Liu (2006) conducted an irrigation experiments during different growing stages of winter wheat *(Triticum aestivum* L.) at North China to identify suitable irrigation schedules for winter wheat. The aim was also to develop relationships between irrigation and yield, water-use efficiency (WUE), irrigation water-use efficiency (WUEi), net water-use efficiency (WUEet) and evapotranspiration (ET). A comparison of irrigation schedules for wheat suggested that for maximum yield, 300 mm is an optimal amount of irrigation, corresponding to an ET value of 426 mm. Results showed that with increasing ET, the irrigation requirements of winter wheat increase as do soil evaporation but excessive amounts of irrigation can decrease grain yield, WUE, and WUE. These results indicate that excessive irrigation might not produce greater yield or optimal economic benefit, thus, suitable irrigation schedules must be established.

Sher and Parvender (2006) carried out a field experiment during winter on sandy loam soils in Haryana, India, to evaluate the effects of irrigation regimes (IW/CPE 0.5, 0.7 and 0.9) on growth, yield and nutrient uptake of wheat under late-sown conditions. The irrigation level IW/CPE 0.9 (4 irrigations) being statistically at par with IW/CPE 0.7 (3 irrigations) produced significantly higher plant height, number of tillers/m^2, 1000-grain weight and straw yield than IW/CPE 0.5 (2 irrigations), which was at par with 3 irrigations. The irrigation regime IW/CPE 0.9 recorded significantly higher dry matter accumulation, grains per spike and grain yield than IW/CPE 0.7 and 0.5. The percentage increase in grain yield due to IW/CPE 0.9 over IW/CPE 0.7 and 0.5 was 14.1 and 21.3%, respectively. N, P and K uptake by both grain and straw also increased progressively with increasing number of irrigations.

Grain yield and water use efficiency (WUE) of wheat *(Triticum aestivum* L.) in arid environment can be improved by applying irrigation selectively to allow soil water deficits to develop at non-critical stages of crop development. Zhang *et al*, (2005) conducted a field experiment on a loam soil in China to determine the grain yield, yield components, and water use characteristics of spring wheat in response to regulated deficit irrigation (RDI) schemes. Wheat grown under the RDI schemes produced 29% higher grain yield than wheat grown under water deficit-free control 6.2 t ha^{-1}). Among six RDI schemes studied, wheat having a high water deficit at the jointing stage, but free from water deficit from booting to grain-filling produced highest grain yield (7.26 t ha^{-1}). Compared with the control, wheat plants grown under the RDI schemes received 59 mm (or 15%) less water via irrigation, but they either extracted 41 mm more (or 74%) water from the soil profile. Grain yield increased as ET increased from 415 to 460 mm, and declined beyond 460 mm. The WUE values varied from 0.0116 to 0.0168 t ha^{-1} mm^{-1}, and wheat grown under the RDI had 26% greater WUE compared with the control. Grain yield and WUE of spring wheat can be greatly improved by regulated deficit irrigation with reduced amounts of water. This practice is particularly valuable in arid regions where wheat production relies heavily on irrigation.

Onyibe (2008) conducted a field trial to study the effect of irrigation regime (60, 75 and 90% Available Soil Moisture (ASM) on the growth and yield of two recently introduced wheat cultivars (Siete cerros and Pavon 76)). The result revealed that increase of irrigation regime from 60 to 90% ASM did not significantly affect most of the growth, yield and yield parameters evaluated in the study. Each increase in irrigation regime however increased days to maturity, water use and thermal time but decreased water use efficiency. Pavon 76 produced superior grain yield than Siete ceros only in one season. Pavon 76 had a higher LAI, more tillers and spikes/m^2 and larger grain size, but had shorter plants, lower grain weight and grain number/spike and matured earlier than Siete cerros. Irrigation level of 60% ASM is recommended for both varieties in the Sudan savanna ecology. At this ASM the highest water use efficiency of 4.0-4.8 kg/mm/ha was obtained and grain yield was not significantly compromised. Grain yield was more strongly correlated with grain weight per spike than with grain number per spike.

Drought tolerance levels in some wheat lines and cultivars based on uniform regional wheat yield trial (URWYT-M-75) were investigated by Baghani and Ghodsi (2006) using a strip plot design based on complete block design with 3 replications in Iran. The main plots (horizontal factor) were composed of 3 levels of irrigation (10, 20 and 30 days interval), while the sub-plots (vertical factor) were of 20 lines or cultivars of spring bread wheat set up for URWYT (M-75-1-20). Sowing date and sowing and fertilizer rates were under normal condition. Soil water content was also determined. The results showed that when irrigation interval was 10 days, the line yields of M-75-8, M-75-6, M-75- 2 and M-75-16 were higher than other lines. When the irrigation interval was 20 days, the highest lines were observed for M-75-2, M-75-14, M-75-16 and M-75-12. In 30 days irrigation interval, the lines of M-75-15, M-75-4, M-75-2 and M-75-14 had maximum yields. As a summary, M-75-2 line was better than others showing good flexibility and water use efficiency, under normal and stress conditions.

The growth rate, yield and yield components of 4 wheat cultivars (Sabalan/1- 27-56-4, Anza/3/Pi/Nor//Hys/4/sefid, 4493-P.1533-Bez and Sabalan) under rainfed conditions and 2 irrigation regimes (irrigation at planting time and ear emergence, and irrigation at planting time, ear emergence and grain filling) were studied in Maragheh, Iran. Abdorrahmani *et al.* (2005) reported that crop growth rate, relative growth rate, dry matter accumulation per unit area, number of ears per unit area, number of grains per ear, 1000-grain weight, biological yield, grain yield, harvest index, plant height and productivity were evaluated. Drought stress reduced dry matter production, crop growth rate and relative growth rate. Green cover percentage, crop growth rate, and relative growth rate did not significantly vary among the cultivars. All traits except the number of grains per ear and harvest index were affected by water deficit. No significant variation was observed between irrigation regimes. The green cover percentage, plant height, crop growth rate, biological yield and productivity were significantly correlated with grain yield. The mean green cover had the greatest positive correlation with grain yield. This trait can be recommended as a suitable index for the evaluation of the field performance of various crops.

Mushtaq and Muhammad (2005) conducted a field studies in Pakistan to determine the effect of different irrigation frequencies on the growth and yield of wheat cv. Uqaab-2000 on a clay loam soil. Results revealed that wheat receiving 5 irrigations at crown root + tiller + boot + milk + grain development stages produced significantly taller plants and maximum number of fertile tillers per unit area. It was, however, not significantly superior to 4 irrigations applied at crown root + boot + milk + grain development stages for number of grains per spike, 1000-grain weight and grain yield. Plant height, 1000-grain weight and wheat grain yield were significantly higher under 4 irrigations applied at crown root + boot + grain development and crown root + boot stages of plant growth, respectively. A grain yield reduction of 6.63 and 12.20% and increase of only 1.45% was obtained by applying 3, 2 and 5 irrigations, respectively, compared to 4 irrigations.

Ghodpage and Gawande (2008) conducted a field experiment in Maharashtra, India, during rabi season to investigate the effect of scheduling irrigation (2, 3, 4, 5 and 6 irrigations) at various physiological growth stages of late-sown wheat. The maximum grain yield of 2488 kg/ha was obtained in 6 irrigations treatment and it was significantly superior over all other treatments. In general, there was consistent reduction in grain yield due to missing irrigation. A yield reduction of 9.88% was recorded when no irrigation at dough stage was scheduled. Further, missing irrigation at tillering and milking stages resulted in 21.94% yield reduction. It was still worse when no irrigation was scheduled at tillering, milking and dough stages, recording 29.30% yield reduction. Approximately 50% loss in grain was observed when irrigation was missed at tillering, flowering, milking and dough stages. The ratio between consumptive use of water (Cu)/irrigation number was higher in 2-irrigation treatment compared to 6-irrigation treatment although the total value of Cu was higher for 6-irrigation treatment.

Chaudhary and Dahatonde (2007) carried out an experiment in Maharashtra, India to study the effects of irrigation frequency (irrigation at CRI [crown root initiation], jointing, flowering and milk stages or I4; I4 + irrigation at the tillering stage or I5; and I5 + irrigation at the dough stage) and quantity (irrigation at 100, 75 or 50% of the net irrigation requirement), and kaolin (0 or 6% kaolin sprayed at 50 days after sowing) on the performance of wheat. Grain yield did not significantly vary with irrigation frequency. Irrigation at 100% of the net irrigation requirement resulted in the highest grain yield (27.32 quintal/ha). Water consumption increased with the increase in irrigation frequency and quantity. Water use efficiency was highest under I5 (87.74 kg ha-1 cm-1) and irrigation at 100% of the net irrigation requirement (85.29 kg ha-1 cm-1). Kaolin significantly reduced grain and straw yields, water consumption, and water use efficiency. [1 quintal=100 kg].

Alsohaibani (2007) conducted a field experiment in Saudi Arabia to evaluate the effects of irrigation level (65, 100 and 170 mm accumulated vapour) on the growth and yield of different bread wheat lines (L.9, L.11 and L.18) and the local cultivar (Yecorarogo). Irrigation level had highly significant effect only on spike length, but had significant effect on biological and grain yields and their components. Grain yield reduction was 16.4% and biological yield reduction was 13-20% at 100 mm accumulated vapour. No significant differences in these parameters were observed between 65 and 100 mm accumulated vapour rates.

An Experiment was carried out by Jana and Mitra (2004) on wheat cv. Sonalika giving irrigation at crown root initiation, tillering, flowering and dough stages. They found that irrigation increased plant height, number of effective tillers, ear plant^{-1} and grain and straw yields.

Irrigation plays a positive role in increasing the number of tillers, ear plant^{-1} and grain of wheat. Ear length and number of grains reduced significantly if irrigation is stopped at tillering and booting stages of wheat (Hefni *et al.*, 2000) Singh and Singh (2001) reported that growth of wheat was poor when crop was grown under rainfed condition. Under this condition tiller number, panicle length, grain number and 1000-grain weight were lower.

Ashok and Sharma (2004) conducted field trials in the winter seasons of 199091 at Karnal, Haryana, India, where wheat cv. HD-2285 was irrigated at IW: CPE ratios or 0.6,0.9 or 1.2. It was observed that the irrigation treatments increased dry matter accumulation.

Mandal *et al.* (2002) conducted a field experiment in India during 1984-86 and 1986-87 on wheat with 2 levels of irrigation: one at crown root initiation (CRI) and at CRI + booting stages and reported that LAI increased significantly with increasing levels of irrigation.

Nahar and Paul (1998) reported that LAI was higher in irrigated plants than in the rainfed plants at all the vegetative phases in wheat (cv.Kanchan). They also found that LAI reached a certain Peak and then declined.

Pal *et al*. (2002) conducted a field experiment during winter season on sandy loam of Ranchi. The treatment consisted of three irrigation schedule (2 irrigation at CRI and maximum tillering, booting and milk stages). They observed that application of 4 irrigations gave higher crop growth rate (CGR) than 2 or 3 irrigations.

Relative Growth Rate (RGR) is the rate of dry matter increase per unit total dry matter (TDM) per unit time (Milthorpe and Moorbby, 1997).

Grain and straw yields and yield contributing characters gradually increased with increasing number of irrigation (Islam, 2003). The highest grain and straw yields, the maximum plant height , the highest number of effective tillers, and the maximum number of grains spike^{-1} were obtained by three irrigations (I_4) applied at 25, 50 and 70 days after sowing. The increased grain and straw yields in I_4 treatment over control was 60.7% and 59.4% with irrigation.

Razi- us- Shams (2001) observed that the effect 0f irrigation treatments on yield and yield contributing characters were statistically significant. When irrigation frequency was increased the grain and straw yields, number of tillers, panicle length, number of grains panicle^{-1} were gradually increased over control.

Jadhav and Jadhav (2000) reported that significantly higher number of spikelets spike^{-1} was obtained from 4 and 5 irrigations compared to 2irrigations.

Yadav *et al.* (2001) reported that two irrigations scheduled at CRI and milking stages gave the maximum number of grains spike^{-1}(65) of wheat, which was found to be at par with those at one irrigation. Eunus *et al*. (1998) observed higher number of grains in irrigated plots than in no irrigated ones.

Ottman *et al*. (2000) conducted a field experiment on a Casa Grande sandy loam soil in 1995 and 1996 growing seasons at the University of Arizona Maricopa Agricultural Centre, USA. The treatments consisted of 3 levels of N (0, 2.4 and 6.7 gm m^{-2}) until anthesis and irrigation based on 30%, 50% and 70% depletion of plant available soil water. It was observed that irrigation frequency during grain filling increased 1000-grain weight.

