Effect of Vermicompost and Zinc on Performance of Wheat (*Triticum aestivum* L.) in Loamy Sand Soil

दोमट बलुई मृदा में गेहूँ [*ट्रिटिकम् एसटाईवम्* एल.] के निष्पादन पर वर्मीकम्पोस्ट एवं जिंक का प्रभाव

Bhanwar Lal Meena

Thesis

Master of Science in Agriculture

उत्तमा वृतिस्तु कृषिकर्मैव

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Department of Soil Science and Agricultural Chemistry
S.K.N. COLLEGE OF AGRICULTURE, JOBNER - 303329
SWAMI KESHWANAND RAJASTHAN AGRICULTURAL UNIVERSITY,
BIKANER

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Thesis

Submitted to the
Swami Keshwanand Rajasthan Agricultural University, Bikaner
in partial fulfilment of the requirement
for the degree of

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in the

Faculty of Agriculture

(Soil Science & Agricultural Chemistry)

By

Bhanwar Lal Meena

2012

Swami Keshwanand Rajasthan Agricultural University, Bikaner
S.K.N. College of Agriculture, Jobner

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Dated :…………2011

This is to certify that the thesis entitled **"Effect of vermicompost and zinc on performance of wheat (*Triticum aestivum* L.) in loamy sand soil"** submitted for the degree of **Master of Science** in the subject of **Soil Science and Agricultural Chemistry** embodies bonafide research work carried out by **Mr. Bhanwar Lal Meena** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by the advisory committee on …………….

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Dated :----------- 2012

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Place : Jobner
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1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is very important staple and remunerative *rabi* crops, cultivated in almost all the countries of the world. Among major wheat producing countries, India ranked second next to china with regards to its production in world (Agriculture Sectors National Portal). It is the second most important cereal crop after rice in India, and grown under diverse agro-climatic conditions. In India it is grown on 28 million hectare area with a production of 80.71 million tonnes having an average productivity of 2891 kg/ha (Economics survey 2009-10). It contributes 30 per cent of total protein in the human diet and also contributes substantially in feeding of livestock (Timisina and Cannor, 2001).

The population of India is more than 1.21 billion and based on the present rate of population growth of 1.5 per cent the demand for wheat is expected to be around 109 million tonnes by 2020 (Indian Economy of Agricultural, 2009-10). As there is no scope to increase the net cultivated area, which has stabilized at 141 million hectares, consequently the land to man ratio is narrowing rapidly. Therefore, the future requirement has to be met through vertical growth.

Uttar Pradesh, Punjab, Haryana, Gujarat, Rajasthan and Bihar are major wheat growing states in India .In Rajasthan it is cultivated in about 30.36 lakh hectares of land with total production of 10.4 million tonnes having an average productivity of 3433 kg ha^{-1} (Anonymous, 2010-11). Highest area (2.36 lakh hectares) and production (10.49 lakh tonnes) of wheat is under Ganganagar district (DOA,Raj. 2010-11.).

The productivity of wheat in Rajasthan is low as compared to Punjab and Haryana is mainly due to arid and semi arid climate. Sandy soils are of wide occurrence in Rajasthan. These soils are excessively permeable mainly because of their coarse texture and poor organic matter content. The moisture retention capacity of these soils is also very low and more than one third of applied water or through rains get lost through deep percolation (Mann and Singh 1975). Wheat is an exhaustive crop of soil nutrients. The deteriorating soil health, declining soil organic matter and increase of micronutrient deficiencies has put a big question mark on the sustainability of wheat production.

Soil organic matter plays a key role in influencing the nutrient dynamics in soils. It acts as a sink by hoarding the nutrients temporarily through array of biochemical processes ranging from adsorption reactions to organic-nutrient forms. Organically held plant nutrients play a vital role in sustaining plant nutrient availability. It also maintains optimum temperature and moisture in soil.

Vermicompost, now a days gaining more and more importance as a substitute of other organic manures due to its comparatively higher nutrient concentration with quick release of nutrients and which are available mostly to the current crop. It also takes part in improving the physical conditions of the soil. Vermicompost is an eco- friendly and an effective way to recycle agriculture and kitchen waste. It can also be called as biological manure and its application not only adds plant nutrients(macro and micro) and growth regulators but also increases soil water retention, nutrient content and organic carbon content of the soil.

Besides all these, vermicompost also improves soil aeration, reduces soil erosion and evaporation losses of water. It accelerates the process of humification , stimulates the microbial activity, deodorification of obnoxious smell, destruction of pathogens and detoxification of pollutant (Manna and Hagra ,1996)

The increased use of high analysis fertilizers under intensive agriculture with low or no addition of organic manures has also created micronutrient deficiency in the soil. Micronutrients have been come to occupy an important position in Indian Agriculture. In many part of country, currently several million hectares of crop land have been reported to be affected by the zinc deficiency and approximately one third of the human population suffers from an inadequate intake of zinc. Low zinc content in grain and straw result in poor zinc nutrition of human beings and animals has recently received considerable attention (Cak Mak 2008). Zinc as a plant nutrient now stands third in importance next to nitrogen and phosphorus and has become increasingly important in agricultural production during the past two decades. (Takkar and Randhawa, 1980).

Zinc is a constituent part of certain enzymes like triose phosphate and dehydrogenase in higher plants as well as in micro organisms. Zinc plays an indirect role in synthesis of chlorophyll and protein and also regulates water absorption. It is also concerned with carbohydrate metabolism, activation of various enzymes and is necessary for the formation of amino acids like tryptophan which is involved in the formation of IAA hormone. It also catalyses the process of oxidation in plant cells, transformation of carbohydrates and help in the formation of auxins.

Long-term studies, being carried out at several locations in different cropping systems indicated that application of all the needed nutrients through chemical fertilizers has deleterious effect on soil fertility leading to unsustainable yields (Hegde, 1992; Nambiar et al., 1992). These studies further indicated that integration of chemical fertilizers with organic sources of nutrients will be able to maintain soil fertility and sustain crop productivity. The interactive advantages of combining inorganic and organic sources of nutrients generally proved superior to the use of each component separately (Nambiar and Abrol, 1989; Singh and Yadav, 1992). Thus to maintain the soil health, integrated nutrient management approaches involving organic and mineral sources need to be standardized.

Wheat Raj 3077 has emerged as promising variety for this region and information on use of vermicompost and zinc with (100% RDF) is meager in light textured soils of this tract. Therefore, a field experiment entitled "Effect of Vermicompost and zinc on performance of wheat (*Triticum aestivum* L.) In loamy sand soil " was conducted in *rabi* season 2010-11 with the following objectives:

(i) To study the effect of vermicompost and zinc on physico-chemical properties of soil,

(ii) To evaluate the effect of vermicompost and zinc on growth, yield and quality of wheat and

(iii) To work out the economics of the treatment.

2. REVIEW OF LITERATURE

2.1 Effect of vermicompost

2.1.1 Physico-chemical properties of soil

An improvement in porosity, hydraulic conductivity, water holding capacity, pH and CEC was observed as a result of manure application (Singh and Singh 1974).

Bhatia and Shukla (1982) found that continuous application of organic and its combination with inorganic fertilizers significantly increased the hydraulic conductivity of soil over control. The increase in hydraulic conductivity might be due to increase in soil organic matter content and subsequent increase in porosity of soil as a result of increase in soil aggregate size. However, the effect of organic matter in improving WHC was quite prominent in soils with comparatively less clay content (Somani and Saxena, 1977).

Luishuxin *et al.* (1992) reported that application of vermicompost to soil resulted in increased N, P, K, Fe, Mn, Cu, Zn, organic carbon content and CEC values.

Bellaki *et al.* (1998) observed a significantly lower bulk density with the application of various organic materials along with the application of vermicompost to meet 50 per cent nitrogen to soil resulted in increased N, P, K, Fe, Mn, Cu, Zn, organic carbon content and CEC values and decreased bulk density of the soil.

Organic manures have been generally valued as sources of the primary nutrients but they are also potential sources of micro nutrients Itnal, (1998).

Reddy and Reddy (1999) reported a significant increase in DTPA extractable Fe, Mn, Cu and Zn content in soil with integrated use of vermicompost and poultry manure.

Nethra *et al.* (1999) found the maximum available nitrogen content (493.31 kg/ha) in the plot receiving the application of vermicompost @ 5 t ha^{-1} and 100% N, P and K.

Maheswarappa *et al.* (1999) found that the application of vermicompost alone and in combination with NPK have been found to decrease bulk density, improved soil porosity and maximum water holding capacity .

Vasanthi and Kumar Swamy (1999) reported significantly higher grain yield of rice and enhanced available status of N, P, K and micronutrients in the soil, with the application of vermicompost @ 5 to 10 t ha^{-1} along with recommended dose of NPK.

Shreeniwas (2000) reported that available nitrogen in soil increased significantly with increasing level of vermicompost.

Sharma *et al.* (2000) observed a significant reduction in bulk density with significant improvement in WHC, CEC, available N, P and S status of soil with addition of crop residue and FYM.

Rezacnejad *et al.* (2001) reported that organic amendment significantly increased soil organic matter content and plant available N, P and K.

Addition of organic manure like FYM, crop residue along with inorganic fertilizer had a beneficial effect in increasing the N, P and K availability, which was also observed by Tolanur and Badnur (2003).

Thomas and Lal (2004) reported increase in soil organic carbon values of up to 0.586% with the application of farm compost @ 5 t/ha in combination with poultry manure @ 0.5 t/ha or vermicompsot @ 1 t/ha.

A field experiment was conducted by Yadav (2005) during *rabi* 2003-04 and 2004-06 at Jobner in Typic Ustipsamment. The results showed that the bulk density of soil decreased significantly besides increase in total pore space, saturated hydraulic conductivity, moisture content, organic carbon and available N and S content of surface soil at harvest stage of crop with the application of FYM @ 10 t ha^{-1} + 2 per cent clay mixing.

Selvi *et al.* (2005) also noticed reduction in bulk density of soil with application of organics alone and in combination with inorganics.

Use of chemical fertilizers in combination with organic manure is essentially required to improve the soil heath (Bajpai *et al.* 2006).

Yadav *et al.* (2009) reported that the combined use of organic manures and chemical fertilizers improves the physical condition of soil more effectively than continuous addition of chemical fertilizes alone.

Zhao *et al.* (2009) reported that organic manures significantly influenced soil properties and crop yields. Farm yard manure combined with chemical fertilizer management (FYM+NP) resulted in higher increase in OC, available –N and available P.

2.1.2 Growth, yield attributes and yield

Gupta (1994) found significant increase in number of effective tillers and of wheat with the application of 8 t FYM ha^{-1} over control.

Bhakar *et al.* (1997) reported that application of 15 t FYM ha^{-1} gave significant higher number of total tillers, effective tillers and grain per ear of barley over no FYM and 5 t FYM ha^{-1} but was at par with 10 t FYM.

A significant improvement in growth, yield and quality of wheat due to application of 15 t FYM ha^{-1} along with full recommended dose of N and P was observed by Dudhat *et al.* (1997).

Kathuria (1997) in a field experiment observed that at later stages, all the growth parameters increased significantly by the application of different organic manures as compared to no organic manure.

In a field experiment on sugarcane the application of 5 t ha^{-1} vermicompost + 100% RDF increased the yield which was 35.9 per cent higher over control (Zende *et al.*, 1998).

Laddha and Totawat (1998) concluded that incorporation of 10 t FYM ha^{-1} and phosphorus upto 30 kg ha^{-1} increased grain and stover yields of inter crops and sorghum.

Yadav *et al.* (1999) reported significantly higher content of N, P, S and Fe at 60 DAS under poultry manure in wheat like wise the uptake of N, P, S, Fe and K by seed and stover of wheat also increased significantly.

Vasanthi and Kumar Swamy (1999) reported significantly higher grain yield of rice and enhanced available status of N, P, K and micronutrients in the soil, with the application of vermicompost @ 5 to 10 t ha^{-1} along with recommended dose of NPK.

Ranwa and Singh (1999) in an investigation at Hisar reported that application of vermicompost at the rate of 10 t ha^{-1} was at par with 7.5 t ha^{-1} in number of effective tillers, length of ear, number of grains per spike, grain weight per spike, grain and straw yield of wheat but these were significantly higher with repats to application of vermicompost @ 5 t ha^{-1}.

Channabasana *et al.* (2008) reported that application of vermicompost @ 3.8 t ha^{-1} and poultry manure @ 2.4 t ha^{-1} recorded significantly higher plant height (86.30 cm), and higher number of tillers (94.60) per square metre at 90 DAS and also recorded higher test weight (42.73 g) , seed yield (3043 kg ha^{-1}), and protein content (13.41%) as compared to other treatments in wheat crops.

Rajput (2008) studied the effect of nutrient management practices on the growth and yield of pearlmillet (*P. glaucum cv.)* Pusa 605). The highest yield was obtained with 5 t farmyard manure/ha. Each unit increase in N level (0, 30 and 60 kg/ ha) enhanced the growth, yield components (Plant population, plant height and test weight) and yield of peal millet. The highest grain yield (24 q/ha) was obtained with the highest N level.

Ram Lal *et al.* (2008) found that application of 75% RDF NPK fertilizers + 5 tonnes vermicompost-mustard straw/ha gave significantly higher grain and straw yield 48.09 and 74.59 q/ha respectively as compared to the recommended rate of NPK (80:48:0) and it was at par with 100% recommended rate of NPK + 10 tonnes FYM/ha and 50% recommended rate of NPK + 7.5 tonnes vermicompost-mustard straw/ha.

Ashoka *et al.* (2009) reported that application of RDF + 25 kg $ZnSO_4$ /ha + vermicompost @ 3.5 t ha^{-1} recorded significantly higher growth parameters and quality parameters *viz.,* protein (cereals).

Mishra *et al.* (2009) observed that application of organic manure caused a significant improvement in shoot length, number of grains per plant and chlorophyll contents of leaves.

Malik *et al.* (2009) reported that among the three types of fertilizers application zero level , recommended NPK, and recommended NPK+ vermicompost the recommended NPK+ vermicompost significantly enhanced effective tillers, peduncle length and grain yield of wheat crop.

