EFFECT OF VERMICOMPOST AND NPK ON THE GROWTH, CHEMICAL COMPOSITION AND YIELD OF WHEAT

By

MOHAMMAD SAIFUL ISLAM BHUIYAN
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Approved by:

(Dr. Md. Nurul Islam)
Professor
Supervisor

(Dr. Sirajul Hoque)
Professor
Co-supervisor

(Dr. G. N. C. Sutradhar)
Associate Professor
Chairman
Examination Committee

শেরে বাংলা কৃষি বিশ্ববিদ্যালয়
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh

Ref. Date:..........................

CERTIFICATE

This is to certify that the thesis entitled, **"EFFECT OF VERMICOMPOST AND NPK ON THE GROWTH, CHEMICAL COMPOSITION AND YIELD OF WHEAT"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN SOIL SCIENCE**, embodies the result of a piece of *bona fide* research work carried out by **MOHAMMAD SAIFUL ISLAM BHUIYAN**. Registration No. 23947/00254 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 29/11/05

Dhaka, Bangladesh

(Dr. Md. Nurul Islam)

Supervisor

Telephone : 8126183, 9144270-9, Fax : +8802 9112649, E-mail : vcsau@dhaka.net

Dedicated to

My

Beloved Parents

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Place: Dhaka

Dated:

Mohammad Saiful Islam Bhuiyan

M.S. Student,

Reg. No. 23947/00254

Dept. of Soil Science

S.A.U.

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ABSTRACT

A field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka 1207 during the *Rabi* season of 2004-2005 to study the effect of vermicompost and NPK on the growth, chemical composition and yield of wheat. The experimental soil was silty clay in texture having pH of 6.0. The treatments were 4 levels of vermicomposts viz. V_0(0 t ha^{-1}), V_1(1 t ha^{-1}), V_2(2 t ha^{-1}), V_3(3 t ha^{-1}), and 4 levels of chemical fertilizers viz. F_0 = (0-0-0 kg ha^{-1}), F_1 = low (40-30-20 kg ha^{-1}), F_2 = medium (80-60-40 kg ha^{-1}) and F_3 = high (120-80-60 kg ha^{-1}) of N-P_2O_5-K_2O with 16 treatments combinations and 3 replications. The results demonstrated that with the increasing the doses of vermicomposts and chemical fertilizers increased grain and straw yield of wheat significantly. The maximum significant grain and straw yields were obtained with the treatment combinations V_3F_2 or V_2F_3. The highest doses of vermicompost and chemical fertilizers increased N, P, K and S concentrations in wheat plant significant at different stages of plant growth and also enhanced N, P, K and S uptake significantly at the ripening stage. Application of chemical fertilizers failed to increase organic matter content of post harvest soil, where as vermicomposts showed a significant positive effect. Vermicompost and chemicals fertilizers also increased N, P, K and S status of soil significantly.

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LIST OF ABBRIVIATIONS

ABBREVIATION	FULL WORD
AEZ	Agro-Ecological Zone
@	At the rate
CEC	Cation Exchange Capacity
cm	Centimeter
$CuSO_4.5H_2O$	Green vitriol
cv.	Cultivar(s)
CV%	Percentage of Coefficient of Variance
DMRT	Duncan's Multiple Range Test
e.g.	example
et al	and others
FYM	Farm Yard Manure
g	Gram
H_3BO_3	Boric acid
$HClO_4$	Perchloric acid
HNO_3	Nitric acid
H_2O_2	Hydrogen per oxide
H_2SO_4	Sulfuric acid
i.e	that is
K	Potassium
kg	Kilogram
kg ha^{-1}	Kg per hectare
K_2SO_4	Potassium Sulfate
LSD	Least Significant Difference
S	Sulphur
TSP	Triple Super Phosphate
m	Meter
mL	Milliliter
mm	Millimeter
MP	Muriate of Potash
N	Nitrogen
NaOH	Sodium Hydroxide
NPK	Nitrogen, Phosphorus and Potassium
NS	Not Significant
OM	Organic matter
pH	Hydrogen ion concentration
^0C	Degree Celsius
%	Percent
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
t ha^{-1}	Ton per hectare

Chapter 1
Introduction

Chapter 1

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the second most important cereal crop after rice in Bangladesh. About 642.10 thousand hectares of land in Bangladesh is covered by wheat cultivation with the annual production of 1253 thousand tons (BBS, 2005). Wheat is well adapted to our climate and can play a vital role in recovering our food shortage. Unfortunately, the average yield of wheat is quite low in Bangladesh in comparison to other wheat growing countries of the world. Imbalanced fertilizer application is one of the major causes of low yield of wheat in Bangladesh (Saerah *et al.*, 1996).