Upadhyaya and Dubey (2003) performed a field experiment on wheat where 3 irrigations frequencies viz. (a) one irrigation at CRI stage, (b) two irrigation one each at CRI and booting stages and (c) four irrigations one each at crown root initiation (CRI), booting, flowering and milking stage were included. They observed that grain yield varied significantly with irrigation frequencies. Four irrigations performed the maximum grain yield which was significantly greater than one or two irrigations.

Patil *et al*. (2002) conducted a field experiment with irrigation at Agricultural Research Station, Niphad, Maharashtra during the winter (rabi) season of 199293. There were 3 irrigations treatments *viz*. one irrigation at 42 days after sowing, two irrigations at 21 and 65 DAS and five irrigation at 21,42,65,85 and 105 DAS. They observed that grain yield of wheat was 1.17 t ha^{-1} when irrigated once at 42 DAS, 1.69 t $ha^{-1}$when irrigated twice at 21 and 65 DAS and 2.1 t ha^{-1} when irrigated five times at 21,42,65,85 and 105 DAS.

Ghosh *et al.* (2003) in Kalyani, West Bengal carried out experiment on wheat grown as pure and intercropping system and observed that without irrigation , with irrigation at 21 and 65 DAS and with irrigation at four critical growth stages crop gave grain yields of 2.08 tha^{-1}, 2.99 t ha^{-1}, 3.40 t ha^{-1}respectively. Hosamani *et al.* (2003) conducted experiments at Dharwad, Karnataka, India where the treatment consisted of 3 irrigation frequencies one irrigation (at CRI), two irrigations (one each at CRI and tillering stages) and five irrigations (one each at CRI, tillering, booting, flowering and dough stages). They observed that mean grain yield was 1.04, 1.36 and 1.90 t ha^{-1}with one, two and five irrigation respectively.

BARI (2000) recorded maximum straw yields with three irrigations applied at CRI, maximum tillering and grain filling stages of crop. Irrigations given at CRI+ maximum tillering (MT), CRI+ Booting (BT) and CRI+grain filling (GR) were at par in respect of number of spikes m^{-2} and grains spike^{-1} , but had highest spikes and grains over CRI+MT stages.

Naser (1999) reported that two irrigations at 30 and 50 DAS significantly increased grain and straw yields over control. The highest grain and straw yields, the maximum number of tillering plant^{-1}, the highest spike length, the maximum number of grains spike^{-1} were recorded in I4 treatment where two irrigations were applied. The I_4 treatment increased grain and straw yields by 58.1% and 54.5% respectively over control. The control treatment showed the lowest result in all parameters.

Cooper (1998) reported that harvest index increases with increase in irrigation frequencies. Boogaard *et al.* (1999) carried out an experiment in a Mediterranean environment in North Syria with wheat under rainfed and irrigated conditions and reported that under rainfed conditions harvest index was increased.

The findings presented above indicate that irrigation influences growth and yield through affecting yield components at different phonological stages. Irrigation at different critical stages showed variable responses to growth, yield and yield contributing characters. The literature discussed above suggests that irrigation water should be applied at critical crop growth stages depending on the soil moisture situation to achieve higher yield of wheat crops.

2.2 Effect of vermicompost

Vermicompost, it helps to increase the density of microbes and also provides the vital macro nutrients viz., N, P, K, Ca, Mg and micronutrients such as Fe, Mo, Zn, Cu etc. Apart from this, it also contains plant growth promoting substances like NAA, cytokinins, gibberlins etc. The chemical analysis of vermicompost produced at Dharwad revealed the availability of N, P and K content at 0.8, 1.1 and 0.5 per cent, respectively. Vermicompost contains significant quantities of nutrients, a large beneficial microbial population and biologically active metabolites, particularly gibberellins, cytokinins, auxins and group B vitamins which can be applied alone or in combination with organic or inorganic fertilizers, so as to get better yield and quality of diverse crops (Bhawalker, 1991).

Kang *and Juo* (1986) reported that positive influence of worm cast on the shoot fresh biomass of wheat seedlings. Khan (2002) reported that the plant height of maize on loamy soil was better in plots supplied with vermicompost than plots which received FYM.

Kler and Bains (1992) observed that application of FYM @ 20 t ha^{-1} resulted in higher plant height (96.8 cm) and higher dry matter accumulation (128.1 q ha^{-1}) compared to RDF (88.5 cm and 114.0 q ha^{-1}), respectively.

Steel *et al.* (1994) observed the increased shoot and dry weight of wheat plants in the presence of earthworms. Significantly higher dry matter production was recorded with the application of vermicompost @ 2 to 4 t ha^{-1} and was on par with FYM @10 t ha^{-1}. This might be attributed to the increased uptake of available nutrients which caused increased photosynthetic rate resulting in higher dry matter production (Kumar *et al* 2004).

Behera (1995) observed that application of FYM to wheat @10 t ha^{-1} increased the number of spikes per meter row length over the control (without FYM during all the three years of experimentation). Further, the number of grains $spike^{-1}$, grain weight $spike^{-1}$ and 1000-grain weight (except in the first year) were significantly higher with FYM application.

According to Nehra *et al.* (2001) application of FYM at 15 tonnes ha^{-1}, vermicompost at 10 and 15 tonnes and pressmud at 2.5 and 5 tonnes ha^{-1} increased grain yield by 27.5, 28.5, 46.7, 13.6 and 27.3% during 1997-98, and by 20.8, 23.2, 40.9, 11.9 and 19.1% during 1998-99, respectively, over no organic manure.

The field experiment was conducted by Singh and Singh (2005) under sandy loam in texture, low in organic carbon (0.38%) and available nitrogen (160.7 kg ha^{-1}), medium in available phosphorus (8.37 kg P ha^{-1}), rich in potassium (314.6 kg K ha^{-1}) and slightly alkaline (pH 7.96) in reaction of soil. The application of organic manures improved the yield attributing characters, grain and biological yields compared to no organic manure. However, grains ear^{-1} remained unaffected by various organic sources of nutrients. An increase of 6.83, 5.20, 9.57 and 15.56% in number of effective tillers, and 8.3, 3.61, 8.40 and 12.65% in grain weight ear^{-1} was observed in pooled data with FYM at 15 tonnes ha^{-1}, vermicompost at 7.5, 10 and 15 tonnes ha^{-1} over no organic manure, respectively. The effect of vermicompost at 10 tonnes and FYM at 15 tonnes ha^{-1}, being statistically at par with each other, were superior to no organic manure during both the years in respect of yield-attributing characters.

Kumar *et al.* (2005) noticed that application of FYM @ 20 t ha^{-1} to rice resulted in seed yield of 48.8 q ha^{-1}, as compared to the control (29.5 q ha^{-1}). It was also noticed that seeds harvested from the plot receiving FYM @ 20 t ha^{-1} had less unfilled seeds (17.7%) compared to the control (21.5%).

Singh *et al.* (2007) also reported 29.9, 18.8, 35.5 and 15.2% increase in yield owing to FYM application at 15 t ha^{-1} and VC at 7.5, 10 and 15 t ha^{-1}, respectively over no organic manure. Yadav (2005) also reported similar results.

Singh *and Singh* (2005) found that significantly higher grain and biological yields over other treatments were recorded with VC at 15 tonnes ha^{-1}, except that grain yield obtained with VC at 10 and 15 tonnes ha^{-1} were statistically at par. Overall, the increase in grain yield was 29.91, 18.81, 35.45 and 45.21% owing to FYM 15 tonnes ha^{-1} and VC 7.5, 10 and 15 tonnes ha^{-1} over no organic manure, respectively. The harvest index was not influenced significantly by the application of organic manures.

Patil and Bhilare (2006) reported that application of vermicompost prepared from locally available organic materials (wheat straw, press mud cake and FYM), application of press mud cake (PMC) 50% + FYM 50% recorded the highest plant height (92 cm), number of tillers plant^{-1} (3) and seed yield (39 q ha^{-1}) in wheat over application of these manures separately.

Khandwe *et al*. (2006) carried out a field experiment during the rabi season of 2002-2003 and 2003-2004 on a clay loam soil to evaluate the effect of vermicompost and NPK on wheat yield (*Triticum aestivum*) in agri-silviculture system. Wheat Malwa Shree (HI 83-81), Malwa Shakti (HI 84-98) and JW –17 combine with basal dose of vermicompost 3 t/ha and 50 % recommended dose of NPK recorded significant differences over to vermicompost alone treatment and control (No use of NPK). While treatment 100 % recommended dose of NPK gave at par results. Treatment vermicompost 3 t/ha gave significant differences over control. Silvi component Khamer (Gmelina arborea) recorded average height 315 cm and diameter at breast height 21 cm during two years. It has less shedding character hence it could minorly affected wheat yield but it is further estimated that timber of Khamer tree give approximate net return of Rs 0.55 lakh/ha from cutting after the period of six years. In view of economics treatment vermicompost 3 t/ha with 50 % recommended dose of NPK curtailed at least half cost of the chemical fertilizer as well as sustained yield. Besides, in terms of intangible returns vermicompost not only supplies essential elements to plant but also improve physiochemical and biological properties of soil.

Singh *et al*. (2007) found that application of FYM to wheat induced better growth of plant, which resulted in taller plant, more tillers m^{-2}, length of spike, grain weight spike^{-1}, test weight, yield of grain and straw over the control. Increase in plant height, higher number of tillers m^{-2} and increased yield of wheat with the application of FYM were also reported by Kumar and Ahlawat (2004).

Kumar *et al.* (2007) also recorded higher yield of rice-wheat with the use of organic they also reported that bio-fertilizers have added advantage in wheat production.

Channabasanagowda *et al.* (2008) reported that application of VC @ 3.8 t ha^{-1} + poultry manure @ 2.45 t ha^{-1} in wheat, recorded significantly higher plant height (86.30 cm), number of leaves (60.10 $plant^{-1}$), 1000-seed weight (42.73 g) and seed yield (3043 kg ha^{-1}), vigour index (3223), seedling dry weight (311.27 mg $plant^{-1}$), protein content (13.41%) compared to other treatments.

The tallest plant and highest dry matter production of wheat were recorded with the treatment *in situ* incorporation of RS + FYM @5 t ha^{-1} + PSM + *Azospirillum* and *in situ* incorporation of RS + PM @ 10 t ha^{-1} + PSM (Yadav *et al.*, 2009).

Application of VC and FYM in combination also showed effect on yield parameters. Spikelets $plant^{-1}$, number of seeds $spike^{-1}$, test weight, harvest index (HI) and yield pot^{-1} were recorded maximum in VC (70%) + FYM (30%) treatment and the magnitude of increase HI and grain yield was 39.67% and 2.80 g pot^{-1}, respectively (Agrawal *et al.*, 2010).

Zhou and Chen (2011) observed increased 1000-grain weight in wheat by mixing of worm cast with N15 labeled chemical fertilizers. Tollenear and Aagulera (1992) opined that application of FYM @ 10 t ha^{-1} significantly increased seed yield (44 q ha^{-1}) and straw yield (59.29 q ha^{-1}) over without FYM (38.10 and 51.06 q ha^{-1}, seed and straw yield, respectively).

According to Khalid Nawab *et al.* (2011) analysis of the data showed that effects of years and FYM levels were significant. The F value for cropping patterns in ANOVA for grain yield was significant ($p<0.05$). Effect of FYM was non-significant with 25t ha^{-1} of FYM producing higher yield than plots to which no FYM had been applied. Main effects of FYM, Potassium and Zinc and interactions were non significant. These results are in agreement with Rajput *et al.*, (1995) who observed that FYM 10 t ha^{-1} + 20 kg N ha^{-1} gave the highest returns.

Yousefi and Sedeghi (2014) conducted this study to investigate the effect of different doses of vermicompost organic fertilizer on chemical fertilizer urea reduce and its impact on the yield and yield components. The experimental design was split plot factorial with on a complete randomized block design with three replications. The treatments included three levels of vermicompost organic fertilizer (5, 10 and 15 Ton ha-1) and five levels of urea chemical fertilizer (0, 25, 50, 75 and 100% the recommended rate based on soil test). The results indicated that the combined application of urea fertilizer, organic fertilizer vermicompost had significant effects on grain yield and grain weight. The maximum yield of the treatments 100% of the recommended urea with 10 and 15 Ton ha^{-1} vermicompost and treatments recommended by 75% urea plus 15 Tom ha^{-1} vermicompost, respectively, which is statistically there was no significant difference between the three groups (4977.3, 4890.7 and 4953.0 kg ha^{-1}, respectively). Thus it can be concluded that the application of vermicompost organic fertilizer, can be reduced chemical fertilizer urea up to 25 percent. Excessive use of chemical fertilizers can have adverse effects on human life and the environment. Therefore, must look to find ways to reduce the use of chemical fertilizers. The use of organic fertilizers is one of the solutions for sustainable fertility.