2.1.3 Nutrient content, uptake and quality

Saiko (1972) reported that application of 2 and 3 t FYM ha^{-1} to winter wheat significantly increased the grain protein content.

Choudhary *et al.* (1983) observed that application of FYM significantly increased the uptake of N, P, and K by wheat grown on medium black soil.

Based on green house experiment, Iavaniqua and Manickrah (1991) observed that application of 100% NPK fertilizer along with organic materials increased the available of N, P, K, Ca, Mg, Fe, Mn, Zn and Cu in soil and their respective uptake in the ragi plant.

In a field trial at Moscow (Russia) grain protein content of winter wheat increased 7.6 per cent with 10 t FYM ha^{-1} and 11.0 per cent with 20 t FYM ha^{-1} (Shatilove and Sharov 1992)

Khanam *et al.* (1997) observed that application of organic manure in addition to the recommended dose of fertilizers increased the uptake of N,P,K,Ca and S by the rice plants.

Jadhav *et al.* (1997) in a pot experiment on rice observed that uptake of major nutrients were highest from 75 kg N ha^{-1} as urea + 25 kg N as vermicompost. Toor *et al.* (1999) while evaluating the effect of vermicompost prepared from different crop residues, reported that increasing rate of vermicompost application increased N and P uptake by wheat.

Subehia (1998) reported that application of organic manure @ 10 t ha^{-1} increased the uptake of P, Ca and Mg by wheat and soyabean. Similarly. Ismail *et al.* (1998) concluded that addition of FYM @ 3 t ha^{-1} significantly enhanced the N and P by groundnut.

Chauhan (2001) reported that integrated use of organics and fertilizers to supply the recommended N in the ratio of 1 : 1 increased the N,P,K and Mg content of wheat grain.

Kumawat (2003) found that the combined application of vermicompost @ 4.5 t ha^{-1} + 40 kg N ha^{-1} recorded significantly higher N, P and K uptake in barley and was at par with vermicompost @ 3 t ha^{-1} + 60 kg N ha^{-1}.

Vardana *et al.* (2008) at Hisar found that application of organic manures (FYM and vermicompost) enhanced the NPK uptake by pearlmillet crop, Vidyadharan (2008) while working on barley at Jobner reported that application of vermicompost at 6 t/ha significantly increased the N, P and K content in grain and straw, protein content in grain and NPK uptake over control.

Ashoka *et al.* (2009) reported that application of RDF + 25 kg $ZnSO_4$ /ha + vermicompost @ 3.5 t ha^{-1} recorded significantly higher growth parameters and quality parameters *viz.,* protein (cereals).

Malik *et al.* (2009) reported that fertilizer application in the form of vermicompost and NPK showed significant difference in protein per cent. Vermicompost application significantly enhanced the concentration of micronutrients (Fe, Zn, Cu and Mn) also.

Patra *et al.* (2009) reported that 25% RDF + 5 t Vermicompost ha^{-1} recorded significantly higher uptake of nitrogen, phosphorus and potassium over 50% RDF + 5 t FYM ha^{-1}.

Shwetha *et al.* (2009) reported that as compared to application of RDF at the time of sowing in the control plot, the grain yield of soyabean and wheat the yield was significantly higher in RDF + FYM and combined use of organic manures + fermented organics. A similar trend was noticed with compost + vermicompost with respect to nutrient uptake in both crops.

2.2 Effect of zinc

2.2.1 Physico-chemical properties of soil

Karelia (1990) noted a significant increase in Zn availability with increasing rate of Zn application but it gradually declined with progress of time. He also found that available P status of the soil decreased due to Zn application.

2.2.2 Growth, yield attributes and yield

Patel *et al.* (1995) reported significant improvement in growth and yield attributing characteristics of wheat with the application of $ZnSO_4.7H_2O$ @ 25 kg ha^{-1} as compared to control.

Khurana *et al.* (1996) conducted a field experiment on loamy sand soil of Ludhiana (Punjab) and reported a significant increase in grain and straw yield of wheat with the increased levels of Zn. The maximum yield of grain (42.0 q ha^{-1}) and straw (70.6 q ha^{-1}) were obtained with 11.2 kg Zn ha^{-1}.

Bathar and Patel (2005) reported that Zn application @5 kg Zn ha^{-1} significantly increased the number of total tillers, earhead length and test weight of grains.

Varshney *et al.* (2008) conducted a field experiment under AICRP on micronutrient at the crop research centre of G.B. Pant University of Agriculture and Technology, Pantnagar during 2002-03 and 2003-2004 to assess the effect of frequency and rate of zn application and reported that increasing levels of Zn significantly increased the grain yield in hybrid rice-wheat crops.

Swami and Shekhawat (2009) conducted a field experiment on rice during kharif season, 2007 consisting three moisture regimes (20, 50 and 75 mm irrigation) and four level of zinc sulphate (0, 15, 30 and 45 kg/ha) replicated three times under factorial randomized block design and reported that the grain and straw yield of rice increased significantly with increasing levels of zinc upto 30 kg $ZnSO_4$/ha.

Pandey *et al.* (2009) conducted a field experiment at research farm of Rajendra Agriculture university, Pusa, Samastipur during the rabi season of 2003-03 and 2003-04 to find out the effect of integrated nutrient management on productivity of late sown wheat. The result showed that with the addition of 10 t /ha FYM + 25 kg $ZnSO_4$/ha together with RDF the grain and straw yield were significantly higher than application of RDF, 125 per cent, RDF 150 per cent RDF alone.

Jana *et al.* (2009) conducted a field experiment on transplanted rice grown on farmers field of red and laterite soil and reported that with the application of Zinc there was significantly higher increase in yield attributes and yield of grain and straw.

Ghulam *et al.* (2009) conducted an experiment in which recommended doses of N, P and K were applied @ 150:100:60 kg N:P_2O_5 : K_2O ha^{-1} respectively in all treatments and zinc was applied @ 4, 8, 12 and 16 kg ha^{-1}

as zinc sulphate at the time of sowing except control and reported that combined Zn and NPK application significantly improved growth and yield parameters of wheat.

2.2.3 Nutrient content, uptake and quality

Singh and Tripathi (1974) studied the effect of zinc nutrition on wheat crop at different growth stages in a sandy loam soil and reported that nitrogen concentration increased due to application of 10 ppm zinc as $ZnSO_4.7H_2O$. The increase in nitrogen content of wheat plant due to zinc application was also recorded by Suryawanshi *et al.* (1984).

Singh (1996) while working at Jobner report that application of 15 and 30 kg $ZnSO_4$ /ha to wheat significantly increased the protein and zinc content and uptake as compared to control.

Sahu *et al.* (1996) found that both content and uptake of N, P, K increased significantly with increased level of Zn upto 5 mg kg^{-1} soil and decreased at higher level. Patil *et al.* (1997) reported that chlorophyll content of wheat leaves increased with increasing zinc rates.

Yadav (1999) also reported significant increase in nitrogen content of grain and straw with increasing level of zinc application.

Sharma and Bapat (2000) reported that zinc content in various plant parts of wheat was increased with increasing levels of zinc, similar results were also reported by Hayak and Gupta (2000) in wheat.

Parihar (2002) reported that the application of 10 kg Zn ha^{-1} significantly increased the content and uptake of N, K, Zn and Ca in grain and reduced P content in grain and straw of wheat.

Dwivedi *et al.* (2002) at Kanpur on maize found that protein content increased significantly with the increase of zinc over control. Increase in tryptophan and leusine content in grain was also increased with the increased in zinc level.

Jain (2004) studied the effect of zinc fertilization on wheat and found that application of zinc at 6.0 kg/ha significantly increased the nitrogen and zinc concentration and their uptake in grain and straw. However, a significant decrease in phosphorus concentration was observed over lower levels of applied zinc (0 and 3.0 kg/ha).

Application of $ZnSO_4$ upto 50 kg/ha increased the N, K, Zn, Ca and Mg content significantly while P, Na and Fe content decreased significantly in grain and straw of wheat (Naga, 2005).

Bathar and Patel (2005) reported that 5 kg Zn/ha over control increases the N, P and Zn content in grains and straw.

Jain and Dahama (2007) conducted a field trial for 2 consecutive winter (Rabi) seasons of 2001-02 to 2002-03 to study the effect of phosphorus and zinc on nutrient uptake of wheat at Alwar (Rajasthan). Four levels of phosphorus (0, 30, 60 and 90 kg) and five level of zinc (0, 3, 6, 9 and 12 kg/ha) were applied along with the RDF doses of nitrogen and potassium. The result showed that phosphorus and zinc interaction caused significant effect on uptake of NPK and Zn of wheat crop.

Ashoka *et al.* (2009) reported that application of RDF + 25 kg $ZnSO_4$ /ha + vermicompost @ 3.5 t ha^{-1} recorded significantly higher growth parameters and quality parameters *viz.,* protein (cereals).

Swami and Shekhawat (2009) conducted a field experiment on rice during kharif season 2007 consisting three moisture regimes (20, 50 and 75 mm irrigation) and four levels of zinc sulphate (0, 15, 30 and 45 kg/ha) and replicated there under factorial randomized block design. Result indicated that the uptake of N, P and K by rice increased significantly with increasing levels of zinc upto 30 kg $ZnSO_4$/ha.

3. MATERIALS AND METHODS

A field experiment entitled "Effect of vermicompost and zinc on performance of wheat (*Triticum aestivum* L.) in loamy sand soil" was conducted during *rabi* season of 2010-11 at the Agronomy Farm, S.K.N. College of Agriculture, Jobner. The details of experimental techniques adopted, criteria used for treatment evaluation and methods followed during entire course of investigation are presented in this chapter.

3.1 Location of Experimental Site

Geographically Jobner is located at 75.28^0 East longitudes and 26.05^0 North latitude at an altitude of 427 metres above mean sea level in Jaipur district of Rajasthan. This region falls under agro-climatic Zone-III A (Semi-Arid Eastern Plains).

3.2 Climate and Weather Conditions

The climate of this zone is typically semi-arid characterized by aridity of atmosphere and scarcity of water. The normal annual rainfall of this locality varies between 400 and 500 mm, 85 per cent of which is received from South-West monsoon during July to September. Winters are usually rainless or with very few showers. There is a wide range of temperature both in the summer (30 to 45^0C) and in the winter (-2 to 10^0C). The relative humidity of the locality fluctuates in between 42 and 59 per cent.

3.3 Meteorological observations

The weather conditions prevailed during the period of experimentation (November, 2010 to April, 2011) were recorded at meteorological observatory of the college farm and have been given in Table 3.1 and graphically depicted in Fig. 3.1.

Table 3.1 Mean weekly weather parameters for crop season (*rabi*, 2010-11)

SMW* No.	Duration		Temp. ^{0}C		Relative humidity %	Evaporation (mm/day)	Total rainfall (mm)	Sunshine hrs/day
	From	To	Max	Min				
47	19/11	25/11	23.1	12.5	77	1.5	018.4	4.3
48	26/11	02/11	23.0	8.1	63	2.0	000.0	7.6
49	03/12	09/12	23.0	6.1	57	2.1	000.0	8.5
50	10/12	16/12	23.3	3.4	55	2.1	000.0	8.0
51	17/12	23/12	24.7	2.0	59	2.3	000.2	8.6
52	24/12	31/12	22.5	7.8	65	2.3	000.0	6.9
1	01/01	07/01	17.8	7.4	71	1.5	000.0	6.4
2	08/01	14/01	22.5	3.7	59	2.3	000.0	9.1
3	15/01	21/01	21.5	1.6	61	1.9	000.0	9.3
4	22/01	28/01	22.5	4.5	57	2.4	000.0	8.6
5	29/01	04/02	23.5	4.3	57	2.4	000.0	9.0
6	05/02	11/02	26.7	7.0	56	2.9	000.8	9.5
7	12/02	18/02	24.0	09.1	67	2.6	032.8	7.2
8	19/02	25/02	23.5	09.1	66	2.9	000.0	8.1
9	26/02	04/03	25.3	11.0	61	2.9	001.0	7.2
10	05/03	11/03	28.1	10.6	53	2.7	000.0	8.7
11	12/03	18/03	33.0	09.5	49	4.1	000.0	9.4
12	19/03	25/03	34.8	12.6	41	4.0	000.0	8.7
13	26/03	01/04	36.2	15.7	39	6.0	000.0	8.8
14	02/04	08/04	34.5	13.5	36	7.0	000.0	8.7
15	09/04	15/04	35.1	17.8	34	4.4	000.0	6.8
16	16/04	22/04	35.9	17.6	34	5.2	000.4	9.1

SMW = Standard meteorological week

3.4 Soil of the experimental field

In order to ascertain the physico-chemical characteristics of the soil, the soil samples were collected from different spots of the experimental field randomly from 0-15 cm soil depths and representative composite sample were subjected to physical and chemical analysis separately. The physico-chemical characteristics of the soil of experimental field are given in Table 3.2.

Table : 3.2 Physico-chemical properties of experimental soil

		Characteristics	Value
A.		**Physical properties**	
1.		**Mechanical composition**	
	(i)	Coarse sand (%)	25.1
	(ii)	Fine Sand (%)	58.4
	(iii)	Silt (%)	9.3
	(iv)	Clay (%)	6.7
	(v)	Textural class	Loamy sand
2.		Particle density (Mg m^{-3})	2.60
3.		Bulk density (Mg m^{-3})	1.51
4.		Porosity (%)	41.92
5.		Saturated hydraulic conductivity (cm h^{-1})	8.10
B.		**Chemical properties**	
	(i)	Organic carbon (%)	0.18
	(ii)	Available nitrogen (kg ha^{-1})	156.65
	(iii)	Available phosphorus (P_2O_5 kg ha^{-1})	17.56
	(iv)	Available potassium (K_2O kg ha^{-1})	149.59
	(v)	Available zinc (ppm)	0.45
	(vi)	CEC [cmol (p^+) kg^{-1}]	5.20
	(vii)	ECe (dSm^{-1} at 25 ^0C)	0.90
	(viii)	pH 1:2	8.15

3.5 Cropping history of experimental field

The previous cropping history of the experimental field is presented in Table 3.3.

Table 3.3 Cropping history of the experimental field

Year	*Kharif*	*Rabi*
2008-09	Fallow	Fennel
2009-10	Fallow	Cumin
2010-11	**Fallow**	Wheat

* Experimental crop.