The excessive use of urea, imbalance use of phosphate and potassium fertilizers in the field of horticulture and agronomic crops without considering the other micro or macronutrients are a common practice in Bangladesh. Due to the deterioration of soil fertility and lack of sufficient amount of organic matter in the soil, the yield of vegetables, fruits and other crops are not satisfactory. A balanced supply of essential nutrients is indispensable for optimum plant growth. Continuous use of large amounts of only N, P and K is expected to influence not only the availability of other nutrients to plants because of possible interaction between them but also the build up of some of the nutrients creating imbalances in soils and plants leading to decreased fertilizer use efficiency (Nayyar and Chhibba, 1992).

Among the different sources of organic manure, vermicompost is important in maintaining and enhancing the quality of environment and conserving resources for sustainable agriculture (Simanaviciene *et al.*, 2001). Taking into account the environmental and public health benefits of vermicompost farming, there is a considerable potential to maximize the use of vermicompost to increase yield and to reduce unnecessary usages of chemical fertilizer for crops production in Bangladesh.

Vermiculture can only be done on compostable or decomposable organic matter. The compost prepared by using earthworms is called vermicompost. Vermicompost is the outcome of earthworm activities. Vermicompost is very important aspect of organic farming package today. It is easy to prepare, has excellent properties and is absolutely harmless to environment, soil and plants. Vermi cast is generally more beaded, crisped and micronized, that binds soil particles and contains several enzymes, microorganisms and plant nutrients. It has many functions, namely, micronizing soil particles to medium sized particles, re-distribution of nutrients, reduce runoff of nutrients from surface soil, increasing availability of phosphorous, potassium and nitrogen to plants and mixing of various nutrients. It can also be an important agent of pedogenesis.

The essential elements must be present in soil in optimum levels and in available forms for normal plant growth and development. It is essential to identify the status of these essential nutrients, how they decrease or increase yield and quality of crop and the way by which their available amounts can be maintained in forms and at levels that can give high crop production in the long-term use. Obviously, it is very difficult to determine the exact reason what occurs. But it is clear that this occurs consistently under a particular soil, crop or seasonal condition, then it is a factor that must be considered in sound fertilizer recommendation (Tandon, 1992).

The application of different fertilizers and manures influences the physical and chemical properties of soil and enhance the metabolic activities of soil. The organic and chemical fertilizers are also positively correlated with soil porosity, enzymatic activity and CO_2 production. Organic matter stimulates soil biological activity. Mineral fertilizer enhances soil porosity by increasing regular and irregular pores and causes a priming effect of native soil organic matter (Marinari *et al.*, 2000).

Several types of complexities may arise due to the unbalanced concentrations of different nutrients and as a consequence various interactions occur leading to nutrient deficiencies, toxicities, or other effects of plant nutrient stress (Donahue *et al.*, 1987). Use of organic matter with common chemical source of plant nutrients is one of the easy and simple way to increase the total and quality yield of wheat. Considering the above condition the present experiment has been undertaken with the following objectives:

1. To study the effect of vermicompost and NPK on the yield of wheat.
2. To know the optimum dose of vermicompost and NPK on the yield of wheat.

Chapter 2

Review of literature

Chapter 2

REVIEW OF LITERATURE

It is now realized that agriculture does not only refer to crop production but also to various other factors that are responsible for crop production. Vermicompost is one of the marvelous components in the organic farming and eco farming. Some of the published reports relevant to research topic are reviewed under the following headings:

2.1 Effect and importance of NPK fertilizers on wheat

Niklewski *et al*. (1977) found that average grain yields of wheat were 1.34 and 1.74 t ha^{-1}, respectively, for treatments having manure without NPK and manure with NPK. On the other hand, from an experiment Mobbayad (1982) found that the use of organic and inorganic fertilizer in 50:50 ratios gave yield similar to pure chemical fertilizers. Again, Gaur (1982) reported that the combined effect of N, P_2O_5, K_2O @ 120, 60 and 60 kg ha^{-1} respectively and 2 tons of compost ha^{-1} gave the highest yield of wheat grain.

Yadav (1989) reported from a field trial on loam soil in wheat cv. S-227 crop with 120 kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1} as urea, single superphosphate and KCl or 12 : 12 : 12, 10 : 26 : 26 or 12 : 32 : 16 compound NPK fertilizers at similar rates gave grain yields of 4.17, 3.74, 4.05 and 5.04 t ha^{-1}, respectively, compared with 1.91 t from the untreated control.

Maiti and Mati. (1989) from an experiment reported that the application of N, P_2O_5 and K_2O @ 40, 20, 13.3 ; 80, 40, 26.6 and 120, 60, 40 kg ha^{-1} to four wheat cv. gave average grain yields of 1.37, 1.91 and 1.96 t ha^{-1}, respectively. The results showed that the higher was the dose of N, P_2O_5, K_2O the higher was the yield.