Ibrahim *et al*. (2015) conducted this study to investigate the effect of vermicompost and its mixtures with water treatment residuals on selected physical properties of saline sodic soil and on wheat yield. The treatments were vermicompost, water treatment residuals, vermicompost + water treatment residuals (1:1 and 2:1 wet weight ratio) at levels of 5 and 10 g dry weight kg^{-1} dry soil. The considered physical properties included aggregate stability, mean weight diameter, pore size distribution and dry bulk density. The addition of vermicompost and water treatment residuals had significant positive effects on the studied soil physical properties, and improved the grain yield of wheat. The treatment of (2 vermicompost + 1 water treatment residuals) at level of 5 g kg^{-1} soil gave the best grain yield. Combination of vermicompost and water treatment residuals improved the water treatment residuals efficiency in ameliorating the soil physical properties, and could be considered as an ameliorating material for the reclamation of salt affected soils. The application of vermicompost and water treatment residuals to improve the physical properties in the salt affected soils is a promising technology to meet the requirements of high plant growth and cost-effective reclamation.

Dastmozd *et al*. (2015) conducted this study for sustainability in food production and sustainable agricultural systems. The present study explored the effect of vermicompost fertilizer as a biological agent compared with fertilizers on yield and yield components of wheat to enhance the qualitative and quantitative yield. Experimental treatments were carried out at seven levels. The results showed that application of 1800 kg ha vermicompost with 80 kg ha NPK fertilizers improved significantly grain yield and wheat morphological and physiological characteristics such as thousand grain weight, plant height, number of spikes per hectare, number of grains per spike, and harvest index. The results of the experiments also indicated that vermicompost fertilizer can improve soil productivity and soil quality.

Hadis *et al*. (2018) conducted a greenhouse pot experiment to determine the effects of vermicompost, inorganic fertilizers and their combinations on nutrient uptake, yield and yield components of wheat. Four levels (0, 2, 4 and 6 tha^{-1}) of vermicompost and four levels (0, 33.33, 66.67 and 100% ha^{-1}) of the recommended NPK fertilizers were used. Bread wheat variety, Kekaba was used as a test crop. Vermicompost applied at 2, 4 and 6 t ha^{-1} increased grains yield of wheat by 11, 17 and 26% over control respectively whereas 33.33, 66.67 and 100% NPK fertilizers increased the grain yield by 10, 24 and 30%, respectively over the control. Vermicompost applied at 6 t ha^{-1} resulted in the highest nutrient uptake and it increased grain uptake of N, P and K by 51, 110 and 89% over control respectively whereas among fertilizer rates, the highest uptake was produced by 100% NPK treatment and it increased the N, P and K uptake in the grain by were 79, 100 and 96% over control, respectively.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka during the period from November 2016 to March 2017. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analyses.

3.1. Site description

The experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28. The land area is situated at 23°41′N latitude and 90°22′E longitude at an altitude of 8.6 meter above sea level. The experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

3.2. Climate

The experimental area is under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the rabi season (October-March).

3.3. Soil

The farm belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental area was flat having available irrigation and drainage system. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were doneby Soil Resources and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in AppendixII.

3.4. Treatments

The following treatments were included in this experiment

Factor A: Irrigation – 4 levels

1. I_0 = Noirrigation
2. I_1 = Irrigation at 18 days after sowing (DAS)
3. I_2 = Irrigation at 18 and 47 days after sowing(DAS)
4. I_3 = Irrigation at 18, 47 and 76 days after sowing (DAS)

Factor B: Vermicompost – 3 levels

1. V_0 = Novermicompost
2. V_1 = Vermicompost @ 5 tha^{-1}
3. V_2 = Vermicompost @ 10 tha^{-1}

3.5. Seed collection

Seeds of BARI Gom- 26 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. It is a high yielding variety and suits better as a late variety. Plant height ranges from 95-105 cm producing 4-5 tillers $plant^{-1}$. Seeds $spike^{-1}$ is 35-40 containing white coloured seed. It matures within103-112 days and yields between 4300-5000 kg ha^{-1}. The cultivar is claimed to be resistant to leaf rust and leaf spot.

3.6. Preparation of experimental land

The land was first ploughed on 20 October, 2016 by disc plough. The land was then harrowed again on 27 and 30 October to bring the soil in a good tilth condition. The final land preparation was done by disc harrow on 7 November, 2017. The land was prepared thoroughly and leveled by a ladder. Weeds and stubbles were removed from the field. The experiment was laid out on 12 November, 2017 according to the design adopted.

3.7. Fertilizer dose and methods of application

The N, P_2O_5, and K_2O were applied respectively at the rate of 115, 67 and 60 kg ha^{-1} as urea, triple super phosphate and muriate of potash. Vermicompost was applied according to the treatment. Vermicompost and all other fertilizers except urea were applied as basal dose, whereas urea were applied in equal two splits respectively at final land preparation on, 18 days after sowing (DAS) and 47 DAS.

3.8. Experimental design

The experiment was laid in Split Plot Design with three replications (block). Each replication was first divided into 12 subplots where treatment combinations were assigned. Thus the total number of unit plots was 12×3=36. The size of the unit plot was 3m × 2m. The distance maintained between two unit plots was 0.5m and that between blocks was 1m. The treatments were randomly assigned to the plots within each replication. The layout of the experiment has been shown in appendix III.

3.9. Sowing of seeds

Seeds were sown on 16th November, 2016by hand. Seeds were sown in line and then covered properly with soil. The line to line distance for wheat was 20 cm and plant to plant distance was 4-5 cm.

3.10. Intercultural operations

3.10.1. Weeding

During plant growth period two hand weedings were done. First weeding was done at 20 days after transplantation followed by second weeding at 15 days after first weeding.

3.10.2. Plant protection measures

The wheat crop was infested by aphid and rodent. Therefore, contact insecticide

(Malathion @ 22.2 mm per 10 litres of water) was given two times and 2% zinc sulphide was applied in some times because wheat field was highly infested by rodent.

3.10.3. General observation of the experimental field

The field was observed time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest was minimized.

3.11. Harvesting and postharvest operation

Maturity of crop was determined when 90% of the grains became golden yellow in color. Ten plants plot^{-1} were preselected randomly from which data on different growth and yield attributes were collected and 1 m^2 areas from middle portion of each plot was harvested separately and bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done. The grains were cleaned and sun dried to a moisture content of 12%. Straw was also sun dried properly.

3.12. Recording of data

Experimental data were recorded from 40 days of sowing and continued up to harvest. The following data were recorded during the experimentation.

3.12.1. Growth characters

1. Plant height(cm)
2. Number of tillers plant^{-1}
3. Dry weight plant^{-1} (g)

3.12.2. Yield contributing parameters

1. Spike length (cm)
2. Number of spikelets spike^{-1}
3. Number of filled grains spike^{-1}
4. Number of unfilled grains spike^{-1}
5. Weight of 1000 seeds (g)

3.12.3. Yield parameters

1. Grain yield (t ha^{-1})
2. Straw yield (t ha^{-1})
3. Biological yield (t ha^{-1})
4. Harvest index (%)

3.13. Procedures of recording data

A brief outline of the data recording procedure is given below:

3.13.1. Crop growth characters

3.13.1.1. Plant height (cm)

Plant height was measured at 20 days interval starting from 40 days after sowing (DAS) and continued up to harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading, and to the tip of spike after heading. The collected data were finally averaged.

3.13.1.2. Number of tillers plant^{-1}

Number of tillers plant^{-1} were counted at 20 days interval starting from 40 DAS and up to harvest and finally averaged as their number plant^{-1}.

3.13.1.3. Dry weight of plant (g)

Five plants at different days after sowing (40, 60, 80 DAS and at harvest) were collected and dried at 70°C for 24 hours. The dried samples were then weighed and averaged.

3.13.2. Yield and yield contributing characters

3.13.2.1. Spike length (cm)

Spikelengthwerecountedfromfiveplantsfrombasalnodeoftherachistoapexof each spike and then averaged. This was taken at different days after sowing (DAS) separately.

3.13.2.2. Number of spikelets spike^{-1}

Number of spikelets were counted from 5 spikes and averaged to determine the number spikelets spike^{-1}.

3.13.2.3. Number of grains spike^{-1}

The number of grains spike^{-1} was counted from 10 randomly selected spike and average value was measured expressed as number of grains spike^{-1}.

3.13.2.4. Weight of 1000 grains (g)

One thousand cleaned dried grains were counted randomly from each plot and weighed by using a digital electric balance when the grains retained 12% moisture and the mean weight was expressed in gram.

3.13.2.5. Grain yield (t ha^{-1})

Grain yield was determined from the central 1 m^2 area of each plot and expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

3.13.2.6. Straw yield (t ha^{-1})

Straw yield was determined from the central 1 m^2 area of each plot, after separating the grains. The samples after sun drying were weighed and finally converted to t ha^{-1}.

3.13.2.7. Harvest index (%)

It denotes the ratio of economic yield to biological yield and was calculated with the following formula.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.14. Statistical analysis

The data collected on different parameters were statistically analyzed with split plot design using the MSTAT computer package program. Least Significant Difference (LSD) technique at 5% level of significance was used to compare the mean differences (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from present study for different crop characters, yields and other analyses have been presented and discussed in this chapter.

4.1. Growth parameters

4.1.1. Plant height (cm)

Effect of irrigation

Plant height of wheat was significantly influenced by different levels of irrigation at different growth stages (Fig. 1 and Appendix IV). Results revealed that the highest plant height [34.44, 75.65, 85.22 and 90.67 at 40, 60, 80 days after sowing (DAS) and harvest, respectively] were found from I_3 (Irrigation at 18, 47 and 76 DAS) followed by I_1 (Irrigation at 18 DAS) and I_2 (Irrigation at 18 and 47 DAS) where the lowest plant height (25.02, 67.54, 71.99 and 77.05 cm at 40, 60, 80DAS and, harvest respectively) was found from I_0 (No irrigation). Similar results were also observed by Amin *et al*. (2015), Al-Tahar *et al*. (2011) and Ali and Amin (2007).

Effect of vermicompost

Significant variation was observed in plant height at different growth stages influenced by different rates of vermicompost (Fig. 2 and Appendix IV). It was observed that the highest plant height (36.19, 76.84, 84.68 and 90.65 cm at 40, 60, 80 DAS and at harvest, respectively) was found fromV_2 (Vermicompost @ 10 t ha^{-1}) followed by V_1 (Vermicompost @ 5 t ha^{-1}) where the lowest plant height 24.11, 66.54, 73.01 and 78.08 cm at 40, 60, 80 DAS and at harvest, respectively) was found from V_0 (No vermicompost). Patil and Bhilare (2006) and Khandwe *et al*. (2006) also found similar results with the presentstudy.