3.6 Quality of irrigation water

The experimental crop was irrigated by an open well. The results of the chemical analysis of irrigation water are given in Table 3.4.

Table: 3.4 Composition of irrigation water used for irrigating the experimental field

S.No.		Characteristics	Value
1.		Soluble cations (meL^{-1})	
	i.	$Ca^{2+} + Mg^{2+}$	6.2
	ii.	Na^{+}	9.1
	iii.	K^{+}	0.1
2.		Soluble anions (meL^{-1})	
	i.	Cl^{-}	3.1
	ii.	CO_3^{2-}	3.3

iii.	HCO_3^-	7.8
iv.	SO_4^{2-}	1.2
3.	pH	8.3
4.	EC (dSm^{-1} at 25℃)	1.54
5.	SAR	7.87
6.	SSP	60.06
7.	RSC (meL^{-1})	5.2
8.	Class (USSL)*	C_3S_1

* United State Salinity Laboratory, Riverside Calif. May 1953. Though the well water was little saline sodic but it could be safely used in light textured soil to irrigate the crop.

3.7 Chemical composition of vermicompost

The nitrogen, phosphorus and potassium content of vermicompost applied in the experimental field are given in Table 3.5

Table: 3.5 Nutrient content of vermicompost

Nutrient	Per cent
Nitrogen	1.7
Phosphorus (P_2O_5)	0.8
Potassium (K_2O)	1.10

3.8 Experimental details

3.8.1 Treatments

Treatments consisted of four levels of vermicompost and four levels of zinc to wheat. The different treatments and their symbols used are given in Table 3.6.

Table: 3.6 Treatments and their symbols

	Treatment	Symbol
A.	**Vermicompost levels (t ha^{-1})**	
i	Control	V_0
ii	2.4	$V_{2.4}$
iii	4.8	$V_{4.8}$
iv	7.2	$V_{7.2}$
B.	**Zinc levels (kg ha^{-1})**	
i.	Control	Zn_0
ii.	2.5	$Zn_{2.5}$
iii.	5.0	$Zn_{5.0}$
iv.	7.5	$Zn_{7.5}$

3.8.2 Experimental details

(i)	Season	*Rabi*, 2010-11
(ii)	Crop	Wheat
(iii)	Variety	Raj-3077
(iv)	Seed rate	120 kg ha^{-1}
(v)	Experimental design	RBD
(vi)	Replication	3
(vii)	Total number of treatments	16
(viii)	Total number of plots	16 x 3 = 48

(ix)	Plot size	
	(a) Gross	4 x 3 = 12 m^2
	(b) Net	3 x 2.53 = 7.59 m^2
(xi)	Row spacing	23 cm
(xii)	Plant spacing	5 cm
(xiii)	Location	Agronomy farm S.K.N. College of Agriculture, Jobner

3.8.3 Design and layout of experiment

Field experiment having 16 treatment combinations and three replications with 48 plots in total was laid out in randomized block design. The treatments were randomly allotted to different plots using random number table (Fisher and Yates, 1963). The plan of layout of experiment along with allocation of the treatments and other details has been shown in Fig. 3.2.

3.9 Details of crop raising

The schedule of pre and post sowing operations carried out in the field during the crop season are given the in Table 3.7 and details of the crop raising are described as under:

3.9.1 Field preparation

The experimental field was ploughed thoroughly by a tractor drawn disc plough followed by cross harrowing and planking. Thereafter, the field was laid out manually into plots according to the plan of layout (Fig. 3.2).

3.9.2 Treatment application

(a) Vermicompost

The vermicompost was applied in the field as per treatments and was thoroughly mixed at the time of sowing.

(b) Zinc

Zinc was applied as per treatments through zinc sulphate. The weighed quantity of zinc sulphate was broadcasted in respective plot and was incorporated uniformly in whole the plot.

A basal dose of 100 kg N + 60 kg P_2O_5 40 kg K_2O through urea DAP and MOP was applied. The full dose of phosphorus and potassium as per treatment and half dose of nitrogen (50 kg ha^{-1}) adjusting the N supplied by DAP were drilled in soil at the depth of 8-10 cm before sowing. Remaining half dose of nitrogen was top dressed just before I irrigation at CRI stage.

3.9.3 Seed treatment

Before sowing, the seeds of wheat were treated with Bavistin @ 2 g kg^{-1} seed to prevent seed and soil borne diseases.

3.9.4 Seed rate and sowing

Seeds of wheat cv. Raj.-3077 (Laxmi) @ 120 kg ha^{-1} were sown on November 25, 2010 in rows spaced at 23 cm apart with the help of bullock drawn 'deshi' plough.

3.9.5 Intercultural operations

One hoeing cum weeding was done at 30 DAS with the help of 'Kassi'. The extra plants were also thinned out at this stage, keeping plant to plant distance of about 5 cm.

3.9.6 Irrigation

Six irrigations were applied to crop as per schedule. Irrigations were given manually by check basin method.

Table 3.7: Schedule of agronomic operations

S.No.	Particulars	Years 2010-2011
1.	Ploughing and planking	Before 15 days of sowing
2.	Date of layout	27.11.2010
3.	Treatments and nutrients applications	28.11.2010
4.	Sowing	29.11. 2010
5.	I irrigation	20.12. 2010
	II irrigation	09.01.2011
	III irrigation	01.02. 2011
	IV irrigation	20.02. 2011
	V irrigation	10.03. 2011
	VI irrigation	23.03. 2011
6.	Top dressing (50 kg N ha^{-1} at first irrigation)	20.12. 2011
7.	Weeding and hoeing	24.12. 2011
8.	Harvesting	20.04. 2011
9.	Threshing and winnowing	28/29.04.11

3.9.7 Variety of the crop

The wheat variety Raj.-3077 used for sowing in the experiments is a high yielding variety. The variety matures in about 130-135 days and is suitable for saline environment and normal and in late sown conditions.

3.9.8 Seed and sowing

Before sowing, the seeds were treated with Bavistin 2 g kg^{-1} seed for control of termites. The sowing was done in row spaced at 23 cm apart using the seed rate 120 kg ha^{-1}.

3.9.10 Irrigation

Besides one pre-sowing irrigation, the crop was given six irrigation at different stages viz., CRI, tillering, late jointing, flowering, milking and dough stage during the period of experimentation.

3.9.11 Weeding and hoeing

In order to minimize crop weed competition, one weeding and hoeing was done manually at 25 to 30 days after sowing.

3.9.12 Harvesting

The harvesting was done on 20 April 2011. Out of ten row planted, eight central rows measuring a net area was harvested separately from each plot. The harvested material of each plot was dried up in bundles, tagged and kept on threshing floor for sun drying.

3.9.13 Threshing and winnowing

After drying, the produce of each plot was weighed separately for biological yield of dry matter at harvesting. Threshing was done manually by beating with wooden sticks and winnowed traditionally.

Observations

Evaluation of treatments was done based on soil and plant observations as under:

3.10 Plant Studies

3.10.1 Plant height

Five plants were selected randomly from each plot and tagged. Height of individual plants was recorded at harvest from base of the plant to top of the main shoot by metre scale and expressed as average height in cm.

3.10.2 Leaf area index

As per schedule, leaf area of five plants from each plot was recorded with the help of leaf area meter (model 3100 , USA). All the leaves from sample plants were detached from ligules, inserted in the conveyor belt of the instrument and the total leaf area measured was computed as leaf area per plant. Leaf area index was calculated as per formula given below (Watson, 1958).

$$\text{Leaf area index} = \frac{\text{Total leaf area (cm}^2\text{)}}{\text{Total land area (cm}^2\text{)}}$$

3.10.3 Number of effective tillers

The ear bearing tillers were counted at harvesting in metre row length.

3.10.4 Number of ears per plant

The total number of ears were counted non destructively and these were averaged as per metre row length.

3.10.5 Test weight

One thousand grains were counted from the grain sample taken after weighing the produce of individual plots for chemical estimations and weighed. The weight was recorded and expressed in gram as test weight.

3.10.6 Grain yield

After recording the biological yield, the material was threshed manually and winnowed. The clean grains obtained from individual plot were weighed and the weights were recorded as grain yield which were converted into quintals per hectare.

3.10.7 Straw yield

Straw yield was obtained by subtracting the grain yield from biological yield. The straw yield recorded under each plot was converted into quintals per hectare.

3.11 Plant Analysis

3.11.1 Nutrient content

Nitrogen, phosphorus, potassium and zinc content in grain and straw were determined. For this purpose, plot wise representative samples of grain and straw were taken, ground and analyzed for their nitrogen, phosphorus, potassium and zinc content the straw sample were also taken, ground and analyzed for their nitrogen, phosphorus, potassium and zinc content using standard methods. The results were expressed as per cent (nitrogen, phosphorus and potassium) and ppm (zinc) on dry weight basis.

3.11.2 Nutrient uptake

After obtaining the content the uptake of nitrogen, phosphorus, potassium and zinc were calculated using following formulae.

Nutrient (N,P&K Uptake (kg ha^{-1}) =

$$\text{Nutrient (N,P\&K Uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) in grain / straw x Grain /straw yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Nutrient (Zn) Uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (ppm) in grain/ straw x Grain/ straw yield (kg ha}^{-1}\text{)}}{1000}$$

3.11.3 Crude protein content in grain

The crude protein content in per cent was obtained by multiplying the per cent nitrogen content in grain with a conversion factor 6.25 (A.O.A.C., 1955).

3.11.4 Chlorophyll content in leaves

Representative fresh leaf samples were taken at flowering stage for chlorophyll determination. The samples were washed with running water, 0.01 N HCl and then twice with distilled water and dried with blotting paper. Out of this, 100 mg leaf material was taken and homogenized in 80 per cent acetone and then final volume of 10 ml was made. This aliquot was centrifuged for 10 minutes at 2000 rpm to clear supernatant. Absorbance of clear supernatant was measured by spactrophotometer at 652 nm. The quantity of chlorophyll was calculated, using the following formula and expressed in mg g^{-1} fresh leaves (Arnon, 1949).

$$\text{Total chlorophyll (mg } g^{-1}) = \frac{A(652) \times 29 \times \text{Total volume (ml)}}{\alpha \times 1000 \times \text{weight of sample (g)}}$$

Where, α is the path length = 1 cm

3.12 Soil studies

3.12.1 Soil physical properties

The bulk density, saturated hydraulic conductivity and moisture retention (at1/3 and 15 bars) of soil at harvest of crop were determined as per method mentioned in Table 3.8.

3.12.2 Soil chemical properties

The organic carbon, available nitrogen, phosphorus, potassium and zinc were determined at harvest stage of crop from surface (0-15 cm) layer as per methods mentioned in Table 3.8.

3.13 Statistical Analysis

The experimental data recorded were subjected to statistical analysis using analysis of variance as outlined by Panse and Sukhatme (1967). The critical difference for the treatments comparison was worked out wherever the 'F' test were found significant at 5 per cent level of significance.

3.14 Economics

The economics of a treatment is the most important consideration before making any recommendation to the farmer for its adoption. In order to determine the effectiveness and economics of the treatment, the additional costs involved due to application of vermicompost and zinc were taken into account. The net returns from each treatment were calculated so as to decide the most effective treatment.

Net return = Gross return – Cost of total inputs

Table 3.8 Methods for soil and plant analysis

S.No.	Item of analysis	Method	Reference
A.	**Soil analysis**		
1.	Mechanical analysis	International pipette method	Piper (1950)
2.	Bulk density (Mg m^{-3})	Undisturbed core sampler method	Singh (1980)
3.	Particle density (Mg m^{-3})	Pycnometer method methods, USDA Hand Book No. 60	Richards (1954)
4.	Porosity (%)	Calculated by using the formula USDA Hand book No. 60	Richards (1954)
5.	Saturated hydraulic conductivity	Undisturbed soil sample by constant Head method (7 cm diameter and 8 cm height)	Singh (1980)
6.	Moisture retention at 1/3 bar	Pressure plate membrane apparatus method	Richards (1954)
7.	Moisture retention at 15 bars	Pressure plate membrane apparatus method	Richards (1954)
8.	Soil Reaction (pH)	With the help of pH meter in 1:2 soil water suspension	Piper (1950)
9.	Electrical conductivity (dSm^{-1})	With the help of EC analyser (1:2 water suspension)	Piper (1950)
10.	Cation exchange capacity (cmol (p^{+}) kg^{-1})	The method No. 19 of USDA Hand Book No. 60	Richards (1954)
11.	Organic carbon (percent)	Walkley and Black's rapid titration method	Piper (1950)
12.	Available nitrogen (kg ha^{-1})	Alkaline potassium permanganate method	Subbiah and Asija (1956)
13.	Available phosphorus (kg ha^{-1})	Extraction with 0.5 M $NaHCO_3$ at pH 8.5 and development of color with $SnCl_2$	Olsen et al. (1954)

14.	Available potassium (kg ha^{-1})	Estimation with 1 N ammonium acetate at pH 7.0 and determined by flame photometer	Metson (1956)
15.	DTPA zinc (ppm)	Extraction with 0.005 M DTPA + 0.001 M $CaCl_2$ + 0.1 M TEA (pH 7.3) extractant and estimated by AAS.	Lindsay and Norvell (1978)
B.	**Plant analysis**		
1.	Digestion of plant sample-1	Wet digestion of plant sample with H_2SO_4 and H_2O_2	Jackson (1967)
2.	Nitrogen content	Spectrophotometer determination after development of color with Nesseler's reagent.	Snell and Snell (1949)
3.	Digestion of plant sample-II	Wet digestion of sample with triacid mixture as per the method described	Johnson and Ulrich (1959)
4.	Phosphorus content (%)	Estimation of phosphorus by spectrophotometrically using vanadomolybdo phosphoric yellow colour method in nitric acid system.	Jackson (1967)
5.	Potassium content (%)	Analysis of suitable aliquot of digested material with the help of flame photometer	Richard (1954)
6.	Zinc content	By wet digetion of plant samples with diacid mixture and was analysed with the help of AAS	Lindsay and Norvell (1978)
7.	Protein content	The protein content in per cent was obtained by multiplying the per cent nitrogen content in seed with conversion factor 6.25	A.O.A.C. (1955)
8.	Chlorophyll content (%)	Fresh leaves was extracted in 80% acetone and chlorophyll contents was estimated by spectrophotometrically	Arnon (1949)

4. RESULTS

Results of field experiment entitled "Effect of Vermicompost and zinc on performance of wheat (*Triticum aestivum* L.) in loamy sand soil" conducted at Agronomy farm, S.K.N. College of Agriculture, Jobner (Swami Keshwanand Rajasthan Agricultural University, Bikaner), during *rabi* season 2010-11 are presented in this chapter. The data relating to various criteria used for treatment evaluation were analyzed statistically using standard statistical methods to test their significance. The analyses of variance for data have been presented in the appendices at the end. The data recorded for important characters have also been presented graphically for elucidation of the important trends wherever, necessary.