McMahon (1989) conducted an experiment on P availability to wheat and concluded that granular P fertilizers were effective than powder forms and row application being better than broadcasting. He also observed that wheat showed little response to N or P alone but there was a strong N × P interaction with 75-100 kg P_2O_5 ha^{-1} increasing grain yield by 1.5 t ha^{-1}. In acid soil triple super phosphate was proved as the best fertilizer and single superphospate was proved as a good source of Ca.

Rajput *et al.* (1989) found that when wheat cv. Zaughoon-79 was treated with different combinations of 0-150 kg N and 30 or 60 kg P_2O_5 ha^{-1} the highest grain yield was recorded with 100 kg N and 60 kg P_2O_5 ha^{-1}.

Mondal and Mondal (1990) observed in a trial that when wheat was treated with 120 kg Nha^{-1} along with 0, 30 or 60 kg P_2O_5 per hectare the grain yields recorded were 2.46, 2.83 and 3.12 t ha^{-1}, respectively.

Results from a field experiment conducted by Patel *et al.* (1995) showed that grain yield of wheat was increased with increasing rate of NPK fertilizer and was highest with 120 : 60 : 40 kg NPK ha^{-1}.

The effect of various doses and ratios of NPK on sulfur and nitrogen content in various parts of winter wheat was studied by Kastori and Jocic, (1995) in a stationary field experiment and found that grain yield and the content of sulphur and nitrogen were lowest in the variants with no nitrogen fertilizer applied. The application of potassium and phosphorous had no significant effect on the content of sulphur and nitrogen in wheat, while the effect of these fertilizers on grain yield was lower than the effect of nitrogen fertilizer. High positive correlation was found between nitrogen and sulfur content in all studied parts of wheat. The results indicated that long-term application of NPK fertilizers on a chernozem soil not only affected the yield, but also led to interaction between nutrient elements, while their content may be significantly altered in plants.

An experiment was conducted in Faisalabad, Pakistan during 1999-2000 with NPK at 50 : 50 : 0, 75 : 75 : 0, 100 : 100 : 50 and 175 : 125 : 50 ratios on the chemical composition of wheat and found that moisture, ash and protein content increased with increasing rates of NPK fertilizers. The NPK fertilizers had no significant effects on the fat and fibre content of wheat. (Ayesha *et al*, 2002).

Shah (2002) conducted a field experiment to compare the yield, yield component and NPK content in grain and straw of ten wheat varieties and reported that the recommended doses of NP fertilizers (150 kg N ha^{-1} and 90 kg P_2O_5 ha^{-1}) were applied in the form of urea and DAP at the time of sowing and first irrigation. He found that average N, P and K content of grains in wheat varieties were 2.09%, 0.59% and 0.43%, respectively and the average N, P and K content of straw were 0.543%, 0.064% and 1.650%, respectively.

A field experiment was conducted in Bahawalpur, Pakistan during the 2000/2001-2001/2002 *rabi* season to determine the effect of NPK fertilizer rates on the growth and yield of wheat. The seeds were sown with NPK fertilizer at 0 : 0 : 0, 100 : 50 : 0; 150 : 100 : 50 and 200 : 100 : 50 kg ha^{-1}. The highest grain yield (4293 kg ha^{-1}) was recorded with 150 : 100 : 50 kg NPK ha^{-1} (Cheema *et al.*, 2003).

2.2 Effect and importance of vermicompost on crop

Vermicomposting is the managed bioconversion of organic materials through earthworm consumption (Blickwedel and Mach, 1983). Vermiculture and vercomposting experiments have been set up in many countries like England, France, Germany, Italy, Israel, USA, Japan, The Philippines, India and other parts of South-East Asia, Australia, Cuba, The Bahamas and many countries in Africa and South America (Edwards and Bohlen, 1996).

When vermicasts have been compared with the surrounding soils it is observed that casts have a high base exchange capacity and are generally rich in total organic matter, total exchangeable bases, phosphorous, exchangeable potassium, manganese and total exchangeable calcium. Vermicompost helps to improve and protect fertility of topsoil and also helps to boost up productivity by 40% with 20 to 60% lower nutrient inputs. It also enhances the quality of end products and thereby creating significant impact on flexibility in marketing as well as increases the storage time. Vermicompost contain 30 to 50% humic substances which help in the stimulation of plant growth, particularly that of roots, drilling mud and emulsifiers (Dussere, 1992).

Rao *et al.* (2000) from a field experiment carried out at the Indian Agricultural Research Institute, New Delhi, India revealed that application of 3 t vermicompost ha^{-1} to chickpea improved dry matter accumulation, grain yield and grain protein content in chickpea, soil N and P and bacterial count, dry fodder yield of succeeding maize, total N and P uptake by the cropping system over no vermicompost.

A study was conducted in India on two wheat cultivars to investigate the effect of chemical fertilizers (NPK fertilizer), and organic manure (vermicompost). Results showed that plant height, dry matter production and grain yield were higher at higher dose of vermicompost. Number of tillers and leaves per plant were very low at early stages of growth and suddenly increased after adding different concentrations of vermicompost and organic manure (Khandal and Nagendra., 2002).