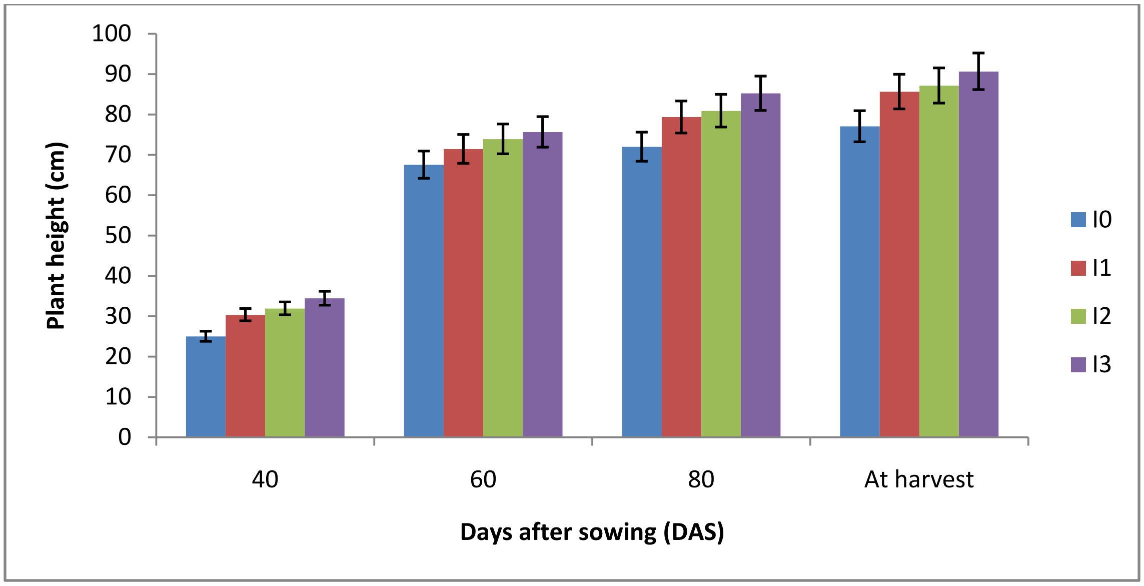

Fig. 1. Plant height of wheat at different days after sowing (DAS) as influenced by irrigation ($LSD_{0.05}$ = 1.74, 1.66, 2.82, 3.19 respectively at 40, 60, 80 DAS and harvest, respectively)

I_0 = No irrigation
I_1 = Irrigation at 18 DAS
I_2 = Irrigation at 18 and 47 DAS
I_3 = Irrigation at 18, 47 and 76 DAS

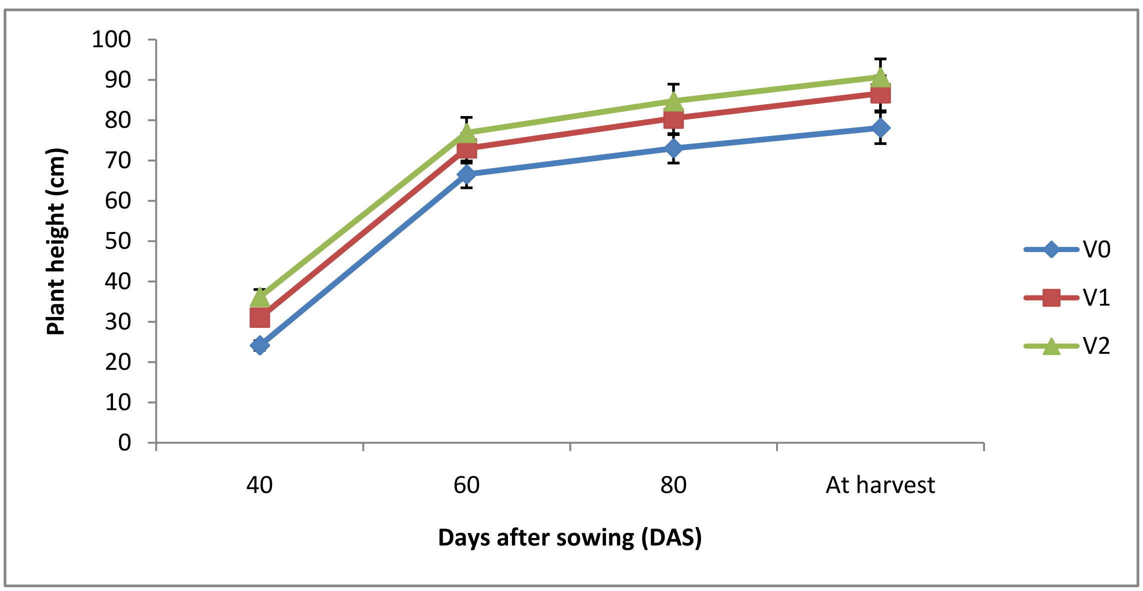

Fig. 2. Plant height of wheat at different days after sowing (DAS) as influenced by vermicompost ($LSD_{0.05}$ = 1.51, 1.25, 1.50, 1.78 respectively at 40, 60, 80 DAS and harvest, respectively)

V_0 = No vermicompost
V_1 = Vermicompost @ 5 t ha^{-1}
V_2 = Vermicompost @ 10 t ha^{-1}

Interaction effect of irrigation and vermicompost

Interaction effect of irrigation and vermicompost showed significant differences on plant height of wheat at different growth stages (Table 1 and Appendix IV). It was noted that the highest plant height (39.94, 80.46, 90.75 and 95.47 cm at 40, 60, 80 DAS and at harvest, respectively) were found from the interaction of I_3V_2, which was statistically identical with I_3V_1 at 80 DAS and harvest followed by I_1V_2 and I_2V_2. The lowest plant height (20.69, 62.78, 67.53 and 72.39 at 40, 60, 80 DAS and at harvest, respectively) were found from the interaction of I_0V_0 followed byI_0V_1.

Table 1. Plant height of wheat at different days after sowing (DAS) as influenced by the interaction of irrigation and vermicompost

Treatment	Plant height (cm)			
	40 DAS	60 DAS	80 DAS	At harvest
I_0V_0	20.69 h	62.78 f	67.53 h	72.39 h
I_0V_1	25.68 f	68.47 e	70.55 g	75.38 g
I_0V_2	28.69 e	71.36 d	77.89 d	83.40 d
I_1V_0	23.48 g	64.79 f	72.92 fg	77.65 f
I_1V_1	30.60 d	72.72 d	80.73 c	87.54 c
I_1V_2	36.97 b	76.77 bc	84.40 b	91.73 b
I_2V_0	24.22 fg	67.77 e	75.15 ef	80.23 e
I_2V_1	32.39 c	75.21 c	81.91 c	89.20 c
I_2V_2	39.15 a	78.77 ab	85.67 b	92.02 b
I_3V_0	28.06 e	70.84 d	76.42 de	82.04 de
I_3V_1	35.33 b	75.64 c	88.49 a	94.49 a
I_3V_2	39.94 a	80.46 a	90.75 a	95.47 a
$LSD_{0.05}$	1.773	2.262	2.453	1.93
CV(%)	5.74	6.31	7.57	5.76

I_0 = No irigation
I_1 = Irrigation at 18 DAS
I_2 = Irrigation at 18 and 47 DAS
I_3 = Irrigation at 18, 47 and 76 DAS

V_0 = No vermicompost
V_1 = Vermicompost @ 5 t ha^{-1}
V_2 = Vermicompost @ 10 t ha^{-1}

4.1.2. Number of tillers plant^{-1}

Effect of irrigation

Significant influence on number of tillers plant^{-1} of wheat was observed due to different irrigation levels at different growth stages (Fig. 3 and Appendix V). Results showed that the highest number of tillers plant^{-1} (2.152, 2.434, 4.387 and
4.249 cm at 40, 60, 80 DAS and at harvest, respectively) were found from I_3 (Irrigation at 18, 47 and 76 DAS) followed by I_2 (Irrigation at 18 and 47 DAS) whereas the lowest number of tillers plant^{-1} (1.069, 1.284, 2.616 and 2.407 at 40, 60, 80 DAS and at harvest respectively) was found from I_0 (No irrigation). Similar findings were also found by Khan *et al*. (2007), Ali and Amin (2007), Sher and Parvender (2006) and Onyibe (2008) which supported the present study.

Effect of vermicompost

Significant difference was found in number of tillers plant^{-1} of wheat at different growth stages influenced by different rates of vermicompost (Fig. 4 and Appendix V). Results exposed that the highest number of tillers plant^{-1} (2.183, 2.481, 4.262 and 4.051 at 40, 60, 80 DAS and at harvest respectively) was found from V_2 (Vermicompost @ 10 t ha^{-1}) followed by V_1 (Vermicompost @ 5 t ha^{-1}) where the lowest number of tillers plant^{-1} (1.168, 1.407, 2.852 and 2.671 at 40, 60, 80 DAS and at harvest respectively) was found from V_0 (No vermicompost). The results obtained from the present study was similar with the findings of Singh and Singh (2005) and Patil and Bhilare(2006).

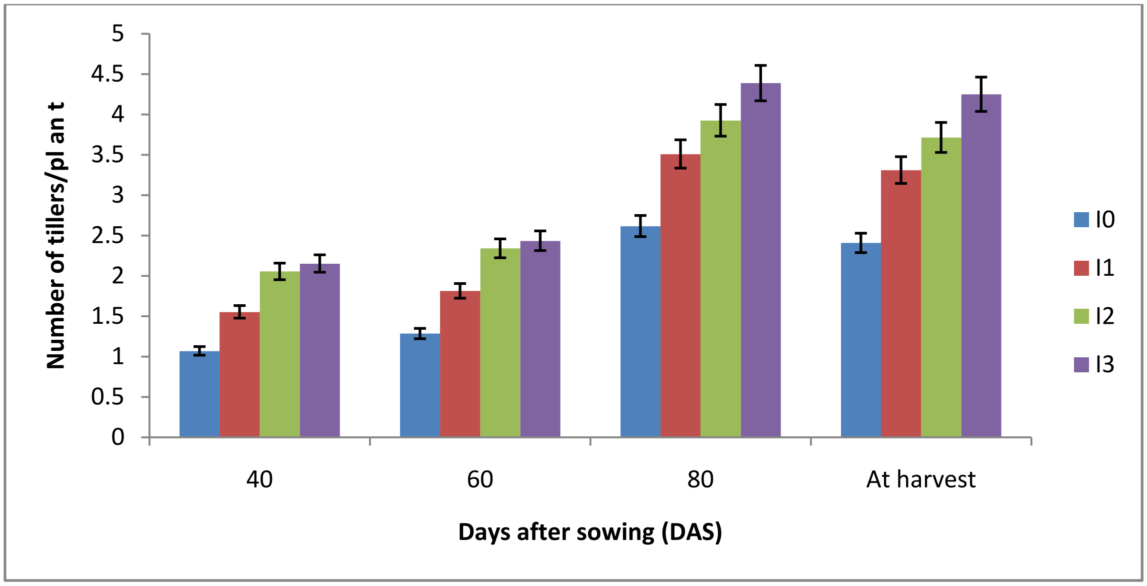

Fig. 3. Number of tillers plant^{-1} of wheat at different days after sowing (DAS) as influenced by irrigation (LSD$_{0.05}$ = 0.104, 0.089, 0.167, 0.202respectively at 40, 60, 80 DAS and harvest, respectively)

I_0 = No irrigation
I_1 = Irrigation at 18 DAS
I_2 = Irrigation at 18 and 47 DAS
I_3 = Irrigation at 18, 47 and 76 DAS

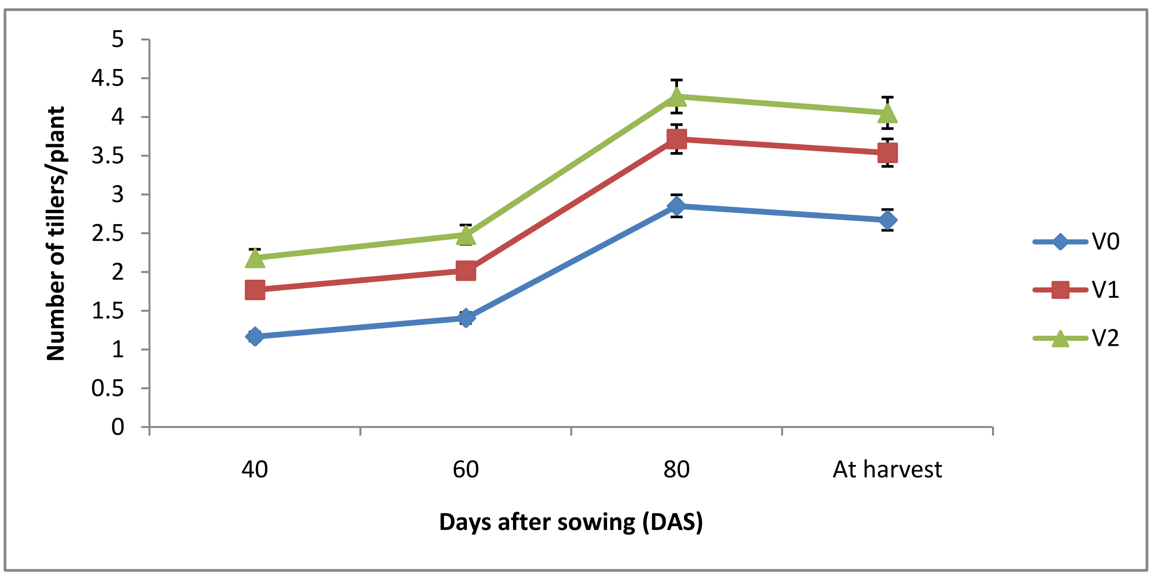

Fig. 4. Number of tillers plant^{-1} of wheat at different days after sowing (DAS) as influenced by vermicompost (LSD$_{0.05}$ = 0.289, 0.390, 0.402, 0.409 respectively at 40, 60, 80 DAS and harvest, respectively)

V_0 = No vermicompost
V_1 = Vermicompost @ 5 t ha^{-1}
V_2 = Vermicompost @ 10 t ha^{-1}

Interaction effect of irrigation and vermicompost

Number of tillers plant^{-1} at different growth stages of wheat was significantly influenced by combined effect different levels of irrigation and vermicompost (Table 2 and Appendix V). Results indicated that the highest number of tillers plant^{-1}t (2.630, 2.96, 4.967 and 4.907 at 40, 60, 80 DAS and at harvest respectively) was found from the treatment combination of I_3V_2 which was significantly different from all other treatment combinations followed by I_2V_2 and I_3V_1. The lowest number of tillers plant^{-1} 0.820, 1.047, 2.036 and 1.910 (at 40, 60, 80 DAS and at harvest respectively) was found from the treatment combination of I_0V_0 which was statistically identical with I_0V_1.