The experimental findings are presented under the following appropriate sub heads:

4.1 Effect of vermicompost and zinc on physico-chemical properties of soil

4.1.1 Bulk density

4.1.2 Saturated hydraulic conductivity

4.1.3 Moisture retention at 1/3 and 15 bars

4.1.4 Organic carbon

4.1.5 Available nitrogen

4.1.6 Available phosphorus

4.1.7 Available potassium

4.1.8 Available zinc

4.2 Effect of vermicompost and zinc on growth of wheat

4.2.1 Plant height

4.2.2 Leaf area index

4.3 Effect of vermicompost and zinc on yield attributes of wheat

4.3.1 Number of effective tillers

4.3.2 Number of ears per plant

4.3.3 Test weight

4.4 Effect of vermicompost and zinc on yield of wheat

4.4.1 Grain yield

4.4.2 Straw yield

4.5 Effect of vermicompost and zinc on nutrient content and uptake of wheat

4.5.1 Nitrogen content and uptake

4.5.2 Phosphorus content and uptake

4.5.3 Potassium content and uptake

4.5.4 Zinc content and uptake

4.6 Effect of vermicompost and zinc on quality of wheat

4.6.1 Crude protein content in grain

4.6.2 Chlorophyll content in leaves

4.7 Economic

4.1 Effect of vermicompost and zinc on physico-chemical properties of soil

The data relating to the effect of vermicompost and zinc on bulk density , saturated hydraulic conductivity , moisture retention at 1/3 and 15 bars , organic carbon, available nitrogen, phosphorus, potassium and zinc of soil at harvest stage have been summarized in Tables 4.1and 4.2 and also depicted in Figures 4.1 and 4.2. Whereas, the analysis of variance have been given in appendices-I and II.

4.1.1 Bulk density

Effect of vermicompost

The data presented in Table 4.1 revealed that in comparison to control (V_0) an application of the vermicompost @ of 4.8 and 7.2 t ha^{-1} resulted in a significant decrease in bulk density at harvest. However, with the application of vermicompost @ 2.4 t ha^{-1} the decrease in bulk density was non significant. The highest decrease in bulk density of soil was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} decreased the bulk density of soil to the extent of 4.03, 2.31 and 1.05 per cent respectively as compared to control.

Effect of zinc

The critical appraisal of data presented in Table 4.1 revealed that the effect of zinc application on bulk density of the soil at harvest was found non-significant.

4.1.2 Saturated hydraulic conductivity

Effect of vermicompost

The data presented in Table 4.1 showed that with the application of vermicompost @ 4.8 and 7.2 t ha^{-1} there was a significant increase in saturated hydraulic conductivity as compared to control (V_0). However, an application of vermicompost @ 2. 4 t ha^{-1} the increase in saturated hydraulic conductivity was non significant. The incorporation of vermicompost @ 7.2, 4.8 and 2.4 t $ha-^{1}$ increased the saturated hydraulic conductivity of soil to the extent of 29.24, 16.21 and 5.10 per cent respectively as compared to control (V_0).

Effect of zinc

The data in Table 4.1 revealed that an application of zinc the increase in saturated hydraulic conductivity of soil was non significant.

Table: 4.1 Effect of vermicompost and zinc levels on bulk density, saturated hydraulic conductivity and moisture retention (at 1/3 bar and 15 bars) of soil

Treatments	Bulk density ($Mg\ m^{-3}$)	Saturated hydraulic conductivity ($cm\ h^{-1}$)	Moisture retention at 1/3 bar (%)	Moisture retention at 15 bars (%)
Vermicompost levels				
V_0	1.513	7.83	9.60	2.86
$V_{2.4}$	1.497	8.23	10.18	3.04
$V_{4.8}$	1.478	9.10	10.90	3.40
$V_{7.2}$	1.452	10.12	11.87	3.88
SEm$\pm$	0.006	0.17	0.23	0.07
CD (P=0.05)	0.017	0.50	0.66	0.19
Zinc levels				
Zn_0	1.492	8.55	10.40	3.24
$Zn_{2.5}$	1.490	8.73	10.46	3.27
$Zn_{5.0}$	1.481	8.96	10.67	3.32
$Zn_{7.5}$	1.477	9.04	11.02	3.35
SEm$\pm$	0.006	0.17	0.23	0.07
CD (P=0.05)	NS	NS	NS	NS

NS= Non significant

4.1.3 Moisture retention at 1/3 and 15 bars

Effect of vermicompost

An appraisal of data presented in Table 4.1 showed that moisture retention of soil both at 1/3 and 15 bars were increased significantly with an application of vermicompost @ 4.8 and 7.2 t ha^{-1} as compared to control (V_0). However, an application of vermicompost @ 2.4 t ha^{-1} the increase in moisture retention of soil both at 1/3 and 15 bars was non significant. The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} increased the moisture retention of soil at 1/3 bar to the extent of 23.64, 13.54and 6.04 per cent, respectively as compared to control.

Similarly, the application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} also increased the moisture retention of soil at 15 bars to the extent of 35.66, 18.88 and 6.29 per cent, respectively over the control

Effect of zinc

Data given in Table 4.1 further indicated that the effect of application of zinc on moisture retention of soil both at 1/3 and 15 bars were non significant

4.1.4 Organic carbon

Effect of vermicompost

The data presented in Table 4.2 indicate that the effect of vermicompost on organic carbon content of soil was found to be significant with increasing levels of vermicompost. The highest increase in organic carbon content of soil was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0). The increase in organic carbon content of soil was in order of 70.46, 39.37 and 11.41 per cent due to application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1}, respectively as compared to control.

Table: 4.2 Effect of vermicompost and zinc levels on organic carbon, available N, P_2O_5, K_2O and Zn content in soil

Treatments	Organic carbon (per cent)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})	Available Zn (ppm)
Vermicompost levels					
V_0	0.19	120.00	17.12	166.20	0.38
$V_{2.4}$	0.22	126.00	18.78	177.00	0.41
$V_{4.8}$	0.27	130.20	20.67	186.40	0.45
$V_{7.2}$	0.33	135.00	22.64	196.60	0.49
SEm$\pm$	0.01	1.09	0.46	3.19	0.01
CD (P=0.05)	0.02	3.16	1.33	9.20	0.03
Zinc levels					
Zn_0	0.24	121.31	22.90	176.80	0.38
$Zn_{2.5}$	0.25	125.65	21.41	180.72	0.42
$Zn_{5.0}$	0.26	129.54	19.20	183.58	0.45
$Zn_{7.5}$	0.26	134.70	15.70	185.10	0.49
SEm$\pm$	0.01	1.09	0.46	3.19	0.01
CD (P=0.05)	NS	3.16	1.33	NS	0.03

NS= Non significant

Effect of zinc

It is evident from the data in Table 4.2 that the effect of zinc on organic carbon content of soil was non-significant.

4.1.5 Available nitrogen

Effect of vermicompost

The data presented in Table 4.2 indicate that the available nitrogen content of soil was increased significantly with increasing levels of vermicompost. The highest increase in available nitrogen content of soil was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0). The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1}. increased the available nitrogen content of soil to the extent of 12.5, 8.5 and 5.0 per cent ,respectively as compared to control.

Effect of zinc

It is evident from the data in Table 4.2 that available nitrogen content of soil was also increased significantly with the increasing levels of zinc. The highest available nitrogen content of soil was recorded under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1} increased the available nitrogen content of soil to the extent of 11.03, 6.66 and 3.57 per cent, respectively as compared to control.

4.1.6 Available phosphorus

Effect of vermicompost

The data given in Table 4.2 indicate that the effect of vermicompost on available phosphorus content of soil was also found to be significant with increasing levels of vermicompost. The highest increase in available phosphorus content of soil was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0). . The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} increased the available phosphorus content of soil to the extent of 32.24, 20.73. and 9.69 per cent , respectively as compared to control.

Effect of zinc

It is evident from the data in Table 4.2 that the available phosphorus content of soil was significantly decreased with increasing levels of zinc. The highest decrease in available phosphorus content of soil was recorded under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1} decreased the available phosphorus content of soil to the extent of 31.44, 16.15 and 6.50 per cent, respectively as compared to control.

4.1.7 Available potassium

Effect of vermicompost

The data presented in the Table 4.2 indicate that the effect of vermicompost on available potassium content of soil was found to be significant with increasing levels of vermicompost. The highest increase in available potassium content of soil was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0). The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} increased the available potassium content of soil to the extent of 18.29, 12.15 and 6.49 per cent, respectively as compared to control.

Effect of zinc

It is evident from the data in Table 4.2 that the effect on available potassium content of soil was found to be non significant with the application of zinc.

4.1.8 Available zinc

Effect of vermicompost

The data presented in the Table 4.2 indicate the effect of application of vermicompost on the zinc content of soil which was found to be increased significantly with increasing levels of vermicompost. The highest increase in zinc content of soil was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0). The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} increased the available zinc content of soil to the extent of 27.08, 16.92 and 7.55 per cent, respectively as compared to control.

Effect of zinc

It is evident from the data in Table 4.2 that the zinc content of soil was significantly increased with the application of zinc. The highest zinc content of soil was recorded under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1}

increased the available zinc content of soil to the extent of 29.02, 18.99 and 9.49 per cent, respectively as compared to control.

4.2 Effect of vermicompost and zinc on growth of wheat

The data pertaining to the effect of vermicompost and zinc levels on plant height and leaf area index at harvest of wheat are being summarized in Table 4.3 and depicted in Figure 4.3 , whereas, the analysis of variance have been given in Appendix- III.

4.2.1 Plant height

Effect of vermicompost

A perusal of data in Table 4.3 indicates that with the application of vermicompost the increase in plant height of wheat was found to be significant. The highest increase in plant height was recorded under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control. However, the increase in plant height with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} increased the plant height to the extent of 13.03, 10.86 and 6.72 per cent, respectively as compared to control.

Effect of zinc

It is evident from the data in Table 4.3 that the plant height was also increased significantly with the application of zinc. The highest plant height was recorded under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). However, the increase in plant height with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0}$,The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1}, increased the plant height to the extent of 10.75, 7.65 and 3.99 per cent, respectively as compared to control.

Table: 4.3 Effect of vermicompost and zinc levels on plant height, leaf area index at harvest of wheat

Treatments	Plant height (cm)	Leaf area index
Vermicompost levels		
V_0	92.01	2.69
$V_{2.4}$	98.20	3.39
$V_{4.8}$	102.01	3.82
$V_{7.2}$	104.00	4.06
SEm$\pm$	1.12	0.11
CD (P=0.05)	3.24	0.31
Zinc levels		
Zn_0	93.80	2.73
$Zn_{2.5}$	97.55	3.38
$Zn_{5.0}$	100.98	3.80
$Zn_{7.5}$	103.89	4.05
SEm$\pm$	1.12	0.11
CD (P=0.05)	3.24	0.31

4.2.2 Leaf area index at harvest

Effect of vermicompost

A perusal of data in Table 4.3 revealed that with the application of the vermicompost there was increase in leaf area index at harvest which was also found to be significant. The highest increase in leaf area index was recorded under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control. However, the increase in leaf area index at harvest with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} increased the leaf area index at harvest to the extent of 50.92, 42.00 and 37.17 per cent, respectively as compared to control.

Effect of zinc

It is evident from the data Table 4.3 that with the application of zinc, the leaf area index at harvest was increased significantly. The highest leaf area index at harvest was recorded under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). However, the increase in leaf area index at harvest with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0}$. The application of zinc @ 7.5, 5.0 and 2.5 kg/ha increased the leaf area index at harvest to the extent of 48.35, 39.19. and 23.80 per cent, respectively as compared to control.

4.3 Effect of vermicompost and zinc on yield attributes of wheat

The data pertaining to the effect of vermicompost and zinc levels on number of effective tillers, number of ears per plant and test weight of wheat are being summarized in Table 4.4 and illustrated in Figure 4.4 , whereas , their analysis of variance have been given in Appendix - IV.

4.3.1 Number of effective tillers

Effect of vermicompost

The data presented in the Table 4.4 indicate that the effect of vermicompost on number of effective tillers per meter row length of wheat was found to be significant. The highest increase in number of effective tillers was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0). However, the increase in number of effective tillers with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} increased the number of effective tillers to the extent of 29.78, 23.04 and 12.05 per cent, respectively as compared to control.

Effect of zinc

The visualization of the data in Table 4.4 indicates that the number of effective tillers of wheat was significantly affected by zinc treatments. The highest number of effective tillers was recorded under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0) However, the increase in number of effective tillers with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0.}$ The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1} increased the number of effective tillers to the extent of 25.83, 18.13 and 7.21 per cent, respectively as compared to control.

Table: 4.4 Effect of vermicompost and zinc levels on number of effective tillers, number of ears per plant and test weight of wheat

Treatments	Number of effective tillers per metre row length	Number of ears per plant	Test weight (g)
Vermicompost levels			
V_0	56.45	2.82	37.90
$V_{2.4}$	63.21	3.16	40.00
$V_{4.8}$	69.30	3.47	41.10
$V_{7.2}$	73.10	3.66	42.00
SEm$\pm$	1.56	0.08	0.51
CD (P=0.05)	4.51	0.24	1.46
Zinc levels			
Zn_0	57.90	2.90	38.20
$Zn_{2.5}$	62.40	3.12	39.90
$Zn_{5.0}$	68.90	3.45	40.98
$Zn_{7.5}$	72.86	3.64	41.92
SEm$\pm$	1.56	0.08	0.51
CD (P=0.05)	4.51	0.24	1.46

4.3.2 Number of ears per plant

Effect of vermicompost

The data presented in the Table 4.4 indicate that the effect of vermicompost on number of ears per plant of wheat was found to be significant. The highest increase in number of ear per plant was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0) However, the increase in numbers of ears per plant with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. The application of vermicompost @ 7.2, 4.8 and 2.4 t/ha increased the number of ears per plant of wheat to the extent of 29.78, 23.04 and 12.05 per cent, respectively as compared to control.