A field experiment was conducted by Ranwa and Singh (1999) at Hisar, Haryana, India during the winter seasons of 1994-96 to study the effect of integration of nitrogen with vermicompost on wheat crop. The treatment comprised 5 levels of organic manures, viz., no organic manure, farmyard manure at 10 t ha^{-1}, vermicompost (at 5, 7.5 and 10 t ha^{-1}) and 5 levels of N viz. 0, 50, 100, 150 kg ha^{-1} and recommended fertilizer. They reported that the application of organic manures improved yield attributes and grain, straw and biological yields of wheat. Application of vermicompost at 7.5 or 10 t ha^{-1} resulted in higher yields than 10 t ha^{-1} FYM.

A field experiment was conducted in Orissa, India, during the *kharif* season of 1999 to determine the effect of integrated application of vermicompost and chemical fertilizer on rice cv. Lalat. Yield components were increased by integrated application of vermicompost and chemical fertilizes compared to the other treatments. The highest results in terms of straw and crop yields were obtained with 50% vermicompost + 50% chemical fertilizers (Das *et al.*, 2002).

The combined application of organic and inorganic N sustained the productivity. Soil available nutrients like N, P and K increased significantly with the application of various organic sources of nutrients in combination with fertilizers over the fertilizer alone. The highest grain yields of *rabi* sorghum and chickpea weres obtained with 50 percent N through green manure plus 50 percent fertilizer N (Tolanur and Badanur, 2003).

Vasanthi and Kumaraswamy (1999) from an experiment with vermicompost and NPK fertilizers showed that the grain yields of rice were significantly higher in the treatments that received vermicompost from any of the 5 to 10 t ha^{-1} organic materials (sugarcane trash, Ipomea, banana peduncle etc) with N, P and K at recommended levels than in the treatment that received N, P and K alone. Organic carbon content and fertility status as reflected by the available status of N, P, and K, micronutrients and CEC were higher and bulk density were lower in the treatments that received vermicompost plus N, P and K than in the treatments with N, P and K alone. It was found that vermicompost at 5 t ha^{-1} would be sufficient for rice crop when applied with recommended levels of N, P and K.

Vermicompost produced higher yield of tomato than the chemical fertilizer treated and control plots. Same margin of production was obtained in snake gourd, bitter gourd and lady's finger. All the plots of lady's finger at one time were completely damaged due to severe virus attack. It was observed that crops grown under chemical fertilizer became yellowish rapidly while crops grown under vermicompost remained green. Germination of different seeds in the vermicomposted plots were higher than the control and chemical fertilizer treated plots (Zahid, 2001).

2.3 Nutrient status of vermicompost

Vermicompost contains 2.29 folds more organic carbon, 1.76 times total nitrogen, 3.02 folds phosphorous and 1.60 times potassium than normal compost. Earthworms decrease the C: N ratio from 14.21 to 10.11 and an average 56.03% of organic waste can be converted into vermicompost by the activities of earthworms in short time (Sohrab and Sarwar, 2001).

Robinson *et al.*(1992) reported that the nutrients present in vermicompost are readily available and the increase in earthworm populations on application of vermicompost and mulching leads to the easy transfer of nutrient to plants thus providing synchrony in ecosystems.

Kumari and Kumari (2002) from an experiment stated that vermicompost is a potential source of organic manure due to the presence of readily available plant nutrients, growth enhancing substances and number of beneficial microorganisms like N fixing, P solubilising and cellulose decomposing organisms.

Vermicompost contain more organic matter, N, P, S, Ca and Mg. It was shown that worm-worked composts have better texture and soil enhancing properties, hold typically higher percentages of N, P and K (Zahid, 2001).

Harris *et al.* (1990) reported that earthworm excreta is the excellent soil conditioning material with higher water holding capacity and less time for releasing nitrogen into the soil. The nutrient level of the vermicompost was about two times greater than natural compost and the use of vermicompost is important for the farmers to get better quality crop yields.

The organic wastes could be efficiently converted into vermicompost with a recovery of 74.65 - 87% in a composting period of 3 months. Earthworm biomass was doubled irrespective of organic waste used in a period of 2 months. Major nutrients (NPK) and micronutrient (Cu, Zn, Fe and Mn) contents were slightly higher in all the vermicompost samples than in normal compost. Vermicompost had lower C : N ratio and pH than normal compost irrespective of the source of organic waste. Microbial population was considerably higher in vermicompost than in normal compost (Chowdappa *et al*., 1999).

Earthworms influence the changes in various chemical parameters governing the compost maturity of local grass, mango leaves and farm wastes. There was a decrease in C :N ratio, while humic acid, cation exchange capacity and water soluble carbohydrates increased up to 150 days of composting. Compost maturation was achieved up to a period of 120 and 150 days in farm wastes and mango leaves, respectively, while more than 150 days would be required to reach the maturity in case of local grass. Inoculation of earthworms reduced the composting by 13 days (Talaskilkar *et al*., 1999).