Table 2. Number of tillers plant^{-1}at different days after sowing (DAS) as influenced by the interaction of irrigation and vermicompost

Treatment	Number of tillers plant^{-1}			
	40 DAS	60 DAS	80 DAS	At harvest
I_0V_0	0.820 h	1.047 h	2.063 h	1.910 h
I_0V_1	1.020 gh	1.167 h	2.393 g	2.167 h
I_0V_2	1.367 ef	1.640 fg	3.390 e	3.143 f
I_1V_0	1.087 g	1.243 h	2.823 f	2.640 g
I_1V_1	1.647 d	2.040 de	3.720 d	3.540 de
I_1V_2	1.927 c	2.157 cd	3.983 c	3.750 cd
I_2V_0	1.247 fg	1.500 g	2.980 f	2.813 g
I_2V_1	2.107 bc	2.353 bc	4.090 c	3.927 c
I_2V_2	2.810 a	3.167 a	4.707 b	4.403 b
I_3V_0	1.520 de	1.837 ef	3.540 de	3.320 ef
I_3V_1	2.307 b	2.507 b	4.653 b	4.520 b
I_3V_2	2.630 a	2.960 a	4.967 a	4.907 a
$LSD_{0.05}$	0.2322	0.2189	0.2567	0.2896
CV(%)	6.18	7.43	4.61	5.90

I_0 = No irrigation
I_1 = Irrigation at 18 DAS
I_2 = Irrigation at 18 and 47 DAS
I_3 = Irrigation at 18, 47 and 76 DAS

V_0 = No vermicompost
V_1 = Vermicompost @ 5 t ha^{-1}
V_2 = Vermicompost @ 10 t ha^{-1}

4.1.3. Dry weight plant^{-1}

Effect of irrigation

Significant variation was found on dry weight plant^{-1} at different growth stages due to irrigation levels (Fig. 5 and Appendix VI). It was found that the highest dry weight plant^{-1} (at 40, 60, 80 DAS and at harvest respectively) was found from I_3 (Irrigation at 18, 47 and 76 DAS) followed by I_2 (Irrigation at 18 and 47 DAS) where the lowest dry weight plant^{-1} (at 40, 60, 80 DAS and at harvest respectively) was found from I_0 (No irrigation). Jessica and Robert (2017), Amin *et al*. (2015) and Al- Tahar *et al*. (2011) found similar results with the present study.

Effect of vermicompost

Dry weight plant^{-1} at different growth stages of wheat was significantly affected by different rate of vermicompost (Fig. 6 and Appendix VI). It was observed that the highest dry weight plant^{-1} (16.26, 17.47, 27.55 and 34.33 g at 40, 60, 80 DAS and at harvest respectively) was found from V_2 (Vermicompost @ 10 t ha^{-1}) followed by V_1 (Vermicompost @ 5 tha^{-1}) where the lowest dry weight plant^{-1} (9.12, 10.64, 16.68 and 23.81 g at 40, 60, 80 DAS and at harvest respectively) was found from V_0 (No vermicompost). The findings obtained from Channabasanagowda *et al.* (2008) and Ibrahim *et al*. (2015) were similar with the present investigation.

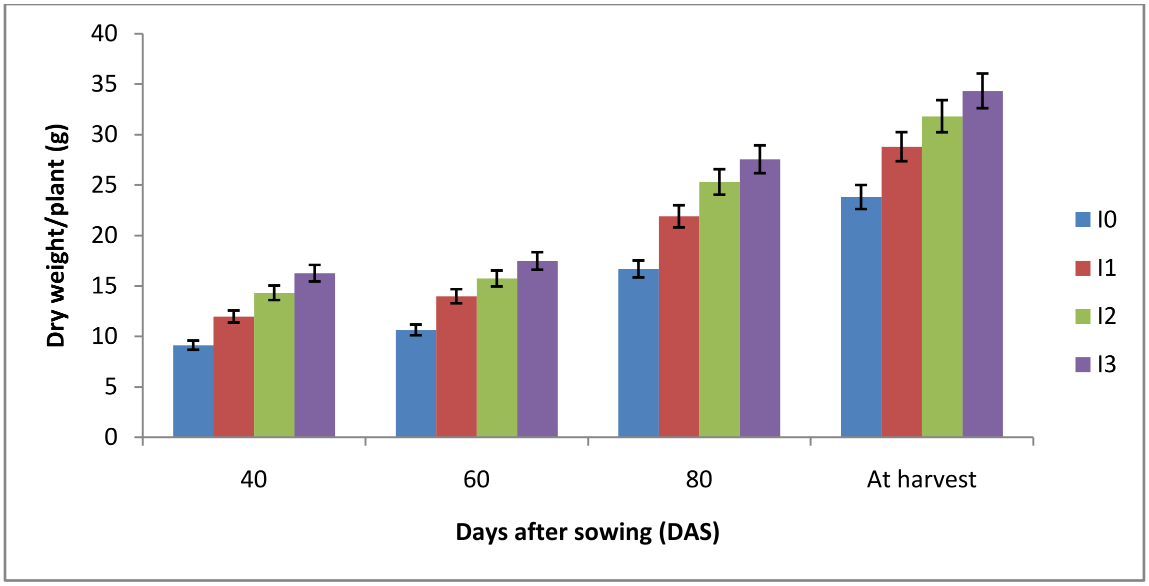

Fig. 5. Dry weight plant^{-1} of wheat at different days after sowing (DAS) as influencedby irrigation (LSD$_{0.05}$ = 1.5, 1.68, 1.74, 1.76respectively at 40, 60, 80 DAS and harvest, respectively)

I_0 = No irrigation
I_1 = Irrigation at 18 DAS
I_2 = Irrigation at 18 and 47 DAS
I_3 = Irrigation at 18, 47 and 76 DAS

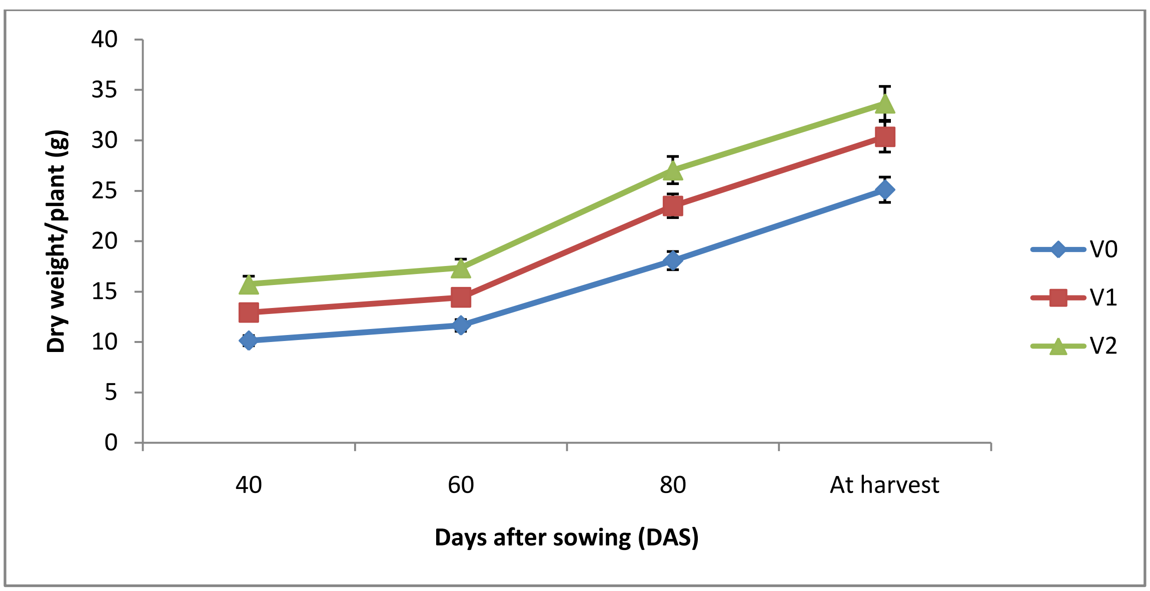

Fig. 6. Dry weight plant^{-1} of wheat at different days after sowing (DAS) as influenced by vermicompost (LSD$_{0.05}$ = 0.43, 1.456, 1.512, 1.526respectively at 40, 60, 80 DAS and harvest, respectively)

V_0 = No vermicompost
V_1 = Vermicompost @ 5 t ha^{-1}
V_2 = Vermicompost @ 10 t ha^{-1}

Interaction effect of irrigation and vermicompost

Significant variation was remarked for dry weight plant^{-1} at different growth stages of wheat due to combined effect of different levels of irrigation and vermicompost (Table 3 and Appendix VI). Results indicated that the highest dry weight plant^{-1} (15.72, 17.33, 27.03 and 33.65 g at 40, 60, 80 DAS and at harvest, respectively) was found from the treatment combination of I_3V_2 followed by I_2V_2 and I_2V_1. The lowest dry weight plant^{-1} (10.11, 11.62, 18.05 and 25.08 g at 40, 60, 80 DAS and at harvest respectively) was found from the treatment combination of I_0V_0 which was statistically identical with I_0V_1 and statistically similar with I_1V_0.

Table 3. Dry weight plant^{-1} of wheat at differentdays after sowing (DAS) as influenced by the interaction of irrigation and vermicompost

Treatment	Dry weight plant^{-1} (g)			
	40 DAS	60 DAS	80 DAS	At harvest
I_0V_0	7.427 i	8.567 i	14.07 i	21.25 i
I_0V_1	7.917 hi	9.713 hi	15.23 i	22.39 i
I_0V_2	12.02 ef	13.65 ef	20.73 gh	27.78 fg
I_1V_0	9.797 gh	11.51 gh	16.46 i	23.53 hi
I_1V_1	12.21 ef	14.63 def	23.75 ef	30.67 de
I_1V_2	13.91 de	15.81 cde	25.50 de	32.20 cd
I_2V_0	10.45 fg	12.51 fg	19.07 h	26.01 gh
I_2V_1	15.06 cd	16.20 cd	26.86 cd	33.53 bc
I_2V_2	17.43 b	18.51 b	29.97 ab	35.93 b
I_3V_0	12.77 e	13.89 ef	22.59 fg	29.51 ef
I_3V_1	16.49 bc	17.15 bc	28.13 bc	34.77 bc
I_3V_2	19.53 a	21.37 a	31.93 a	38.70 a
$LSD_{0.05}$	2.013	1.998	2.476	2.514
CV(%)	9.74	7.20	10.16	11.72

I_0 = No irrigation
I_1 = Irrigation at 18 DAS
I_2 = Irrigation at 18 and 47 DAS
I_3 = Irrigation at 18, 47 and 76 DAS

V_0 = No vermicompost
V_1 = Vermicompost @ 5 t ha^{-1}
V_2 = Vermicompost @ 10 t ha^{-1}

4.2. Yield contributing parameters

4.2.1. Spike length (cm)

Effect ofirrigation

Significant influence on spike length of wheat was observed due to different irrigation levels (Table 4 and Appendix VII). Results revealed that the highest spike length (16.65 cm) was found from I_3 (Irrigation at 18, 47 and 76 DAS) which was statistically identical with I_2 (Irrigation at 18 and 47 DAS) and statistically identical with I_1 (Irrigation at 18 DAS) where the lowest spike length (14.85 cm) was found from I_0 (No irrigation). Ali and Amin (2007), Alsohaibani (2007), Razi-us-shams (2001) and Naser (1999) found similar results with the presentstudy.