Effect of zinc

The visualization of the data in Table 4.4 indicates that the numbers of ear per plant of wheat were significantly affected by zinc treatments. The highest number of ears per plant was recorded under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). However, the increase in numbers of ear per plant with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0}$, The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1} increased the number of ear per plant of wheat to the extent of 25.51, 18.96 and 7.58 per cent, respectively as compared to control.

4.3.3 Test weight

Effect of vermicompost

The data presented in the Table 4.4 indicate that the effect of vermicompost on test weight of wheat was found to be significant. The highest increase in test weight was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0). However, the increase in test weight with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. While the percent increase in test weight of wheat were in order of 10.81, 8.44 and 5.54 due to application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1}, respectively as compared to control.

Effect of zinc

The visualization of the data in Table 4.4 indicates that the test weight of wheat was significantly affected by zinc treatments. The highest test weight was recorded under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). However, the increase in test weight with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0}$, The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1}, increased the test weight of wheat to the extent of 9.73, 7.27 and 4.45 per cent, respectively as compared to control.

4.4 Effect of vermicompost and zinc on grain and straw yield of wheat

The data pertaining to grain and straw yield of wheat as influenced by levels of vermicompost and zinc have been summarized in Table 4.5 and also depicted in Figure 4.5. Whereas, the analysis of variance has been given in Appendix -V.

4.4.1 Grain yield

Effect of vermicompost

It is evident from the data in Table 4.5 that with the application of vermicompost the increase in grain yield of wheat was found to be significant. The highest increase in grain yield was recorded under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control. However, the increase in grain yield with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} increased the grain yield of wheat to the extent of 48.33, 40.66 and 20.0 per cent, respectively as compared to control.

Effect of zinc

An examination of data in Table 4.5 revealed that the grain yield of wheat was significantly affected by zinc treatments. The highest grain yield was recorded under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). However, the increase in grain yield with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1}, increased the grain yield of wheat to the extent of 37.92, 33.19 and 12.80 per cent, respectively as compared to control.

Table :4.5 Effect of vermicompost and zinc levels on grain and straw yield of wheat

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
Vermicompost levels		
V_0	27.10	46.04
$V_{2.4}$	32.52	55.28
$V_{4.8}$	38.12	64.80
$V_{7.2}$	40.20	68.34
SEm±	0.85	1.45
CD (P=0.05)	2.46	4.18
Zinc levels		
Zn_0	28.50	48.45
$Zn_{2.5}$	32.15	54.66
$Zn_{5.0}$	37.96	64.53
$Zn_{7.5}$	39.31	66.83
SEm±	0.85	1.45
CD (P=0.05)	2.46	4.18

4.4.2 Straw yield

Effect of vermicompost

A perusal of data in Table 4.5 indicated that with the application of vermicompost the increase in straw yield of wheat was found to be significant. The highest increase in straw yield was recorded under $V_{7.2}$ followed by $V_{4.5}$ and $V_{2.4}$ treatments as compared to control. However, the increase in straw yield with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} increased the straw yield of wheat to the extent of 48.43, 40.74 and 20.06 per cent, respectively as compared to control.

Effect of zinc

It is evident from the data Table 4.5 that the straw yield of wheat was significantly affected by zinc treatments. The highest straw yield was recorded under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). However, the increase in straw yield with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0}$, The per cent increase in straw yield was in order of 37.93, 33.18 and 12.81 due to application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1}, respectively as compared to control.

4.5 Effect of vermicompost and zinc on nutrient content and uptake of grain and straw of wheat

4.5.1 Nitrogen content and uptake in grain and straw

The data pertaining to the effect of vermicompost and zinc on nitrogen content and uptake of grain and straw of wheat were summarized and presented in Table 4.6. Whereas, the analysis of variance have been given in Appendix -VI.

4.5.1.1 Nitrogen content in grain and straw

Effect of vermicompost

The data presented in the Table 4.6 indicate that the effect of vermicompost on nitrogen content of wheat grain and straw was found to be significant. The highest increase in nitrogen content of grain and straw was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0). However, the increase in nitrogen content of grain and straw with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1}, increased the nitrogen content of grain to the extent of 25.51, 23.44 and 12.0 per cent, whereas, increase in the nitrogen content of straw was to the extent of 19.34, 16.95 and 10.0 per cent, respectively as compared to control.

Table: 4.6 Effect of vermicompost and zinc levels on nitrogen content and uptake in grain and straw of wheat

Treatments	Nitrogen content (per cent)		Nitrogen Uptake (kg ha^{-1})	
	Grain	Straw	Grain	Straw
Vermicompost levels				
V_0	1.45	0.46	39.72	21.32
$V_{2.4}$	1.62	0.51	53.22	28.16
$V_{4.8}$	1.79	0.54	68.93	35.10
$V_{7.2}$	1.82	0.55	73.95	37.77
SEm$\pm$	0.04	0.01	1.84	0.97
CD (P=0.05)	0.11	0.03	5.30	2.79
Zinc levels				
Zn_0	1.48	0.48	42.73	23.24
$Zn_{2.5}$	1.61	0.50	52.44	27.71
$Zn_{5.0}$	1.78	0.53	68.45	34.61
$Zn_{7.5}$	1.81	0.55	72.20	36.78
SEm$\pm$	0.04	0.01	1.84	0.97
CD (P=0.05)	0.11	0.03	5.30	2.79

Effect of zinc

It is obvious from the data in Table 4.6 that nitrogen content of wheat grain and straw also increased significantly under the zinc treatments. The highest increase in nitrogen content of grain and straw was obtained under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). However, the increase in nitrogen content of grain and straw with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0}$, The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1}, increased the nitrogen content of grain to the extent of 22.29, 20.27 and 8.78 per cent whereas increased in the nitrogen content of straw was the extent of 14.73, 11.78 and 5.68 per cent, respectively as compared to control.

4.5.1.2 Nitrogen uptake in grain and straw

Effect of vermicompost

The data presented in the Table 4.6 indicate that with the applicationt of vermicompost the nitrogen uptake of wheat nitrogen in grain and straw was also increased significantly. The highest increase in nitrogen uptake of grain was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0). However, the increase in nitrogen uptake of wheat grain and straw with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1}, increased the nitrogen uptake of wheat grain to the extent of 86.17, 73.53 and 33.98 per cent whereas, increase in nitrogen uptake of wheat straw was to the extent of 77.15, 63.63 and 32.08 per cent respectively as compared to control.

Effect of zinc

It is evident from the data in Table 4.6 that nitrogen uptake of wheat grain and straw increased significantly with the increase in the level of applied zinc. The highest increase in nitrogen uptake of grain and straw was obtained under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). However, the increase in nitrogen uptake of grain and straw with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0.}$ The application of zinc @ 7.5, 5.0 and 2.5 kg/h. increased the nitrogen uptake of grain to the extent of 68.96, 60.19 and 22.72 per cent whereas increase in nitrogen uptake of wheat straw was to the extent of 58.26, 48.92 and 19.23 per cent, respectively as compared to control.

4.5.2 Phosphorus content and uptake in grain and straw

The data pertaining to the phosphorus content and uptake of grain and straw as influenced by levels of vermicompost and zinc are summarized and presented in Table 4.7. Whereas, the analysis of variance have been given in Appendix - VII.

4.5.2.1 Phosphorus content in grain and straw

Effect of vermicompost

The perusal of data in Table 4.7 revealed that phosphorus content of wheat grain and straw increased significantly with the increase in the levels of vermicompost .The highest increase in phosphorus content of grain and straw was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0). However, the increase in phosphorus content of wheat grain and straw with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} increased the phosphorus content of wheat grain to the extent of 20.71, 17.37 and 4.67 per cent whereas increase in phosphorus content of wheat straw was to the extent of 21.27, 16.31 and 7.80 per cent, respectively as compared to control.

Effect of zinc

The critical examination of data in Table 4.7 revealed that phosphorus content of wheat grain and straw decreased significantly with the increase in the levels of zinc. The highest decrease in phosphorus content of grain and straw was obtained under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1} decrease the phosphorus content of wheat grain to the extent of 19.57, 17.05 and 6.46 per cent whereas decrease in phosphorus content of straw was to the extent of 20.33, 15.82 and 7.34 per cent, respectively as compared to control.

4.5.2.2 Phosphorus uptake in grain and straw

Effect of vermicompost

The data presented in Table 4.7 also indicate the effect of vermicompost application on phosphorus uptake of wheat grain and straw which was found to be increased significantly. The highest increase in phosphorus uptake of grain and straw was obtained under $V_{7.2}$ followed by $V_{4.5}$ and $V_{2.4}$ treatments as compared to control (V_0). However, the increase in phosphorus uptake of wheat grain and straw with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} increased the phosphorus uptake of grain to the extent of 79.27, 65.25 and 25.70 per cent whereas increase in phosphorus uptake of straw was to the extent of 80.12, 64.75 and 31.21 per cent, respectively as compared to control.

Table: 4.7 Effect of vermicompost and zinc levels on phosphorus content and uptake in grain and straw of wheat

Treatments	Phosphorus content (per cent)		Phosphorus Uptake (kg ha^{-1})	
	Grain	Straw	Grain	Straw
Vermicompost levels				
V_0	0.45	0.14	12.02	6.42
$V_{2.4}$	0.47	0.15	15.11	8.42
$V_{4.8}$	0.53	0.16	19.86	10.58
$V_{7.2}$	0.54	0.17	21.54	11.56
SEm$\pm$	0.01	0.003	0.62	0.37
CD (P=0.05)	0.02	0.009	1.79	1.06
Zinc levels				
Zn_0	0.55	0.17	16.05	8.67
$Zn_{2.5}$	0.50	0.16	16.94	9.06
$Zn_{5.0}$	0.48	0.15	17.74	9.59
$Zn_{7.5}$	0.46	0.14	17.81	9.66
SEm$\pm$	0.01	0.03	0.62	0.37
CD (P=0.05)	0.02	0.009	NS	NS

Effect of zinc

It is clear from the data in Table 4.7 that with the application of zinc the phosphorus uptake of wheat grain and straw was also found to be increased but was not significant. The highest increase in phosphorus uptake of grain and straw was obtained under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1} increased the phosphorus uptake of wheat grain to the extent of 10.96, 10.52 and 5.54 per cent whereas phosphorus uptake of straw increase to the extent of 14.66, 12.92, and 4.49 per cent, respectively as compared to control.

4.5.3 Potassium content and uptake of grain and straw

The data pertaining to the potassium content and uptake of grain and straw as influenced by levels of vermicompost and zinc are summarized in Table 4.8 Whereas the analysis of variance have been given in Appendix - VIII.

4.5.3.1 Potassium content of grain and straw

Effect of vermicompost

The perusal of data presented in Table 4.8 revealed that potassium content of wheat grain and straw increased significantly with the application of vermicompost. The highest increase in potassium content of grain and straw was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0). However, the increase in potassium content of wheat grain and straw with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} increased the potassium content of wheat grain to the extent of 21.67, 18.60 and 8.38 per cent, whereas potassium content of wheat straw increase to the extent of 15.77, 13.59 and 7.14 per cent, respectively as compared to control.

Effect of zinc

The visualization of data in Table 4.8 indicates that the potassium content of wheat grain was significantly increased by zinc treatments. The highest potassium content of wheat grain and straw was recorded under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). However, the increase in potassium content of wheat grain and straw with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0,}$ The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1} increased the potassium content of wheat grain to the extent of 21.06, 16.53 and 6.45 per cent, whereas increase in potassium content of wheat straw was to the extent of 14.81, 12.42 and 6.32 per cent, respectively as compared to control.

4.5.3.2 Potassium uptake of grain and straw

Effect of vermicompost

It is apparent from the data in Table 4.8 that the effect of vermicompost on potassium uptake of wheat grain and straw was found to be significant. The highest increase in potassium uptake of grain and straw was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0). The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} increased the K uptake of wheat grain to the extent of 80.61, 66.90 and 30.16 per cent, whereas increase in potassium uptake of straw was to the extent of 71.88, 59.92 and 28.68 per cent, respectively as compared to control.

Table: 4.8 Effect of vermicompost and zinc levels on potassium content and uptake in grain and straw of wheat

Treatments	Potassium content (per cent)		Potassium Uptake (kg ha^{-1})	
	Grain	Straw	Grain	Straw
Vermicompost levels				
V_0	0.49	1.29	13.36	59.64
$V_{2.4}$	0.53	1.38	17.39	76.75
$V_{4.8}$	0.58	1.46	22.31	95.38
$V_{7.2}$	0.60	1.49	24.13	102.51
SEm$\pm$	0.01	0.02	0.66	2.69
CD (P=0.05)	0.03	0.07	1.90	7.78
Zinc levels				
Zn_0	0.50	1.30	14.30	63.30
$Zn_{2.5}$	0.53	1.38	17.17	75.93
$Zn_{5.0}$	0.58	1.46	22.19	94.79
$Zn_{7.5}$	0.59	1.49	23.54	100.25
SEm$\pm$	0.01	0.02	0.66	2.69
CD (P=0.05)	0.03	0.07	1.90	7.78

Effect of zinc

The visualization of the data Table 4.8 indicates that the potassium uptake of wheat grain and straw was significantly increased by zinc treatments. However, the increase in uptake of wheat grain and straw with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0.}$ The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1} increased the potassium uptake of wheat grain to the extent of 64.61, 55.17 and 20.06 per cent, whereas increase in potassium uptake of wheat straw was to the extent of 58.31, 49.74 and 19.95 per cent, respectively as compared to control.

4.5.4 Zinc content and uptake of grain and straw

The data pertaining to the zinc content and uptake of grain and straw as influenced by levels of vermicompost and zinc have been summarized in Table 4.9 whereas, the analysis of variance are given in Appendix - IX.