Vermicomposting of sugarcane trash individually and in combination with pressmud using earthworm *Perionyx excavatus* increased significantly N by 34%, P by 87%, K by 40%, Ca by 64%, Mg by 39% and Mn by 11% over the control compost along with a reduction in C :N (15 :1) and C :P (6 :1) ratio due to mineralization and combined action of earthworms and microbes (Ramalingam, 1999).

Saerah *et al*. (1996) conducted an experiment on the effect of compost in optimizing the physical condition of sandy soil. Compost at the rates of 0.0, 16.5, 33.0, 49.5 and

66.0 t ha^{-1} was incorporated into the soil and then wheat was grown. The results indicated that the various application rates were significantly correlated with improvement in physical properties of soil as well as straw and grain yields of wheat.

Organic manure influences favorably plant growth and yield through augmentation of beneficial microbial population and their activities such as organic matter decomposition (Gaur *et al.*, 1971).

2.4 Effect and importance of NPK and manure application on wheat

A study was conducted to determine the effects of some of the fertilizer and manure treatments on wheat yield and NPK uptake by wheat. The application of NP fertilizer with and without manure resulted in significant yield increases over the control. The application of NP-fertilizer and NP-manure increased grain-N from 2.03 (control) to 2.38 and 2.31, respectively. Individual and combined application of NP-fertilizer and manure produced a more pronounced effect on K concentration and uptake in straw than in grain (Baluch *et al.*, 1989).

Song *et al.* (2001) conducted an experiment with winter wheat in China to investigate the effects of application of chemical fertilizer NPK alone and combined with organic manure on the growth characteristics and yield of winter wheat. The application of fertilizer NPK alone or fertilizer NPK combined with various sources (FYM, wheat straw and maize straw) of OM increased the wheat's spike length, grains/spike, and plant height compared with the control treatment, thus enhancing biomass and grain yield of wheat. The application of fertilizer NPK combined with OM had a better yield increase than the application of fertilizer NPK alone, especially combined with farmyard manure at a higher dose. It is concluded that the application of fertilizer

NPK combined with OM not only make good use of resources, but also enhance wheat yield.

The effects of NPK applied through various combinations of vermicompost, farmyard manure, and chemical fertilizers on the growth and yield of wheat were studied. The application of vermicompost significantly increased biomass production and yield of wheat. Treatment with 75% vermicompost + 25% farmyard manure resulted in the greatest plant height, leaf number, fresh weight, dry weight and number of spikelets per plant, number of seeds per spike, 1000 grain weight, grain yield per plot and harvest index (Agrawal *et al.*, 2003).

Jat and Ahlawat (2004) reported from a field experiment carried out at the Indian Agricultural Research Institute, New Delhi, India reported that application of 3 t vermicompost ha^{-1} to chickpea improved dry matter accumulation, grain yield and grain protein content in chickpea, soil N and P and bacterial count, dry fodder yield of succeeding maize, total N and P uptake by the cropping system over no vermicompost treatment.

A field experiment was conducted by Rawat and Pareek (2003) with farmyard manure at 0, 5, 10 or 15 t ha^{-1} and NPK at 0 : 0 : 0, 30 : 20 : 10, 60 : 30 : 20, 90 : 40 : 30 or 120 : 50 : 40 kg ha^{-1} in wheat crop in a field experiment conducted in Jobner, Rajastan, India during the *rabi* season of 1998-99 to determine the effects of FYM and NPK on the yield and nutrient uptake of the crop. The yield and NPK content of wheat grain and straw increased with increasing rates of FYM and NPK uptake of the crop also increased with increasing rates of FYM and NPK. The treatments had no significant effects on the organic carbon and available NPK content in the soil at harvest.

A field experiment was conducted at Mymensingh, Bangladesh with wheat variety Kanchan with no mineral fertilizer, 110 kg N, 90 kg P or 100 : 90 : 40 kg NPK/ha and no manure or 8 or 16 t biogas effluent or cattle manure/ha. Average grain yields and protein contents were higher in plots treated with biogas effluent than with cattle manure or the control. Biogas effluent application resulted in the tallest plants, but straw production was highest with cattle manure. There was no significant difference between yields from plots treated with 8 or 16 t biogas effluent, and although yields increased with level of cattle manure, 8 t biogas effluent gave better results than 16 t cattle manure. Assessment of the manure treatments in combination with mineral fertilizers showed that 8 t biogas effluent + NPK gave the highest grain yield but 16 t biogas effluent + 100 kg N gave the highest protein content (Uddin *et al.* 1994).

Baron *et al.* (1995) found that the addition of organic manure has a positive influence not only on soil properties but also on the mineral nutrition of plants and yield of wheat.