Effect of vermicompost

Significant difference was found in terms of spike length of wheat due to different rates of vermicompost (Table 4 and Appendix VII). It was observed that the highest spike length (16.87 cm) was found from V_2 (Vermicompost @ 10 t ha^{-1}) which was statistically identical with V_1 (Vermicompost @ 5 t ha^{-1}) where the lowest spike length (14.51 cm) was found from V_0 (No vermicompost). Singh *et al*. (2007) observed similar results which supported the presentstudy.

Interaction effect of irrigation and vermicompost

Spike length was significantly influenced by interaction of irrigation and vermicompost (Table 4 and Appendix VII). It was noted that the highest spike length (18.09 cm) was found from the treatment combination of I_3V_2 followed by I_2V_2 and I_3V_1. The lowest spike length (13.49 cm) was found from the treatment combination of I_0V_0 followed by $I_1V_0$and I_2V_0.

4.2.2 Number of spikelets spike^{-1}

Effect of irrigation

Significant variation was found on number of spikelets spike^{-1} due to irrigation (Table 4 and Appendix VII). Results showed that the highest number of spikelets spike^{-1} (56.67) was found from I_3 (Irrigation at 18, 47 and 76 DAS) followed by I_2(Irrigation at 18 and 47 DAS) where the lowest number of spikelets spike^{-1} (48.42) was found from I_0 (No irrigation). Ali and Amin (2007) and Jadhav and Jadhav(2000) also found similar results with the present study.

Effect of vermicompost

Number of spikelets spike^{-1} of wheat was significantly affected by different rate of vermicompost (Table 4 and Appendix VII). Results exposed that the highest number of spikelets spike^{-1} (57.01) was found from V_2 (Vermicompost @ 10 t ha^{-1}) followed by V_1 (Vermicompost @ 5 t ha^{-1}) where the lowest number of spikelets spike^{-1} (47.46) was found from V_0 (No vermicompost). Agrawal *et al.,* (2010) found similar result which supported the presentstudy.

Interaction effect of irrigation and vermicompost

Significant variation was remarked for number of spikelets spike^{-1} of wheat due to combined effect of different levels of irrigation and vermicompost (Table 4 and Appendix VII). Results indicated that the highest number of spikelets spike^{-1} (63.30) was found from the treatment combination of I_3V_2 which was significantly different from all other treatment combinations followed by I_2V_2. The lowest number of spikelets spike^{-1} (43.36) was found from the treatment combination of I_0V_0 followed by I_1V_0.

4.2.3 Number of filled grains spike^{-1}

Effect of irrigation

Significant variation was found on number of filled grains spike^{-1} due to cause of different irrigation levels (Table 4 and Appendix VII). It was found that the highest number of filled grains spike^{-1} (38.81) was found from I_3 (Irrigation at 18, 47 and 76 DAS) which was statistically identical with I_1(Irrigation at 18 DAS) and I_2(Irrigation at 18 and 47 DAS) where the lowest number of filled grains spike^{-1} (33.64) was found from I_0 (No irrigation). Ali and Amin (2007) also found similar result with the present study.

Effect of vermicompost

Number of filled grains spike^{-1} of wheat was significantly affected by different rate of vermicompost (Table 4 and Appendix VII). It was observed that the highest number of filled grains spike^{-1} (39.45) was found from V_2 (Vermicompost @ 10 t ha^{-1}) which was statistically similar with V_1 (Vermicompost @ 5 t ha^{-1}) where the lowest number of filled grains spike^{-1} (32.42) was found from V_0 (No vermicompost).

Interaction effect of irrigation and vermicompost

Significant variation was remarked for number of filled grains spike^{-1} of wheat due to combined effect of different levels of irrigation and vermicompost (Table 4 and Appendix VII). Results indicated that the highest number of filled grains spike^{-1} (41.58) was found from the treatment combination of I_3V_2 which was statistically similar with I_2V_2 and I_3V_1 followed by I_1V_2. The lowest number of filled grains spike^{-1} (30.20) was found from the treatment combination of I_0V_0 which was close to the treatment combination of I_1V_0 and I_2V_0 but significantly different.

4.2.4 Number of unfilled grains spike^{-1}

Effect of irrigation

Number of unfilled grains spike^{-1} was significantly influenced by different levels of irrigation (Table 4 and Appendix VII). It was observed that the lowest number of unfilled grains spike^{-1}(6.90) was found from I_2 (Irrigation at 18 and 47 DAS) which was statistically identical with I_0 (No irrigation) where the highest number of unfilled grains spike^{-1}(10.70) was found from I_1 (Irrigation at 18 DAS) followed by I_3 (Irrigation at 18, 47 and 76DAS).

Effect of vermicompost

Significant variation was observed in terms of number of unfilled grains spike^{-1} of rice influenced by different rates of vermicompost (Table 4 and Appendix VII). Results revealed that the lowest number of unfilled grains spike^{-1} (6.38) was found from V_2 (Vermicompost @ 10 t ha^{-1}) where the highest number of unfilled grains spike^{-1} (11.34) was found from V_0 (No vermicompost) followed by V_1(Vermicompost@5tha^{-1}).SimilarresultwasalsoobservedbyKumar*etal.*(2005).

Interaction effect of irrigation and vermicompost

Combined effect of different levels of irrigation and vermicompost showed significant difference on number of unfilled grains spike^{-1} (Table 4 and Appendix VII).Itwasnotedthatthelowestnumberofunfilledgrainsspike^{-1}(5.13)wasfound from the treatment combination of I_2V_2 which was statistically similar with I_1V_2, I_2V_1,I_3V_1andI_3V_2.Thehighestnumberofunfilledgrainsspike^{-1}(12.33)wasfound from the treatment combination of I_1V_0 which was statistically identical withI_0V_0.

4.2.5. Weight of 1000 seeds (g)

Effect of irrigation

Significantly influence on 1000 seed weight was observed due to different irrigation levels (Table 4 and Appendix VII). Results showed that the highest 1000 seed weight (45.47 g) was found from I_2 (Irrigation at 18 and 47 DAS) followed by I_1 (Irrigation at 18 DAS) and I_3 (Irrigation at 18, 47 and 76 DAS) where the lowest 1000 seed weight (41.13 g) was found from I_0 (No irrigation). The results on 1000 seed weight obtained from the present study was conformity with the findings of Kong *et al.*, (2008), Ju-Hui (2006) and Sher and Parvender(2006).

Effect of vermicompost

Significant difference was found in terms of 1000 seed weight influenced by different rates of vermicompost (Table 4 and Appendix VII). Results indicated that the highest 1000 seed weight (46.05 g) was found from V_2 (Vermicompost @ 10 t ha^{-1}) followed by V_1 (Vermicompost @ 5 t ha^{-1}) where the lowest 1000 seed weight (40.37 g) was found from V_0 (No vermicompost). Bahera (1995) and, Zhou and Chen (2011) also found similar results with the presentstudy.

Interaction effect of irrigation and vermicompost

Weight of 1000 seed was significantly influenced by combined effect of different levels of irrigation and vermicompost (Table 4 and Appendix VII). Results exposed that the highest 1000 seed weight (48.53 g) was found from the treatment combinationofI_2V_2which was statistically similar with I_3V_2 wherethelowest1000 seed weight (38.77 g) was found from the treatment combination of I_0V_0.

Table 4. Yield contributing parameters of wheat as influenced by irrigation, vermicompost and their interaction

Treatment	Yield contributing parameters				
	Spike length (cm)	Number of spikelets $spike^{-1}$	Number of filled grains $spike^{-1}$	Number of unfilled grains $spike^{-1}$	Weight of 1000seeds(g)
Irrigation					
I_0	14.85 b	48.42 d	33.64 b	7.474 c	41.13 c
I_1	15.67 ab	50.68 c	36.83 a	10.70 a	43.05 b
I_2	16.18 a	54.31 b	37.46 a	6.899 c	45.47 a
I_3	16.65 a	56.67 a	38.81 a	8.706 b	44.18 b
$LSD_{0.05}$	1.078	1.794	1.956	0.7151	1.273
CV(%)	4.39	3.85	4.64	3.88	3.67
Vermicompost					
V_0	14.51 b	47.46 c	32.42 b	11.34 a	40.37 c
V_1	16.13 a	53.10 b	38.19 a	7.614 b	43.95 b
V_2	16.87 a	57.01 a	39.45 a	6.380 c	46.05 a
$LSD_{0.05}$	1.213	1.778	1.321	0.9134	1.103
CV(%)	5.06	4.88	5.18	4.18	3.92.46
Interaction					
I_0V_0	13.49 h	43.36 g	30.20 f	13.63 a	38.77 g
I_0V_1	15.40 de	50.83 de	35.11 d	10.21 bc	41.84 e
I_0V_2	15.66 d	51.08 de	35.62 d	8.277 d	42.78 de
I_1V_0	14.61 g	46.27 f	32.57 e	12.33 a	40.14 f
I_1V_1	15.85 d	52.50 d	38.17 c	7.517 de	43.45 d
I_1V_2	16.56 c	53.27 d	39.73 bc	6.270 ef	45.55 c
I_2V_0	14.87 fg	49.47 e	32.71 e	10.66 b	40.41 f
I_2V_1	16.49 c	53.11 d	38.80 c	6.627 ef	43.59 d
I_2V_2	17.19 b	60.37 b	40.85 ab	5.133 f	48.53 a
I_3V_0	15.07 ef	50.74 de	34.19 de	8.750 cd	42.17 de
I_3V_1	16.78 bc	55.97 c	40.66 ab	6.107 ef	46.90 bc
I_3V_2	18.09 a	63.30 a	41.58 a	5.840 ef	47.33 ab
$LSD_{0.05}$	0.4379	2.58	1.579	1.56	1.366
CV(%)	8.42	4.75	5.34	7.94	5.46

I_0 = No irrigation
I_1 = Irrigation at 18 DAS
I_2 = Irrigation at 18 and 47 DAS
I_3 = Irrigation at 18, 47 and 76 DAS

V_0 = No vermicompost
V_1 = Vermicompost @ 5 t ha^{-1}
V_2 = Vermicompost @ 10 t ha^{-1}

4.3 Yield parameters

4.3.1. Grain yield

Effect ofirrigation

Significantly influence on grain yield was observed due to different irrigation levels (Table 5 and Appendix VIII). It was found that the highest grain yield (3.244 t ha^{-1}) was found from I_3 (Irrigation at 18, 47 and 76 DAS). The second highest grain yield (2.923 T ha^{-1}) was found from I_2 (Irrigation at 18 and 47 DAS) where the lowest grain yield (1.961 t ha^{-1}) was found from I_0 (No irrigation). Jessica and Robert (2017), Bian *et al*. (2016), Amin *et al*. (2015) and Shirazi*et al*. (2014) also found similar results with the present investigation.

Effect of vermicompost

Significant difference was found in terms of grain yield of wheat influenced by different rates of vermicompost (Table 5 and Appendix VIII). It was noted that the highest grain yield (3.431 t ha^{-1}) was found from V_2 (Vermicompost @ 10 t ha^{-1}). The lowest grain yield (1.727 t ha^{-1}) was found from V_0 (No vermicompost). The results obtained from the present study was similar with the findings of Agrawal *et al.* (2010), Zhou and Chen (2011), Yousefi and Sadeghi(2014) and Ibrahim *et al*. (2015).

Interaction effect of irrigation and vermicompost

Grain yield was significantly influenced by combined effect of different levels of irrigation and vermicompost (Table 5 and Appendix VIII). Results indicated that the highest grain yield (4.260 t ha^{-1}) was found from the treatment combination of I_3V_2 which was statistically identical with I_2V_2 followed by I_3V_1 where the lowest grain yield (1.483 t ha^{-1}) was found from the treatment combination of I_0V_0 which was statistically similar with I_1V_0.

4.3.2. Straw yield (tha^{-1})

Effect ofirrigation

Significant variation was found on straw yield due to cause of different irrigation levels(Table5andAppendixVIII).Itwasobservedthatthehigheststrawyield(5.317 t ha^{-1}) was found from I_3 (Irrigation at 18, 47 and 76 DAS) where the lowest straw yield (4.694tha^{-1}) was found from I_0 (No irrigation). The straw yield obtained from I_1 (Irrigation at 18 DAS) and I_2 (Irrigation at 18 and 47 DAS) gave intermediate results. Similar results were also observed by Al-Tahar*et al*. (2011) and Ali and Amin(2007).