4.5.4.1 Zinc content of grain and straw

Effect of vermicompost

The perusal of data in Table 4.9 revealed that the application of vermicompost increased the zinc content of wheat grain and straw significantly. The highest increase in zinc content of grain was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0).

However, the increase in zinc content of wheat grain and straw with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. The application of vermicompost @ 7.2, 4.8 and 2.4 t/ha increased the zinc content of wheat grain to the extent of 23.71, 18.26 and 9.30 per cent, whereas increase in zinc content of wheat straw was to the extent of 26.69, 21.68 and 7.30 per cent, respectively as compared to control.

Effect of zinc

An examination of data in Table 4.9 indicates that the zinc content of wheat grain and straw was significantly increased by zinc treatments. The highest zinc content of grain and straw was recorded under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). However, the increase in zinc content of wheat grain and straw with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0}$. The application of zinc @ 7.5, 5.0 and 2.5 kg/ha increased the zinc content of grain to the extent of 27.13, 21.30 and 9.13 per cent, whereas increase in zinc content of wheat straw was to the extent of 30.67, 25.20 and 9.83 per cent, respectively as compared to control.

4.5.4.2 Zinc uptake of grain and straw

Effect of vermicompost

The data presented in Table 4.9 indicated that the application of vermicompost increased the zinc uptake of wheat grain and straw significantly. . The highest increase in zinc uptake of grain and straw was obtained under $V_{7.2}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0). However, the increase in zinc uptake of wheat grain and straw with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} increased the zinc uptake of grain to the extent of 83.64, 66.47 and 31.25 per cent, whereas increase in zinc uptake of straw was to the extent of 81.44, 67.08 and 28.90 per cent, respectively as compared to control.

Effect of zinc

It is evident from the data summarized in Table 4.9 that the zinc uptake of wheat grain and straw was significantly increased by zinc treatments. The highest zinc uptake of wheat grain was recorded under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). However, the increase in zinc uptake of wheat grain and straw with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0}$. The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1} increased the zinc uptake of wheat grain to the extent of 75.36, 61.58 and 23.11 per cent whereas increase in zinc uptake of wheat straw was to the extent of 80.23, 66.75 and 23.89 per cent, respectively as compared to control.

Table :4.9 Effect of vermicompost and zinc levels on zinc content and uptake in grain and straw of wheat

Treatments	Zinc content (ppm)		Zinc Uptake (g ha^{-1})	
	Grain	**Straw**	**Grain**	**Straw**
Vermicompost levels				
V_0	23.32	16.42	63.89	76.59
$V_{2.4}$	25.49	17.62	83.86	98.70
$V_{4.8}$	27.58	19.98	106.36	131.20
$V_{7.2}$	28.85	20.82	117.33	144.17
SEm±	0.48	0.40	3.84	4.51
CD (P=0.05)	1.38	1.16	11.09	13.03
Zinc levels				
Zn_0	23.00	16.07	66.32	78.94
$Zn_{2.5}$	25.10	17.65	81.65	97.80
$Zn_{5.0}$	27.90	20.12	107.16	131.64
$Zn_{7.5}$	29.24	21.00	116.30	142.28
SEm±	0.48	0.40	3.84	4.51
CD (P=0.05)	1.38	1.16	11.09	13.03

4.6. Effect of vermicompost and zinc on quality of wheat

The data pertaining to the quality of wheat as influenced by levels of vermicompost and zinc are summarized in Table 4.10 and being depicted in Fig.4.6. The analysis of variance has been given in Appendix - X.

4.6.1 Crude crude protein content in grain

Effect of vermicompost

The data presented in Table 4.10 indicate that the effect of vermicompost on crude crude protein content of wheat grain was found to be significant. The highest increase in crude protein content of wheat grain was obtained under $V_{7.5}$ followed by $V_{4.8}$ and $V_{2.4}$ treatments as compared to control (V_0). However, the increase in crude protein content with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. The application of vermicompost @ 7.2, 4.8 and 2.4 t ha^{-1} increased the crude protein content of wheat grain to the extent of 25.33, 23.23 and 11.56 per cent, respectively as compared to control.

Effect of zinc

It is clear from the data in Table 4.10 that the crude protein content of wheat grain was increased significantly by zinc treatments. The highest crude protein content of wheat grain was recorded under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). However, the increase in crude protein content with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0.}$ The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1}, increased the crude protein content of wheat grain to the extent of 22.48, 20.32 and 8.75 per cent, respectively as compared to control.

Table: 4.10 Effect of vermicompost and zinc levels on crude protein content in grain and chlorophyll content of leaves at flowering of wheat

Treatment	Crude protein content in grain (per cent)	Chlorophyll content of leaves at flowering (mg g^{-1})
Vermicompost levels		
V_0	9.08	1.86
$V_{2.4}$	10.13	2.14
$V_{4.8}$	11.19	2.78
$V_{7.2}$	11.38	2.90
SEm$\pm$	0.28	0.08
CD (P=0.05)	0.80	0.23
Zinc levels		
Zn_0	9.25	1.78
$Zn_{2.5}$	10.06	2.15
$Zn_{5.0}$	11.13	2.81
$Zn_{7.5}$	11.33	2.94
SEm$\pm$	0.28	0.08
CD (P=0.05)	0.80	0.23

4.6.2 Chlorophyll content in leaves

Effect of vermicompost

The data presented in the Table 4.10 indicate that the application of vermicompost increased the chlorophyll content of wheat leaves significantly. The highest increase in chlorophyll content of leaves was obtained under $V_{7.2}$ followed by $V_{4.5}$ and $V_{2.4}$ treatments as compared to control (V_0) However, the increase in chlorophyll content of leaves with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. The application of vermicompost @ 7.2, 4.8 and 2.4 t/h. increased the chlorophyll content of leaves to the extent of 55.91, 49.46 and 15.05 per cent, respectively as compared to control.

Effect of zinc

It is evident from the data summarized in Table 4.10 that the chlorophyll content of wheat leaves was significantly increased by zinc treatments. The highest chlorophyll content of wheat leaves was recorded under $Zn_{7.5}$ followed by $Zn_{5.0}$ and $Zn_{2.5}$ treatments as compared to control (Zn_0). However, the increase in chlorophyll content of wheat leaves with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0.}$ The application of zinc @ 7.5, 5.0 and 2.5 kg ha^{-1}. Increased the chlorophyll content of wheat leaves to the extent of 65.16, 57.86 and 20.78 per cent, respectively as compared to control

4.7 Economics

The data regarding effect of vermicompost and zinc on net returns of wheat crop are being summarized in Table 4.11 and diagrammatically shown in Figure 4.7 whereas, the analysis of variance has been given in appendix -XI.

Effect of vermicompost

A perusal of data in Table 4.11 revealed that net returns increased significantly with increasing levels of vermicompost. The maximum net returns (28950 Rs ha^{-1}) was obtained under the treatment $V_{4.8}$ and the minimum (23286 Rs ha^{-1}) was under V_0. However, the decrease in net returns with $V_{7.2}$ treatment was statistically at par with $V_{4.8}$ treatment. On application of vermicompost @ 7.2, 4.8 and 2.4, t ha^{-1}, the increase in net returns was to the extent of 12.84, 24.32 and 11.61, per cent [1], respectively as compared to control.

Effect of zinc

A critical examination of data in Table 4.11 revealed that the effect of zinc on net returns was found significant. The application of zinc significantly increased net returns as compared to control. However, the increase in net returns with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0}$. The application of zinc@ 7.5, 5.0 and 2.5 kg ha^{-1} @ increased the net returns to the extent of 87.67, 77.52 and 28.93 per cent, respectively as compared to control.

Table: 4.11 Effect of vermicompost and zinc levels on net return of wheat

Treatment	Net return (Rs ha^{-1})
Vermicompost levels	
V_0	23286
$V_{2.4}$	25990
$V_{4.8}$	28950
$V_{7.2}$	26278
SEm$\pm$	928
CD (P=0.05)	2679
Zinc levels	
Zn_0	17589
$Zn_{2.5}$	22679
$Zn_{5.0}$	31225
$Zn_{7.5}$	33010
SEm$\pm$	928
CD (P=0.05)	2679

5. DISCUSSION

In the course of presenting the results of the experiment entitled "Effect of vermicompost and zinc on performance of wheat (*Triticum aestivum* L.) in loamy sand soil" significant variations in criteria used for treatments evaluation were observed. The variations which were significant while those assuming uniform trends have been discussed in this chapter to establish cause and effect relationship along with the existing evidences and literature.

5.1 Effect of vermicompost and zinc on physico-chemical properties of soil

Effect of vermicompost

Organic manures have been traditionally used in Indian agriculture for maintaining the soil fertility and productivity. Therefore, to maintain the soil productivity on a sustainable basis, the use of both organic and inorganic source of nutrients seems to be a good management decision.

The application of vermicompost @4.8 and 7.2 t ha^{-1} resulted in significant decrease in bulk density, whereas, a significant increase in saturated hydraulic conductivity, moisture retention at 1/3, and 15 bar in soil was observed (Table 4.1). This might be due to an increase in root biomass, better soil aggregation as well as greater root proliferation (Bhattacharya *et al.*, 2004). High rate of water transmission may be associated with the macro pores of soil as influenced by high organic carbon and better soil aggregation

(Mishra and Sharma, 1997). Similar results have also been reported by a number of workers (Bellakki and Badanur, 1997) and (Sharma *et al.*, 2000).

The data in Table 4.2 showed that the vermicompost also had significant effect on the organic carbon, available N, P, K and Zn content of soil. The significant increase in organic carbon, available nitrogen, phosphorus, potassium and zinc content of the soil after harvest of crop may be ascribed to the beneficial role of vermicompost in mineralization of native as well as its own nutrient content by creating favourable conditions for microbial as well as chemical activities which enhanced the available nutrient pool of the soil. As a matter of fact, all the available nutrients are not taken up by the plant and the rest remains in the soil which improves the available nutrients status of soil after harvest of crop. These results are in agreement with those of Nethra *et al.* (1999), Netwal (2003) and Thomas and Lal (2004).

Effect of zinc

The application of zinc had no significant effect on bulk density, saturated hydraulic conductivity and moisture retention at 1/3 and 15 bar of soil (Table 4.1). The application of Zn significantly increased the available nitrogen content in soil after harvest of crop (Table 4.2). It might be due to effect of zinc on microbial nitrogen fixation in soil which was also indicated by Singh *et al.* (1999).

On the other hand application of zinc significantly decreased the availability of phosphorus (Table 4.2) the cause behind this can be ascribed to antagonistic effect of zinc on availability of phosphorus, due to formation of insoluble zinc phosphate at higher concentration of zinc which reduce the availability of phosphorus. Such findings were also reported by Gour (1994) and Vinay *et al.* (1993),

The application of zinc significantly increased the available zinc in the soil (Table 4.2). This is due to increase in zinc concentration in the soil by application of zinc in the experimental field which was deficient in zinc. The result was in conformity to those of reported by Singh *et al.* (1999).

. However there was no significant effect of zinc on organic carbon and available potassium status of soil

5.2 Effect of vermicompost and zinc on growth and yield attributes of wheat

Effect of vermicompost

It is evident from the results that application of vermicompost significantly increased plant height and leaf area index effective tillers per meter row length, number of ears per plant and test weight at harvest (Table 4.3 and 4.5). It is established fact that vermicompost improves the physical and biological properties of soil including supply of almost all the essential plant nutrients for the growth and development of plants. Thus balance nutrition under favourable environment might have helped in production of new tissues and development of new shoots. The beneficial effect of vermicompost on these parameters might be due to its contribution in supplying additional plant nutrients and increasing availability of native soil nutrients. Another reason could be efficient and greater partitioning of metabolites and adequate transformation of nutrients to developing plant structures. As a result, almost all growth and yield attributes of crop resulted into significant improvement due to application of vermicompost. These results are in agreement with that of Reddy *et al.* (1988), Ranwa and Singh (1999) and Davidayal and Agrawal (1999).

Effect of zinc

The increasing levels of zinc significantly increased the plant height and leaf area index effective tillers per meter row length, number of ear per plant and test weight at harvest (Table 4.3 and 4.4). The favourable influence of applied zinc on these growth parameters and yield attributes may be ascribed to catalystic or stimulatory effect of zinc on most of the physiological and metabolic processes of the plant. Zinc also acts as a metal activator and is an essential component of enzymes such as proteinase and peptidase which are responsible for assimilation of nitrogen. It also helps in chlorophyll formation and plays an important role in nitrogen metabolism. Thereby, resulting into increased uptake of nitrogen by the plants zinc has also been reported to play an important role in regulating the auxin concentration in plants. Zinc deficiency result in a decreased content of auxin. Besides this zinc also enhances the absorption of essential elements by increasing the cation exchange capacity of roots. Thus, the application of zinc in a soil deficient in its content, improved the over all growth and development of plant. These results are in close conformity with those of Yadav (1990) who reported significant increase in plant height, tillers, number of ear and leaf area index in wheat due to application of zinc. The increase in these growth parameters and yield attributes due to application of zinc were also reported by Maliwal *et al.* (1985), Jat (1990), Sharma (1992), Singh, (2000) and Dwidedi *et al.* (2001) in different crops.

5.3 Effect of vermicompost and zinc on grain and straw yield of wheat

Effect of vermicompost

The application of vermicompost enhanced the grain and straw yield significantly (Table 4.5). The significant increase in grain and straw yield under the influence of vermicompost was largely a function of improved growth and yield attributes like plant height, leaf area index, effective tillers per meter row length, number of ear per plant and test weight which consequently increased grain and straw yield. The interrelationship between various yield attributes of the crop and its grain and straw yield had also been observed by Vadiraj *et al.* (1998) in coriander.

Effect of zinc

The grain and straw yield were also significantly increased by the application of zinc (Table 4.5). The favourable influence of applied zinc on grain and straw yield may be due to catalytic or stimulatory effect of zinc on most of the physiological and metabolic processes of plants. The increase in yield might be due to role of Zn in biosynthesis of indole acetic acid and especially due to its role in initiation of primordia of reproductive parts and partitioning of photosynthates towards them (Wear and Hagler, 1968). Thus the application of zinc in a soil deficient in zinc improved over all growth and development of plants and ultimately the grain and straw yield increases. These findings are also supported by Yadav and Vyas (1987), Sharma *et al.* (2000), Parihar (2002), Singh (2004) and Vershney *et al.* (2008).