Mehta and Dafterdar (1984) found that yield of wheat was greater when compost (4.4 t ha^{-1}) + NPK was used than when NPK alone was used.

Laboratory and field experiments were conducted by Guan (1989) to investigate the influence of organic manures on the availability of nitrogen and phosphorus in an alluvial soil in Shandong, China. The application of compost increased the availability of N and P in comparison with the control.

Srivastava *et al.* (1989) conducted a field experiment and observed that direct soil incorporation of organic wastes consisting of paddy straw and water hyacinth (50 :50) in combination with different levels of fertilizer N resulted in increased wheat yield and improved the organic matter and soil nitrogen status. The maximum yield was obtained with 5 t organic wastes plus 100 kg urea ha^{-1}.

Gupta *et al.* (1995) performed an experiment on wheat cv. WH-157 and observed that grain yields and P and N uptake increased with increasing organic manure levels. Organic carbon content increased with the application of organic manure.

Application of organic manure i.e. vermicompost or FYM along with fertilizer NPK had beneficial residual effect in increasing yield, uptake of nutrients in wheat crop as well as available nutrient (NPK) in soil. The best treatment i.e. 50% NPK fertilizer along with vermicompost @ 10 t ha^{-1} was tested in farmers fields. (Kamla Kanwar, 2002).

The continuous use of organic manures along with inorganic fertilizers increased nutrient uptake and nutrient use efficiency of major nutrients than did the inorganic fertilizers alone (Baslar, 2003).

Chapter 3

Materials and methods

Chapter 3

MATERIALS AND METHODS

This chapter includes a brief description of the experimental soil, wheat variety, land preparation, experimental design, treatments, cultural operations, collection of soil and plant samples etc and analytical methods followed in the experiment to study the effect of vermicompost and N, P, K on the growth, chemical composition and yield of wheat.

3.1 Experimental site

The research work relating to the study of the effect of vermicompost and NPK on the growth, chemical composition and yield of wheat was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka 1207 during the *Rabi* season of 2004-2005. The following map shows the specific area of experimental site. (Figure 1)

3.2 Description of soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ- 28) and the General soil type is Shallow Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was air-dried, ground and passed through 2 mm sieve and analyzed for some important physical and chemical parameters. The physical and chemical characteristics of initial soil are presented in Table 1.