Effect of vermicompost

Straw yield of wheat was significantly affected by different rate of vermicompost (Table 5 and Appendix VIII). Results revealed that the highest straw yield (5.477 t ha^{-1}) was found from V_2 (Vermicompost @ 10 t ha^{-1}) where the lowest straw yield (4.42 t ha^{-1}) was found from V_0 (No vermicompost). V_1 (Vermicompost @ 5 tha^{-1}) represented intermediate straw yield compared to others. Similar results were also observed by Patil and Bhilare (2006).

Interaction effect of irrigation and vermicompost

Significant variation was remarked for straw yield of wheat due to combined effect of different levels of irrigation and vermicompost (Table 5 and Appendix VIII). It was found that the highest straw yield (5.78 t ha^{-1}) was found from the treatment combination of I_3V_2which was statistically similar with I_2V_2 followed by I_3V_1. The lowest straw yield (4.183 t ha^{-1}) was found from the treatment combination of I_0V_0 which was statistically similar with I_1V_0.

4.3.3. Biological yield (t ha^{-1})

Effect ofirrigation

Significant variation was found on biological yield due to cause of different irrigation levels (Table 5 and Appendix VIII). It was observed that the highest biological yield (8.561 t ha^{-1}) was found from I_3 (Irrigation at 18, 47 and 76 DAS) where the lowest biological yield (6.656 t ha^{-1}) was found from I_0 (No irrigation). Irrigation treatment, I_1 (Irrigation at 18 DAS) and I_2 (Irrigation at 18 and 47 DAS) gave medium results compared to highest and lowest biological yield.

Effect of vermicompost

Biological yield of wheat was significantly affected by different rate of vermicompost (Table 5 and Appendix VIII). Results indicated that the highest biological yield (8.908 t ha^{-1}) was found from V_2 (Vermicompost @ 10 t ha^{-1}) followedby V_1 (Vermicompost @ 5 t ha^{-1}) where the lowest biological yield (6.147 t ha^{-1}) was found from V_0 (No vermicompost).

Interaction effect of irrigation and vermicompost

Significant variation was remarked for biological yield of wheat due to combined effect of different levels of irrigation and vermicompost (Table 5 and Appendix VIII). Results exposed that the highest biological yield (10.04 t ha^{-1}) was found from the treatment combination of I_3V_2 which was statistically identical with I_2V_2 where the lowest biological yield (5.667 t ha^{-1}) was found from the treatment combination of I_0V_0 followed by I_2V_0.

4.3.4. Harvest index (%)

Effect of irrigation

Harvest index was significantly influenced by different levels of irrigation (Table5 and Appendix VIII). It was found that the highest harvest index (37.10%) was found from I_3 (Irrigation at 18, 47 and 76 DAS) which was significantly different from others followed by I_2 (Irrigation at 18 and 47 DAS). The lowest harvest index (29.23%) was found from I_0 (No irrigation). Similar results were also observed by Jessica and Robert (2017), Amin *et al*. (2015) and Erekul *et al*. (2012).

Effect of vermicompost

Significant variation was observed in terms of harvest index of rice influenced by different rates of vermicompost (Table 5 and Appendix VIII). It was observed that the highest harvest index (37.95%) was found from V_2 (Vermicompost @ 10 t ha^{-1}) where the lowest harvest index (27.98%) was found from V_0 (No vermicompost).

Interaction effect of irrigation and vermicompost

Combined effect of different levels of irrigation and vermicompost showed significant difference on harvest index (Table 5 and Appendix VIII). It was noted that the highest harvest index (42.43%) was found from the treatment combination of I_3V_2 which was statistically identical with I_2V_2. The lowest harvest index (26.18) was found from the treatment combination of I_0V_0 which was statistically identical with I_1V_0 and I_2V_0. Similar results were also observed by Agrawal *et al.*, 2010 and Dastmozd *et al*. (2015).

Table 5. Yield parameters of wheat as influenced by irrigation, vermicompost and their interaction

Treatment	Yield parameters			
	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Irrigation				
I_0	1.961 d	4.694 d	6.656 d	29.23 d
I_1	2.450 c	4.961 c	7.411 c	32.47 c
I_2	2.923 b	5.143 b	8.067 b	35.24 b
I_3	3.244 a	5.317 a	8.561 a	37.10 a
$LSD_{0.05}$	0.1264	0.1548	0.3064	1.519
CV(%)	3.62	3.88	4.71	5.36
Vermicompost				
V_0	1.727 c	4.420 c	6.147 c	27.98 c
V_1	2.777 b	5.190 b	7.967 b	34.60 b
V_2	3.431 a	5.477 a	8.908 a	37.95 a
$LSD_{0.05}$	0.2189	0.2354	0.2896	1.315
CV(%)	3.92	4.48	5.37	5.56
Ineraction				
I_0V_0	1.483 h	4.183 i	5.667 i	26.18 f
I_0V_1	2.137 ef	4.877 f	7.013 f	30.48 e
I_0V_2	2.263 e	5.023 ef	7.287 f	31.03 e
I_1V_0	1.613 gh	4.367 hi	5.980 h	26.96 f
I_1V_1	2.617 d	5.133 e	7.750 e	33.76 d
I_1V_2	3.120 c	5.383 cd	8.503 c	36.68 bc
I_2V_0	1.757 g	4.483 gh	6.240 h	28.14 f
I_2V_1	2.933 c	5.227 de	8.160 d	35.94 c
I_2V_2	4.080 a	5.720 ab	9.800 a	41.64 a
I_3V_0	2.053 f	4.647 g	6.700 g	30.63 e
I_3V_1	3.420 b	5.523 bc	8.943 b	38.24 b
I_3V_2	4.260 a	5.780 a	10.04 a	42.43 a
$LSD_{0.05}$	0.1896	0.2048	0.2896	1.981
CV(%)	4.84	6.88	5.99	8.54

I_0 = No irrigation
I_1 = Irrigation at 18 DAS
I_2 = Irrigation at 18 and 47 DAS
I_3 = Irrigation at 18, 47 and 76 DAS

V_0 = No vermicompost
V_1 = Vermicompost @ 5 t ha^{-1}
V_2 = Vermicompost @ 10 t ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh, during the period from November 2016 to March 2017 to study the effect of vermicompost on growth and yield of wheat under different moisture regimes. The experiment comprised of four levels of irrigation *viz*., I_0 (No irrigation), I_1 (Irrigation at 18 DAS), I_2 (Irrigation at 18 and 47 DAS) and I_3 (Irrigation at 18, 47 and 76 DAS) and three levels of vermicompost *viz*., V_0 (No vermicompost), V_1 (Vermicompost @ 5 t ha^{-1}) and V_2 (Vermicompost @ 10 t ha^{-1}). Thus there were twelve treatment combinations and the experiment was laid out in Split Plot Design with three replications. All the growth characters; plant height, number of tillers $plant^{-1}$, dry weight $plant^{-1}$, yield contributing parameters; spike length (cm), number of spikelets $spike^{-1}$, number of filled grains $spike^{-1}$, number of unfilled grains $spike^{-1}$, weight of 1000 seeds and yield parameters; grain yield, straw yield, biological yield, harvest index varied significantly due to different levels of irrigation and vermicompost and their combination.

In case of the effect of irrigation frequencies, considering growth parameters, the highest plant height [34.44, 75.65, 85.22 and 90.67 cm at 40, 60, 80 days after sowing (DAS) and at harvest, respectively], number of tillers $plant^{-1}$ [2.152, 2.434, 4.387 and 4.249 at 40, 60, 80 days after sowing (DAS) and at harvest respectively] and dry weight $plant^{-1}$ [16, 26, 17.47, 27.55 and 34.33g at 40, 60, 80 days aftersowing (DAS) and at harvest, respectively] were achieved from I_3 [Irrigation at 18, 47 and 76 days after sowing (DAS)]. Considering yield and yield contributing parameters, the highest spike length (16.65cm), number of spikelets $spike^{-1}$ (56.67), number of filled grains $spike^{-1}$ (38.81), grain yield (3.244 t ha^{-1}), straw yield (5.317 t ha^{-1}), biological yield (8.561 t ha^{-1}) and harvest index(37.10%) were obtained from I_3 (Irrigation at 18, 47 and 76 DAS); but the lowest number of unfilled grains $spike^{-1}$ (6.90) and highest 1000 seeds weight (45.47 g) were found from I_2 (Irrigation at 18 and 47 DAS). The lowest plant height (25.02, 67.54, 71.99 and 77.05 cm at40, 60, 80 DAS and at harvest, respectively), number of tillers plant^{-1} (1.069, 1.284, 2.616 and 2.407 at 40, 60, 80 DAS and at harvest, respectively) and dry weight plant^{-1} (9.12, 10.64, 16.68 and 23.81 g at 40, 60, 80 DAS and at harvest, respectively) were found from I_0 (No irrigation). The lowest spike length (14.85 cm), number of spikelets spike^{-1} (48.42), number of filled grains spike^{-1} (33.64), number of unfilled grains spike^{-1} (10.70), 1000 seeds weight (41.13 g), grain yield (1.961 t ha^{-1}), straw yield (4.694 t ha^{-1}), biological yield (6.656 t ha^{-1}) and harvest index (29.23%) were also obtained from I_0 (No irrigation).

In terms of vermicompost application all the studied parameters showed best performance with V_2 (Vermicompost @ 10 t ha^{-1}) whereas V_0 (No vermicompost) showed lowest performance. Results showed that the highest plant height (36.19, 76.84, 84.68 and 90.67 cm at 40, 60, 80 DAS and at harvest, respectively), number of tillers plant^{-1} (2.183, 2.481, 4.262 and 4.051 at 40, 60, 80 DAS and at harvest, respectively), dry weight plant^{-1} (16.26, 17.47, 27.55 and 34.33 g at 40, 60, 80 DAS and at harvest, respectively), spike length (16.87 cm), number of spikelets spike^{-1} (57.01), number of filled grains spike^{-1} (39.45), 1000 seeds weight (46.05 g), grain yield (3.431 t ha^{-1}), straw yield (5.477 t ha^{-1}), biological yield (8.908 t ha^{-1}) and harvestindex(37.95%) were found from V_2 (Vermicompost @ 10 t ha^{-1}). The lowest number of unfilled grains spike^{-1} (6.38) was also found from V_2 (Vermicompost @ 10 t ha^{-1}). The lowest plant height (24.11, 66.54, 73.01 and 78.08 cm at 40, 60, 80 DAS and at harvest, respectively), number of tillers plant^{-1} (1.168, 1.407, 2.852 and 2.671 at 40, 60, 80 DAS and at harvest, respectively), dry weight plant^{-1}(9.12, 10.64, 16.68 and 23.81 g at 40, 60, 80 DAS and at harvest, respectively), spike length (14.51 cm), number of spikelets spike^{-1} (47.46), number of filled grains spike^{-1} (32.42), 1000 seeds weight (40.37 g), grain yield (1.727 t ha^{-1}), straw yield (4.42 t ha^{-1}), biological yield (6.147 t ha^{-1}) and harvest index (27.98%) were found from V_0 (No vermicompost). The highest number of unfilled grains spike^{-1} (11.34) was also obtained from V_0 (No vermicompost).

Regarding the interaction effect of irrigation levels and vermicompost, the highest plant height (39.94, 80.46, 90.75 and 95.47 cm at 40, 60, 80 DAS and at harvest, respectively), number of tillers plant^{-1} (2.630, 2.96, 4.967 and 4.907 at 40, 60, 80 DAS and at harvest, respectively), dry weight plant^{-1}(15.72,17.33,,27.03 and 33.65 g at 40, 60, 80 DAS and at harvest, respectively), spike length (18.09 cm), number of spikelets spike^{-1} (63.30), number of filled grains spike^{-1} (41.58), grain yield (4.260 t ha^{-1}), straw yield (5.78 t ha^{-1}), biological yield (10.04 t ha^{-1}) and harvest index (42.43%) were found from the interaction of I_3V_2. But the highest 1000seeds weight (48.53 g) and lowest number of unfilled grains spike^{-1} (5.133) were found from the treatment combination of I_2V_2. The lowest plant height (20.69, 62.78, 67.53 and 72.39 at 40, 60, 80 DAS and at harvest, respectively), number of tillers plant^{-1} (0.820, 1.047, 2.036 and 1.910 at 40, 60, 80 DAS and at harvest, respectively), dry weight plant^{-1} (10.11, 11.62, 18.05 and 25.08 g at 40, 60, 80 DAS and at harvest, respectively), spike length (13.49 cm), number of spikelets spike^{-1} (43.36), number of filled grains spike^{-1} (30.20), 1000 seeds weight (38.77 g), grain yield (1.483 t ha$^{- 1}$), straw yield (4.183tha^{-1}), biological yield (5.667 t ha^{-1}) and harvest index (26.18) were found from the interaction of I_0V_0. But the highest number of unfilled grains spike^{-1} (12.33) was found from the treatment combination of I_1V_0.