5.4 Effect of vermicompost and zinc on nutrient content, uptake and quality of wheat

Effect of vermicompost

There was significant increase in nitrogen, phosphorus, potassium and zinc content and uptake in grain and straw (Table 4.9).

The positive influence of vermicompost is due to adequate supply of nutrients in root zone and plant system. The increased availability of these nutrients in the root zone coupled with increased metabolic activity at cellular levels might have synthesized more nutrients and their accumulation in various plant parts .Thus crop supplied with higher dose of vermicompost had utilized more nutrients as compared to lower doses resulting in increased nitrogen, phosphorus, potassium and zinc content in grain and straw. The increased uptake in nitrogen, phosphorus, potassium and zinc content in grain and straw seems to be due to the fact that uptake of nutrient is a product of biomass and nutrient content. The results obtained in the present investigation are in close conformity with those of Jadhv *et al.* (1997)

The application of vermicompost significantly increased the protein content of grain and chlorophyll content in leaves at flowering over control (Table 4.10).The significant increase in protein content in grain and chlorophyll content in leaves at flowering on application of vermicompost seems to be due to increased availability of nitrogen to the plant from vermicompost resulting in increased nitrogen content in plant which has significant role in synthesis of protein in grain and chlorophyll in leaves (Baccahane and Sanale 1996).

Effect of zinc

The nitrogen, potassium and zinc content and uptake in grain and straw of wheat increased significantly on application of zinc. Whereas, phosphorus content in grain and straw of wheat decreased with increasing level of zinc (Table 4.10). The significant positive response of wheat to zinc application on nitrogen, potassium and zinc content could be attributed to an enhanced availability of zinc in soil at which the optimum requirement of crop is fulfilled. Whereas the reduction in the concentration of phosphorus owing to higher levels of zinc application might be due to antagonistic relationship of zinc and phosphorus (Olsen, 1972). The increased concentration of zinc created hindrance in absorption and translocation of phosphorus from the root to the above part (Reddy and Yadav, 1994). The significant increase in the phosphorus uptake in grain and straw was probably due to increase in grain and straw yield of wheat. The results obtained get support from the findings of Karelia (1990), Naga (2005) and Parihar (2002).

The protein content of grain and chlorophyll content in leaves also increased significantly due to application of zinc over control. (Table 4.10). The increased content of protein in grain and chlorophyll in leaves due to application of zinc might be due to role of zinc as a metal activator and is an essential component of enzymes such as proteinase and peptidase which are responsible for assimilation of nitrogen in the form of amino acids and protein. It also helps in chlorophyll formation and plays an important role in nitrogen metabolism Jat (1990).

5.5 Effect of vermicompost and zinc on economics

Effect of vermicompost

The increase in dose of vermicompost to 4.8 t ha^{-1} showed higher net return over that of added cost. Therefore best choice of vermicompost is 4.8 tha^{-1} as it is found to be more profitable from economic point of view (Table 4.11 and Appendix VIII).

Effect of zinc

Increase in dose of zinc from to 7.5 kg ha^{-1} showed higher net return that of added cost. The best close of zinc is 5.0 kg Zn ha^{-1} as it is found to be more profitable for economic point view (Table 4.11 and Appendix XI).

6. SUMMARY AND CONCLUSION

Results of the field experiment entitled "Effect of Vermicompost and zinc on performance of wheat (*Triticum aestivum* L.) in loamy sand soil" presented and discussed in the preceding chapters are being summarized and concluded in this chapter.

6.1 Physico-chemical properties of soil

6.1.1 Bulk density

(i) The application of vermicompost @ 4.8 and 7.2 t ha^{-1} had significant reduction in bulk density of soil.

(ii) The application of zinc had no significant effect on bulk density of soil.

6.1.2 Saturated hydraulic conductivity

(i) The application of vermicompost @ 4.8 and 7.2 t ha^{-1} significantly increased the saturated hydraulic conductivity of soil.

(ii) The application of zinc had no significant effect on saturated hydraulic conductivity of soil.

6.1.3 Moisture retention at 1/3 and 15 bars

(i) The application of vermicompost @ 4.8 and 7.2 t ha^{-1} significantly increased the moisture retention of soil both at 1/3 and 15 bars.

(ii) The moisture retention of soil was not affected significantly with the application of zinc.

6.1.4 Organic carbon

(i) The increasing levels of vermicompost significantly increased the organic carbon content in soil.

(ii) The application of zinc had no significant effect on organic carbon content of soil.

6.1.5 Available nitrogen

(i) The available nitrogen of soil increased significantly with increasing levels of vermicompost.

(ii) The application of zinc also significantly increased the available nitrogen in soil.

6.1.6 Available phosphorus

(i) The increase in available phosphorus of soil was found significant with increasing levels of vermicompost.

(ii) The application of zinc significantly decreases the available phosphorus in soil with increasing level of zinc.

6.1.7 Available potassium

(i) The increasing levels of vermicompost had significantly increased the available potassium of soil.

(ii) (ii) The application of zinc had no significant effect on available potassium of soil.

6.1.8 Available zinc

(i) The available zinc in soil increased significantly with .increasing levels of vermicompost

(ii) The application of zinc also significantly increased the available zinc in soil.

6.2 Growth, yield attributes and yield of wheat

6.2.1 Plant height

(i) The plant height increased significantly with the application of vermicompost up to $V_{4.8}$ treatment. However, the increase with $V_{7.2}$ treatment was found to be statistically at par with $V_{4.8}$ treatment.

(ii) The plant height also increased significantly with the increasing levels of zinc up to $Zn_{5.0}$. However the increase with treatment $Zn_{7.5}$ was found to be statistically at par with $Zn_{5.0}$.

6.2.2 Number of ears per plant

(i) The number of ears per plant increased significantly up to $V_{4.8}$ treatment. However, the increase with $V_{7.2}$ treatment was found to be statistically at par with $V_{4.8}$. .

(ii) A significant increase in number of ear per plant was also found with the increasing levels of zinc up to $Zn_{5.0}$ while the increase with treatment $Zn_{7.5}$.was statistically at par with $Zn_{5.0}$

6.2.3 Number of effective tillers (per metre row length)

(i) The number of effective tillers (per metre row length) increased significantly with increasing levels of vermicompost up to $V_{4.8}$ treatment while the increase with the treatment $V_{7.2}$ was statistically at par with $V_{4.8}$

(ii) The number of effective tillers per metre row length also increased significantly with increasing levels of zinc up to $Zn_{5.0}$ treatment but the increase with treatment $Zn_{7.5}$.was statistically at par with $Zn_{5.0}$

6.2.4 Test weight

(i) The Increasing levels of vermicompost significantly increased the test weight of wheat grain up to $V_{4.8}$ treatment. However, increase with the treatment $V_{7.2}$was found to be statistically at par with $V_{4.8}$

(ii) The test weight also increased significantly with increasing levels of zinc up to $Zn_{5.0}$ which was statistically at par with $V_{7.5}$.

6.2.5 Grain yield

(i) The application of vermicompost significantly increased the grain yield up to $V_{4.8}$ treatment. However, increase in grain yield with the treatment $V_{7.2}$. was statistically at par with that of $V_{4.8}$

(ii) Grain yield of wheat increased significantly with increasing levels of zinc up to $Zn_{5.0}$, but was statistically at par with treatment $Zn_{7.5}$.

6.2.6 Straw yield

(i) The application of vermicompost increased straw yield significantly. However increase in straw yield with the treatment $V_{7.2}$ was statistically at par with $V_{4.8.}$

(ii) The increasing levels of zinc significantly increased the straw yield of wheat up to $Zn_{5.0}$ treatment, which was statistically at par with $Zn_{7.5}$ treatment.

6.3 Nutrient content and uptake in grain and straw and quality of wheat

6.3.1 Nitrogen content and uptake in grain and straw

(i) The nitrogen content and uptake in grain and straw increased significantly with increasing levels of vermicompost. However, increase in nitrogen content and uptake of grain and straw with the treatment $V_{7.2}$ was found to be statistically at par with that of $V_{4.8.}$

(ii) The increasing levels of zinc significantly increased the nitrogen content and uptake in grain and straw of wheat up to $Zn_{5.0}$, However, increase with $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0}$.

6.4.2 Phosphorus content and uptake in grain and straw

(i) Phosphorus content and uptake in grain and straw increased significantly with increasing levels of vermicompost. However, the increase in phosphorus content and uptake of grain and straw with treatment $V_{7.2}$ was found to be statistically at par with that of $V_{4.8.}$

(ii) Zinc supplementation significantly decreased phosphorus content in grain and straw with increasing level of zinc. However with increasing levels of zinc increases significantly the phosphorus uptake in grain up to $Zn_{5.0}$.

6.4.3 Potassium content and uptake in grain and straw

(i) Potassium content and uptake in grain and straw increased significantly with increasing levels of vermicompost, while increase in potassium content and uptake of grain and straw with treatment $V_{7.2}$was found to be statistically at par with $V_{4.8}$

(ii) The increasing levels of zinc significantly increased the content and uptake of potassium by grain and straw of wheat up to $Zn_{5.0}$. While increase with treatment $Zn_{7.5}$ the increase in content and uptake of potassium by grain and straw of wheat was statistically at par with that of $Zn_{5.0}$.

6.4.4 Zinc content and uptake in grain and straw

(i) The zinc content and uptake by grain and straw of wheat increased significantly up to treatment $V_{4.8}$ which was found to be statistically at par with $V_{7.2}$.

(ii) Zinc also increased the zinc content and uptake by grain and straw significantly up to $Zn_{5.0.}$ However in this regard, $Zn_{7.5}$ treatment was statistically at par with $Zn_{5.0}$,

6.4.5 Crude protein content of grain

(i) The crude protein content of wheat grain increased significantly with increasing levels of vermicompost, up to treatment $V_{4.8}$ which was found to be statistically at par with $V_{7.2}$.

(ii) Zinc increased the crude protein content in grain significantly increased up to $Zn_{5.0}$, however increase in crude protein content with $Zn_{7.5}$. treatment was statistically at par with $Zn_{5.0}$,

6.4.6 Chlorophyll content of leaves at flowering stage

(i) The chlorophyll content of leaves at flowering stage of wheat crop increased significantly with increasing levels of vermicompost, up to treatment $V_{4.8}$ while the increase in chlorophyll content at flowering stage with treatment $V_{7.2}$. was found to be statistically at par with $V_{4.8}$

(ii) The increasing levels of zinc significantly increased the chlorophyll content of leaves at flowering stage in wheat crop up to $Zn_{5.0}$, however, increase in chlorophyll content with treatment $Zn_{7.5}$. was found to be statistically at par with $Zn_{5.0}$

6.5 Economics

6.5.1 Net returns

(i) The increasing levels of vermicompost significantly increased the net returns of wheat crop up to treatment $V_{4.8}$ which was at par with $V_{7.2}$ treatment.

(ii) The increasing levels of zinc increased the net returns of wheat significantly up to $Zn_{5.0}$ which was at par with $Zn_{7.5}$ treatment.

CONCLUSION

Based on one year experimentation it may be concluded that:

(1) Vermicompost had favourable effect in improving the physical properties and fertility status of loamy sand soil.

(2) The application of vermicompost @ 4.8 t ha^{-1} and zinc @ 5.0 kg ha^{-1} improved plant growth, grain and straw yield, nutrient content, chlorophyll content and quality of grain in terms of crude protein content significantly.

(3) The application of vermicompost @ 4.8 t ha^{-1} and zinc @ 5.0 kg ha^{-1} individually found best treatments in terms of net return.

However, these results are only indicative and require further experimentation to arrive at more consistent and final conclusion to be passed on to farmers.

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Effect of vermicompost and zinc on performance of wheat [*Triticum aestivum* L.) in loamy sand soil

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ABSTRACT

A field experiment was conducted during *rabi* season of 2010-11 at Agronomy farm, S.K.N. College of Agriculture, Jobner (Rajasthan) to study the effect of vermicompost and zinc on performance of wheat (*Triticum aestivum* L.) in loamy sand soil.

The experiment was laid out according to randomized block design with three replications. The treatments were consist of four level of vermicompost (0, 2.4, 4.5 and 7.2 t ha^{-1}) and also four level of zinc(0 2.5, 5.0 and 7.5 kg ha^{-1}) .The zinc was applied through zinc sulphate along with uniform application of recommended doses of nitrogen, phosphorus and potassium in soil on which wheat variety Raj 3077 was grown. The main findings of investigation are summarized as:

The application of vermicompost @ 4.8 and7.2 t ha^{-1} significantly decreased the bulk density while the saturated hydraulic conductivity and moisture retention (at 1/3 and 15 bars) of soil increased significantly at harvest stage of the crop. A significant increase in organic carbon, available nitrogen, phosphorus, potassium and zinc in soil at harvest stage of the crop was observed with increasing level of vermicompost. The plant height, leaf area index, number of effective tillers, number of ears per plant, test weight , grain and straw yield as well as content and uptake of nitrogen, phosphorus, potassium and zinc, protein content in grain , chlorophyll content in leaves at flowering and net return increased significantly on application of vermicompost up to the rate of 4.8 t ha^{-1}.

The effect of zinc application on bulk density, saturated hydraulic conductivity, moisture retention (at 1/3 and 15 bars), organic carbon, and available potassium of soil was found non significant. Whereas, a significant increase in the available nitrogen and available zinc of soil along with a significant decrease in available phosphorus was observed with increasing level of zinc. The plant height, leaf area index, number of effective tillers, number of ears per plant, test weight, grain and straw yield, content and uptake of nitrogen, potassium and zinc in grain and straw, protein content in grain ,chlorophyll content in leaves at flowering and net returns increased significantly increased on application of zinc up to the rate of 5,0 kg ha^{-1} , whereas, phosphorus content in grain and straw significantly decreased significantly however, phosphorus uptake in grain and straw increased significantly.