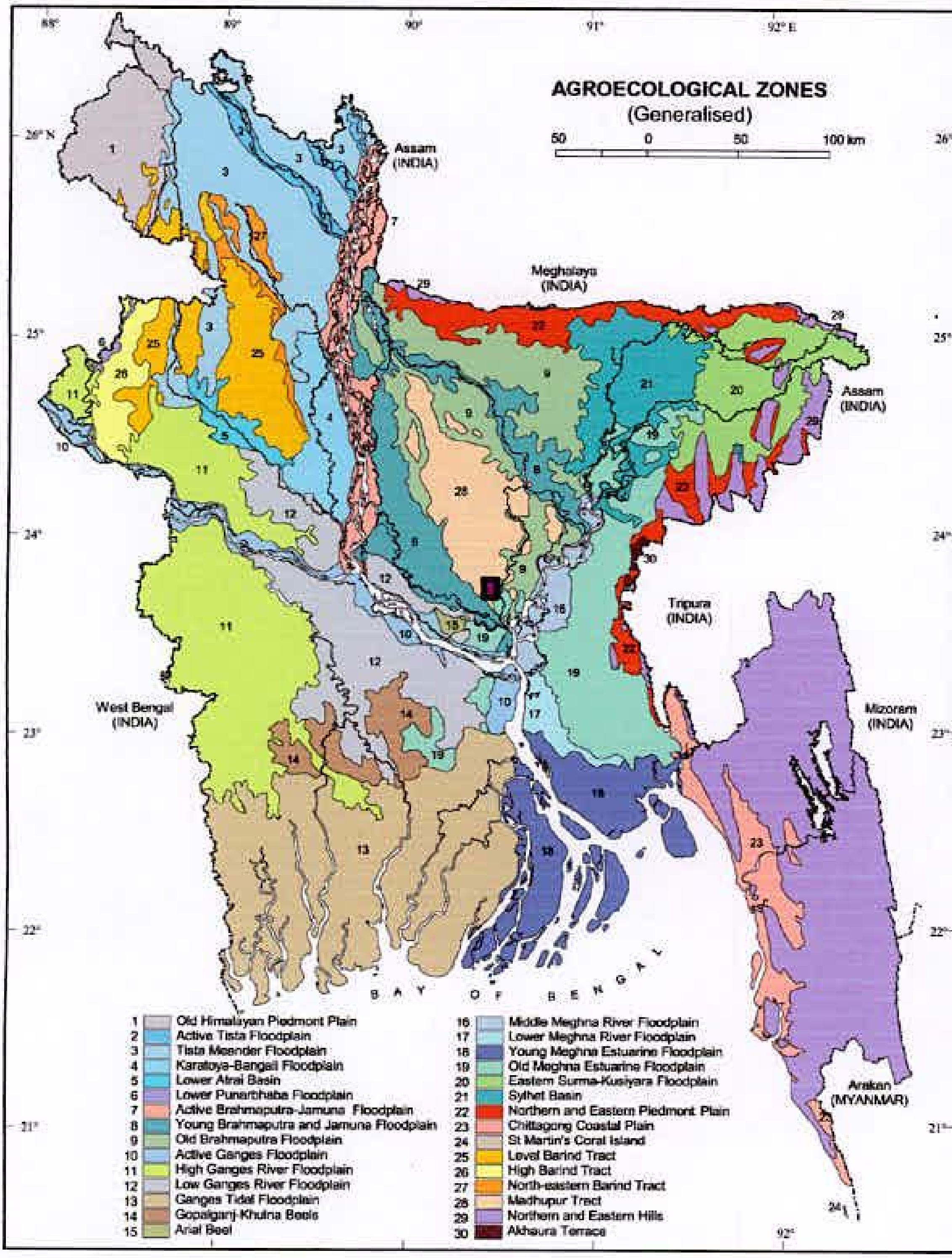


Figure 1 Map showing the experimental site under study

Table 1 Characteristics of the initial soil in experimental field

1.pH		6.0
2. Particle-size analysis of soil	Sand	30.65
	Silt	38.19
	Clay	31.16
3. Textural Class		Silty clay
4. Total N (%)		0.078
5. Organic matter (%)		0.88
6. Phosphorous (%)		0.0015
7. Potassium (%)		0.0053
8. Sulphur (%)		0.0017

3.3 Description of the wheat variety

Shatabdi (BARI GOM-21), a high yielding variety of wheat was used as the test crop in this experiment. This variety was released by Bangladesh Agricultural Research Institute, Joydebpur, Gazipur in 2000. Life cycle of this variety ranges from 105 to112 days. The variety is resistant to diseases, insects and pest attack.

3.4 Preparation of the field

The plot selected for the experiment was opened by power tiller driven rotovator on the 3rd November 2004, afterwards the land was ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed, and the large clods were broken into smaller pieces to obtain a desirable tilth of soil for sowing of seeds. Finally, the land was leveled and the experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in the following section (3.5).

3.5 Layout of the experiment

The experiment was laid out in a two factor Randomized Complete Block Design with three replications. The total number of plots was 48, each measuring 4m × 2.5m ($10m^2$). The treatment combination of the experiment was assigned at random into 16 plots of each at 3 replications. The distance maintained between two plots was 75 cm and between blocks was 150 cm. The layout of the experiment is presented in Figure 2.

3.6 Treatments

The experiment consists of 2 Factors i.e. vermicompost and fertilizer each have four levels. Details of factors and their combinations are presented below:

Factor A: Vermicompost

V_0 = 0 t ha^{-1} (No vermicompost)

V_1 = 1 t ha^{-1} (Low vermicompost)

V_2 =2 t ha^{-1} (Medium vermicompost)

V_3 = 3 t ha^{-1} (High vermicompost)

Factor B: Fertilizer

F_0 = 0 kg N ha^{-1} + 0 kg $P_2O_5ha^{-1}$ + 0 kg K_2O ha^{-1} (No NPK)

F_1 = 40 kg N ha^{-1} + 30 kg P_2O_5 ha^{-1} + 20 kg K_2O ha^{-1} (Low NPK)

F_2 = 80 kg N ha^{-1} + 60 kg $P_2O_5ha^{-1}$ + 40 kg K_2O ha^{-1} (Medium NPK)

F_3 =100 kg N ha^{-1} + 80 kg $P_2O_5ha^{-1}$ + 60 kg K_2O ha^{-1} (High NPK)

Treatment combination

V_0F_0 =Control (No vermicompost + No NPK)

V_0F_1 = (No vermicompost + Low NPK)

V_0F_2 = (No vermicompost + Medium NPK)

V_0F_3 = (No vermicompost + High NPK)

V_1F_0 = (Low vermicompost + No NPK)

V_1F_1 = (Low vermicompost + Low NPK)

V_1F_2 = (Low vermicompost + Medium NPK)

V_1F_3 = (Low vermicompost + High NPK)

V_2F_0 = (Medium vermicompost + No NPK)

V_2F_1 = (Medium vermicompost + Low NPK)

V_2F_2 = (Medium vermicompost + Medium NPK)