Considering the above findings, it can be concluded that the optimum growth and higher yield of wheat cv. BARI gom 26 could be obtained by applying three irrigation at 18, 47 and 76 DAS with vermicompost @ 10 t ha^{-1}. However, further studies are necessary to arrive at a definite conclusion.

CHAPTER VI

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

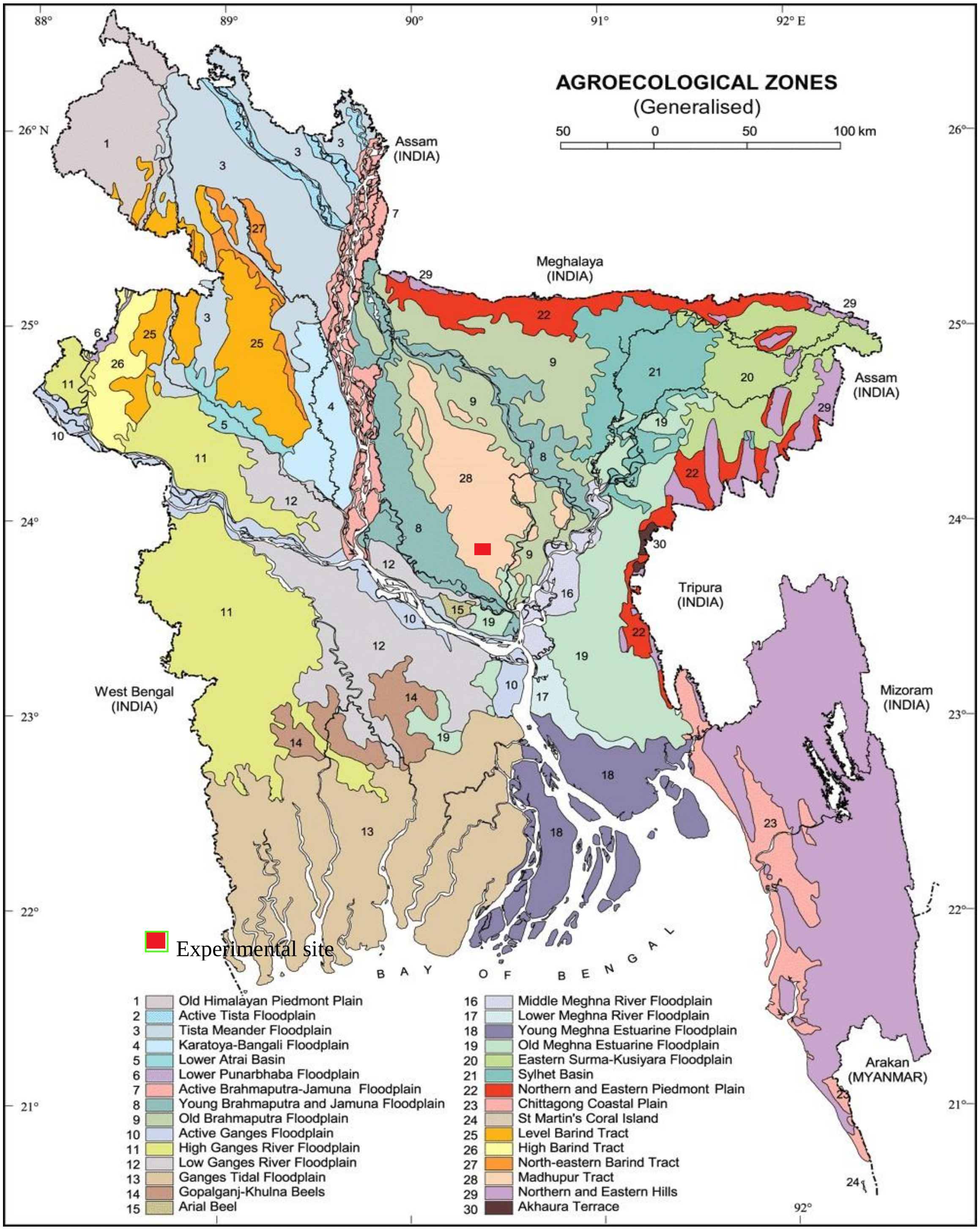


Figure 7. Experimental site

Appendix II. The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation

Particle size constitution:

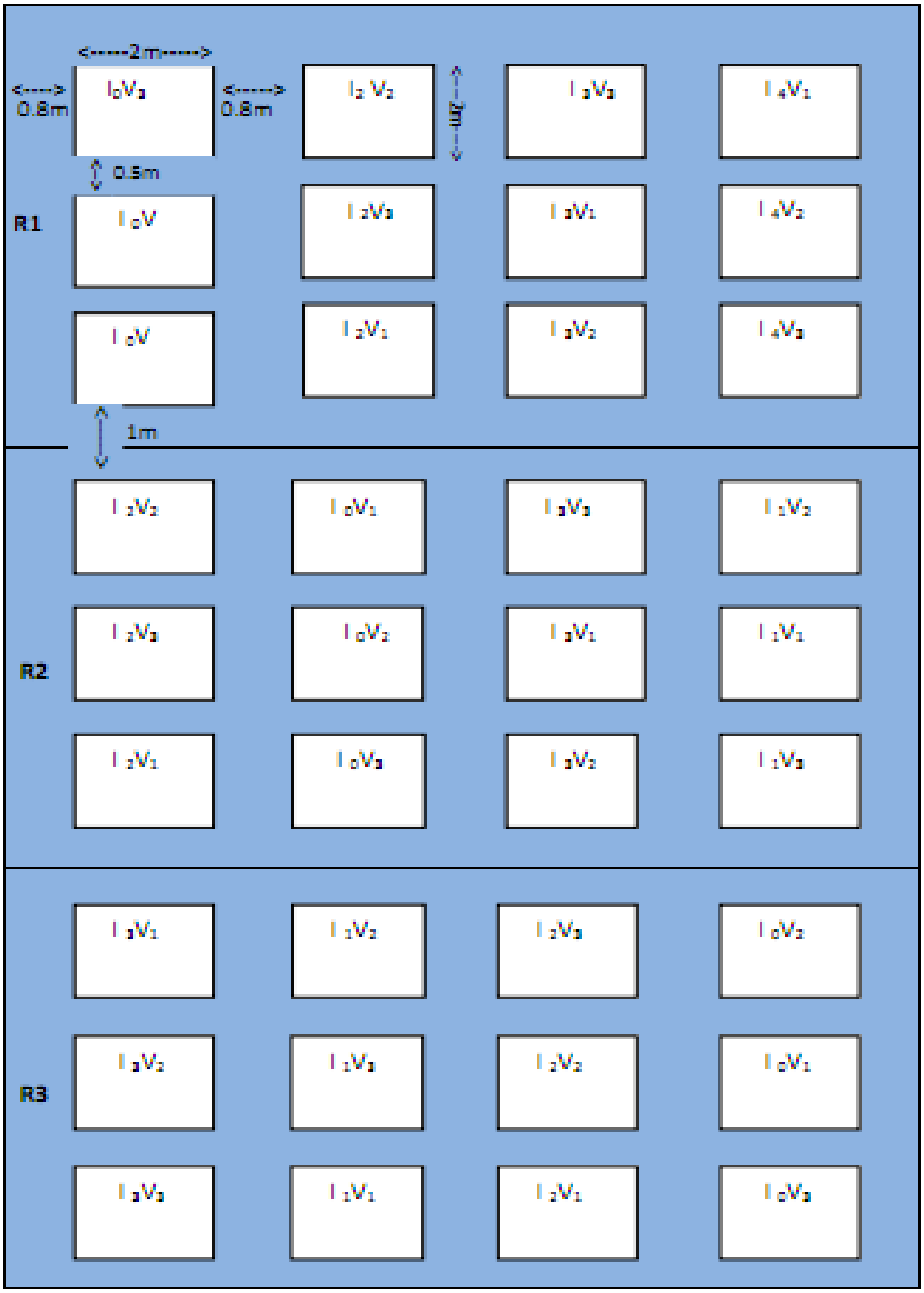
Sand	:	40 %
Silt	:	40 %
Clay	:	20 %

Chemical composition:

Constituents	:	0-15 cm depth
pH	:	5.45-5.61
Total N (%)	:	0.07
Available P (µ gm/gm)	:	18.49
Exchangeable K (µ gm/gm)	:	0.07
Available S (µ gm/gm)	:	20.82
Available Fe (µ gm/gm)	:	229
Available Zn (µ gm/gm)	:	4.48
Available Mg (µ gm/gm)	:	0.825
Available Na (µ gm/gm)	:	0.32
Available B (µ gm/gm)	:	0.94
Organic matter (%)	:	0.83

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

APPENDIX III: Layout of the experiment field



Appendix IV: Mean square of plant height of wheat as influenced by irrigation, vermicompost and their interaction at different days after sowing (DAS)

Sources of variation	Degrees of freedom	Mean square			
		40 DAS	60 DAS	80 DAS	At harvest
Replication	2	3.795	5.734	6.664	5.429
Factor A	3	14.81*	11.48*	27.10*	30.68*
Error	6	7.317	1.771	4.784	7.651
Factor B	2	44.06*	35.15*	48.62*	49.42*
AB	6	6.867*	2.534**	10.97*	13.48**
Error	16	3.049	2.788	8.009	5.243

NS = Non-significant * = Significant at5%level ** = Significant at 1%level

Appendix V: Mean square of number of tillers plant^{-1} of wheat as influenced by irrigation,vermicompost and their interaction at different days after sowing (DAS)

Sources of variation	Degrees of freedom	Mean square			
		40 DAS	60 DAS	80 DAS	At harvest
Replication	2	0.032	0.036	0.016	0.044
Factor A	3	2.249**	2.541**	5.106*	5.438*
Error	6	0.036	0.007	0.007	0.065
Factor B	2	3.126**	3.483*	6.064*	5.839*
AB	6	0.156**	0.199**	0.154*	0.175**
Error	16	0.011	0.008	0.028	0.041

NS = Non-significant * = Significant at5%level ** = Significant at 1%level

Appendix VI: Mean square of dry weight plant^{-1} of wheat as influenced by irrigation, vermicompost and their interaction at different days after sowing (DAS)

Sources of Variation	Degrees of freedom	Mean square			
		40 DAS	60 DAS	80 DAS	At harvest
Replication	2	1.786	2.644	2.736	3.351
Factor A	3	15.37*	16.48*	20.28*	18.36*
Error	6	3.575	5.396	4.806	8.459
Factor B	2	34.47*	47.97*	45.80*	44.45*
AB	6	3.198**	2.588**	7.290*	6.769*
Error	16	5.253	4.832	4.046	5.110

NS = Non-significant * = Significant at5%level ** = Significant at 1%level

Appendix VII: Mean square of yield contributing parameters as influenced by irrigation, vermicompost and their interaction

Sources of variation	Degrees of freedom	Mean square				
		Spike length	Number of spikelets spike^{-1}	Number of filled grains spike^{-1}	Number of unfilled grains spike^{-1}	Weight of 1000 seeds
Replication	2	3.009	3.014	2.997	0.546	5.549
Factor A	3	5.326*	12.77*	13.11*	5.516*	30.40*
Error	6	4.958	6.589	24.47	2.078	4.428
Factor B	2	17.51*	36.53*	68.52*	21.13*	98.76*
AB	6	0.237**	12.449*	1.119**	1.654**	3.843*
Error	16	5.964	6.222	3.832	1.812	5.623

NS = Non-significant * = Significant at5%level ** = Significant at 1%level

Appendix VII: Mean square of yields and harvest index as influenced by irrigation, vermicompost and their interaction

Sources of variation	Degrees of freedom	Mean square			
		Grain yield	Straw yield	Biological yield	Harvest index
Replication	2	0.154	0.220	0.742	2.226
Factor A	3	2.828*	0.637*	6.142*	16.89*
Error	6	0.021	0.027	0.083	0.727
Factor B	2	8.869*	3.583*	23.64*	39.09*
AB	6	0.397**	0.028**	0.624**	10.68*
Error	16	0.016	0.060	0.094	2.310

NS = Non-significant * = Significant at5%level ** = Significant at 1%level