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दोमट बलुई मृदा में गेहूँ [*ट्रिटिकम एस्टीवम* (एल.)] के निष्पादन पर वर्मीकम्पोस्ट एवं जिंक का प्रभाव

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सरांश

दोमट बलुई मृदा में गेहूँ [*ट्रिटिकम एस्टीवम* (एल.)] के निष्नपादन पर वर्मीकम्पोस्ट एवं जिंक के प्रभाव का अध्ययन हेतु वर्ष 2010–2011 में रबी के मौसम में एक प्रयोग श्री कर्ण नरेन्द्र कृषि महाविधालय, जोबनेर (राजस्थान) के शस्य विज्ञान प्रक्षेत्र पर लगाया गया।

यह प्रयोग तीन पुनरावृतियों सहित यादृच्छिक खण्ड अभिकल्पना के अनुसार किया गया। इसमें वर्मीकम्पोस्ट उपचार के चार स्तर (0, 2.4, 4.8 एवं 7.2 टन प्रति हैक्टर) तथा जिंक उपचार के भी चार स्तर (0, 2.5, 5.0 एवं 7.5 किलोग्राम प्रति हैक्टर) थे। जिंक को जिंक सल्फेट द्वारा दिया गया व साथ मे नत्रजन, फास्फोरस एवं पोटैशियम की प्रस्तावित मात्रा मृदा में समान रूप सें देकर, गेहूँ की किस्म राज. 3077 उगाई गई। प्रयोग की मुख्य उपलब्धियां इस प्रकार रहीः–

वर्मीकम्पोस्ट के 4.8 व 7.2 टन प्रति हेक्टर के अनुप्रयोग से फसल कटाई अवस्था पर मृदा के स्थूल धनत्व मे सार्थक कमी तथा संतृप्त जल भार संचालकता व नमी धारिता (1/3 व 15 बार पर), में सार्थक वृद्वि पाई गई। वर्मीकम्पोस्ट के वर्धमान स्तरों के अनुप्रयोग से मृदा मे फसल कटाई अवस्था पर जैविक कार्बन, उपलब्ध नत्रजन, फास्फोरस, पोटैशियम एवं जिंक मे सार्थक वृद्वि पाई गई। जबकि वर्मीकम्पोस्ट की दर 4.8 टन प्रति हैक्टर तक के अनुप्रयोग से पादप ऊँचाई, पत्ती क्षैत्र सुचकांक, प्रभावी कल्लो की संख्या, प्रति पादप बालियाँ की संख्या, बीज परीक्षण भार, दाने व भूसे की उपज तथा दाने एवं भूसे में नत्रजन, फास्फोरस, पोटैशियम व जिंक की मात्रा तथा उदग्रहण, बीज में प्रोटीन की मात्रा, पत्तीयों में पुष्पण अवस्था में हरित पर्णक की मात्रा व शुद्ध आय में सार्थक वृद्धि पाई गयी।

जिंक के अनुप्रयोग से मृदा में स्थूल धनत्व, संतृप्त जलभार संचालकता, नमी धारिता (1/3 व 15 बार पर) जैविक कार्बन व उपलब्ध पोटैशियम मे सार्थक प्रभाव नहीं पाया गया। जबकि जिंक के बढते स्तरों के साथ उपलब्ध नत्रजन व जिंक में सार्थक वृद्वि तथा उपलब्ध फॉस्फोरस में सार्थक कमी पाई गई। जिंक की दर 5.0 किलोंग्राम प्रति हैक्टर तक के अनुप्रयोग से पादप ऊँचाई, पत्तीयों के क्षेत्र सूचकांक, प्रभावी कल्लों की संख्या, प्रति पादप बालियाँ की संख्या, बीज परीक्षण भार, दाने व भूसे की उपज तथा दाने एवं भूसे, में नत्रजन, पोटैशियम, जिंक की मात्रा व उद्ग्रहण तथा दाने में प्रोटीन की मात्रा पत्तियों में पुष्पण अवस्था पर हरित पर्णक की मात्रा व शुद्व आय में सार्थक वृद्धि हुई, हालाकि दाने व भूसे में फास्फोरस की मात्रा में सार्थक कमी जबकि उदग्रहण मे सार्थक वृद्वि पाई गई।

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* एक स्नातकोतर छात्र, मृदा विज्ञान एवं कृषि रसायन विभाग, श्री क.न. कृषि महाविद्यालय, जोबनेर (जयपुर), – 303329

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Appendix – I

Analysis of variance (MSS) for bulk density, saturated hydraulic conductivity and moisture retention (at 1/3 and 15 bars) of soil

Source of variation	d.f.	Mean sum of square			
		Bulk density	, Saturated hydraulic conductivity	Moisture retention (1/3bar)	Moisture retention (15bars)
Replication	2	0.0002945	1.05	0.235	0.015
Vermicompost	3	0.00826*	12.38640*	11.49470*	0.015*
Zinc	3	0.00062	0.59600	0.94110	2.43844
Vermicompost x zinc	9	0.00000	0.00198	0.00199	0.02881
Error	30	0.00040	0.35561	0.62621	0.00013

* Significant at 0.05 per cent level of significance

Appendix – II

Analysis of variance (MSS) for organic carbon, available N, P_2O_5, K_2O and Zn of soil

Source of variation	d.f.	Mean sum of square				
		Organic carbon	Available N	Available P_2O_5	Available K_2O	Available Zn
Replication	2	0.00105	40.0000	5.5258	216.325	0.000765
Vermicompost	3	0.04427*	486.7200*	68.1811*	2025.400*	0.0243*
Zinc	3	0.00090	389.5208*	117.4883*	159.899	0.0273*
Vermicompost x zinc	9	0.00001	0.2418	0.4256	0.205	0.0001
Error	30	0.00063	14.3257	2.5504	121.804	0.0009

* Significant at 0.05 per cent level of significance

Appendix – III

Analysis of variance (MSS) for plant height, leaf area index at harvest of wheat

Source of variation	d.f.	Mean sum of square	
		Plant height	Leaf area index
Replication	2	24.815	0.1295
Vermicompost	3	334.192*	4.3352*
Zinc	3	227.852*	3.9976*
Vermicompost x zinc	9	0.162	0.0296
Error	30	15.078	0.1358

* Significant at 0.05 per cent level of significance

Appendix – IV

Analysis of variance (MSS) for number of Effective tillers per metre row length, number of ears per plant and test weight of wheat

Source of variation	d.f.	Mean sum of square		
		Number of effective tillers per metre row length	Number of ears per plant	Test weight
Replication	2	15.714	0.060	0.465
Vermicompost	3	637.383*	1.593*	37.480*
Zinc	3	532.395*	1.331*	30.587*
Vermicompost x zinc	9	1.647	0.004	0.015
Error	30	29.263	0.081	3.086

* Significant at 0.05 per cent level of significance

Appendix – V

Analysis of variance (MSS) for grain yield and straw yield of wheat

Source of variation	d.f.	Mean sum of square	
		Grain yield	Straw yield
Replication	2	4.417	12.764
Vermicompost	3	418.278*	1208.825*
Zinc	3	306.514*	885.827*
Vermicompost x zinc	9	2.247	6.493
Error	30	8.706	25.161

* Significant at 0.05 per cent level of significance

Appendix – VI

Analysis of variance (MSS) for nitrogen content and uptake in grain and straw of wheat

Source of variation	d.f.	Mean sum of square			
		Nitrogen content		Nitrogen uptake	
		Grain	Straw	Grain	Straw
Replication	2	0.043	0.0013	103.61	16.90
Vermicompost	3	0.349*	0.0191*	2908.87*	654.87*
Zinc	3	0.289*	0.0117*	2285.26*	467.07*
Vermicompost x zinc	9	0.001	0.0000	39.84	6.81
Error	30	0.018	0.0009	40.43	11.19

* Significant at 0.05 per cent level of significance

Appendix – VII

Analysis of variance (MSS) for phosphorus content and uptake in grain and straw of wheat

Source of variation	d.f.	Mean sum of square			
		Phosphorus content		Phosphorus uptake	
		Grain	Straw	Grain	Straw
Replication	2	0.00018	0.00017	10.73306	0.39637
Vermicompost	3	0.02383*	0.00209*	228.41955*	63.12596*
Zinc	3	0.03121*	0.00297*	8.09350	2.62621
Vermicompost x zinc	9	0.00006	0.00001	0.13118	0.04042
Error	30	0.00048	0.00013	4.63315	1.62452

* Significant at 0.05 per cent level of significance

Appendix – VIII

Analysis of variance (MSS) for potassium content and uptake in grain and straw of wheat

Source of variation	d.f.	Mean sum of square			
		Potassium content		Potassium uptake	
		Grain	Straw	Grain	Straw
Replication	2	0.0014	0.0011	9.8798	105.5663
Vermicompost	3	0.0281*	0.1003*	285.2936*	4468.1430*
Zinc	3	0.0238*	0.0888*	223.4871*	3493.0022*
Vermicompost x zinc	9	0.0000	0.0001	3.5671	46.5577
Error	30	0.0014	0.0072	5.1933	87.0075

* Significant at 0.05 per cent level of significance

Appendix – IX

Analysis of variance (MSS) for zinc content and uptake in grain and straw of wheat

Source of variation	d.f.	Mean sum of square			
		Zinc content		Zinc uptake	
		Grain	Straw	Grain	Straw
Replication	2	0.571	1.319	134.005	413.656
Vermicompost	3	70.708*	49.989*	6805.792*	11328.430*
Zinc	3	94.133*	61.302*	6334.993*	10382.045*
Vermicompost x zinc	9	0.200	0.182	104.168	193.032
Error	30	2.729	1.949	177.092	244.200

* Significant at 0.05 per cent level of significance

Appendix –X

Analysis of variance (MSS) for crude protein content in grain and chlorophyll content in leaves of wheat

Source of variation	d.f.	Mean sum of square	
		Crude protein content in grain	Chlorophyll content in leaves
Replication	2	2.7750	0.0816
Vermicompost	3	13.6286*	3.0080*
Zinc	3	11.2886*	3.6200*
Vermicompost x zinc	9	0.0294	0.0387
Error	30	0.9195	0.0768

* Significant at 0.05 per cent level of significance

Appendix – XI

Analysis of variance (MSS) for net return of wheat

Source of variation	d.f.	Mean sum of square
		Net return
Replication	2	49544013
Vermicompost	3	64328704*
Zinc	3	632605739*
Vermicompost x zinc	9	5751492
Error	30	10326828

* Significant at 0.05 per cent level of significance

Appendix –XII

Common cost of cultivation of wheat and other details of cost incurred in treatment application

S.No.	Particulars	Unit ha^{-1}	Rate/ unit (Rs)	Cost Rs ha^{-1}
A.	**Common cost of cultivation**			
1.	Field preparation			
	(a) Ploughing by disc plough	2	625	1250
	(b) Harrowing	2	1200	2400
	(c) Planking	2	250	500
	(d) Layout and bed preparation	10 man days	120	1200
2.	Seed	120 kg	16	1920
3.	Seed treatment (Bavistin)	200 g	65	130
4.	Seed sowing charge by bullock drawn deshi plough			600
5.	Fertilizer			
	(a) Nitrogen through urea +DAP	100 kg	8.00	800
	(b) Phosphorus through DAP	60 kg	22.68	1361
	(c) Potassium through MOP	40 kg	7.00	280
6.	Irrigation (six) including labour charge	6	500	3000
7.	Hand weeding, hoeing and thinning	10 man days	125	1250
8.	Harvesting	15 man days	125	1875
9.	Threshing and winnowing	15 man days	125	1875
10.	Miscellaneous			570
	Total of common cost			19011
B.	**Treatment cost**			
1	Vermicompost			
	(a) V_0	0.0 t	2500 /t	00.00
	(b) $V_{2.4}$	2.4 t	2500 /t	6000
	(c) $V_{4.8}$	4.8 t	2500 /t	12000
	(d) $V_{7.2}$	7.2 t	2500 /t	18000
2	Zinc ($ZnSO_4.7H_2O$)			
	(a) Zn_0	00.0 kg	28	00.00
	(b) $Zn_{2.5}$	12.5 kg	28	350
	(c) $Zn_{5.0}$	25.0 kg	28	700
	(d) $Zn_{7.5}$	37.5 kg	28	1050
C.	**Produce cost**			
1	Wheat grain	-------------	1175 q^{-1}	---------
2	Wheat straw	--------------	250 q^{-1}	---------

Appendix – XIII

Relative economics of different treatment combinations for wheat

Treatments combinations	Treatment cost (Rs ha^{-1})	Common cost (Rs ha^{-1})	Total cost (Rs ha^{-1})	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Gross returns Rs ha^{-1})	Net returns (Rs ha^{-1})
V_0Zn_0	0	19011	19011	22.58	38.38	35813.46	16802
$V_0Zn_{2.5}$	350	19011	19361	25.31	43.03	40400.09	20639
$V_0Zn_{5.0}$	700	19011	19711	30.31	51.52	47701.01	27190
$V_0Zn_{7.5}$	1050	19011	20061	31.57	53.66	49397.44	28511
$V_{2.4}$ Zn_0	6000	19011	25011	26.33	44.76	43007.89	17997
$V_{2.4}Zn_{2.5}$	6350	19011	25361	29.52	50.18	48515.92	22755
$V_{2.4}Zn_{5.0}$	6700	19011	25711	35.34	60.08	57283.49	30772
$V_{2.4}Zn_{7.5}$	7050	19011	26061	36.81	62.58	59320.71	32435
$V_{4.8}Zn_0$	12000	19011	31011	31.53	53.60	50413.92	19403
$V_{4.8}Zn_{2.5}$	12350	19011	31361	35.34	60.09	56870.44	25109
$V_{4.8}Zn_{5.0}$	12700	19011	31711	42.32	71.95	67147.81	34637
$V_{4.8}Zn_{7.5}$	13050	19011	32061	44.08	74.94	69535.83	36650
$V_{7.2}Zn_0$	18000	19011	37011	33.57	57.07	53164.73	16154
$V_{7.2}Zn_{2.5}$	18350	19011	37361	37.63	63.97	59973.55	22213
$V_{7.2}Zn_{5.0}$	18700	19011	37711	45.06	76.61	70811.69	32301
$V_{7.2}Zn_{7.5}$	19050	19011	38061	46.94	79.79	73330.02	34444