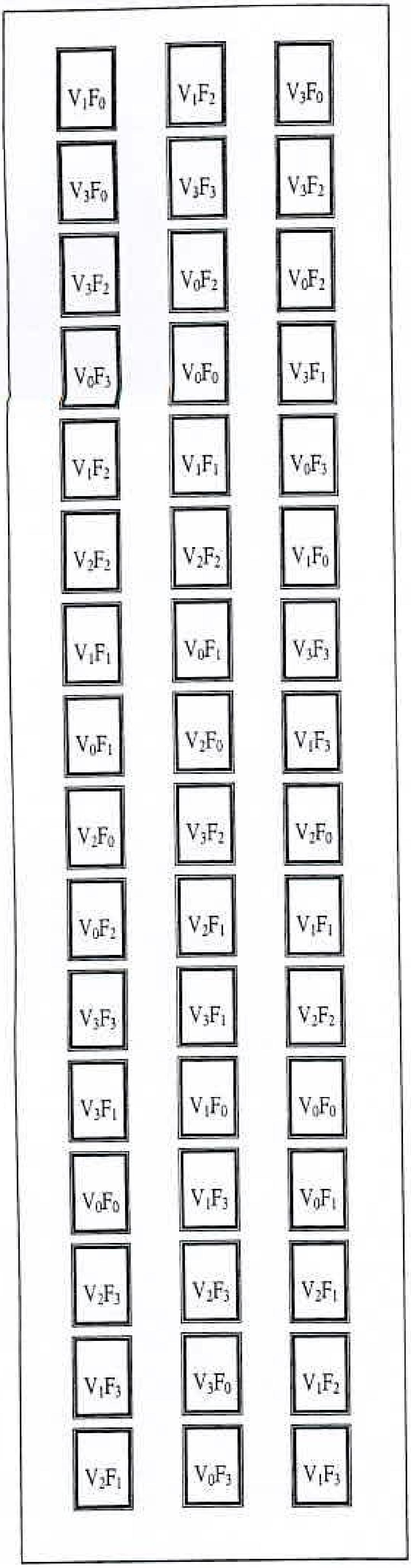
V_2F_3 = (Medium vermicompost + High NPK)

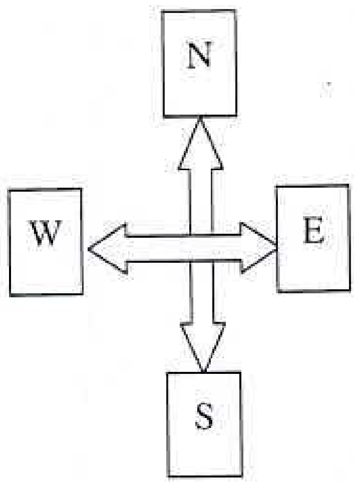
V_3F_0 = (High vermicompost + No NPK)

V_3F_1 = (High vermicompost + Low NPK)

V_3F_2 = (High vermicompost + Medium NPK)

V_3F_3 = (High vermicompost + High NPK)





Plot size : 4 m x 2.50 m ($10\ m^2$)
Plot to plot distance : 75 cm
Block to block distance : 150 cm

Figure 2: Layout of the experimental field

3.7 Application of vermicompost and fertilizers

The required amount of P and K fertilizers (Triple superphosphate and Muriate of Potash respectively) and 50% of the N fertilizer (urea) were uniformly spread on the surface of the individual plot according the treatment combinations. The applied fertilizers in the individual plot were mixed with soil properly by hand spading .The remaining 50% of N (urea) was applied in two splits (after 1st and 2nd irrigation). The required amounts of vermicompost as per treatment combinations were applied uniformly in the canals opened for sowing the seeds of wheat in lines.

3.8 Seed sowing

Wheat seeds were sown on the 10th November 2004 in lines following the recommended line to line distance of 25 cm.

3.9 Cultural and management practices

Various intercultural operations such as thinning of plants, weeding and spraying of insecticides were accomplished whenever required to keep the plants healthy and the field weed free. At the very early growth stage (after 10 days of emergence of seedlings) the plants were attacked by Aphids, which was removed by applying Malathion. Special care was taken to protect the crop from birds especially after sowing and germination stages and at the ripening stage of the crop.

The field was irrigated twice- one at 17 and the other at 50 days of growth of the crop.

3.10 Harvesting

The crop was harvested at maturity on 7th March 2005. The harvested crop of each individual plot was bundled separately. Grain and straw yields were recorded plot wise and the yields were expressed in t ha^{-1}

3.11 Collection of samples

3.11.1 Soil Sample

The initial soil samples were collected randomly from different spots of the field selected for the experiment at 0-15 cm depth before the land preparation and mixed thoroughly to make a composite sample for analysis. Post harvest soil samples were collected from each plot at 0-15 cm depth on 8th March 2005. The samples were air - dried, ground and sieved through a 2 mm (10 mesh) sieve and kept for analysis.

3.11.2 Plant sample

Plant samples were collected from every individual plot for laboratory analysis at three-growth stages of the crop. The growth stages were maximum tillering, flowering and ripening stages. Five plants were randomly collected from each plot by cutting above the ground level. The plant samples were washed first with tape water and then with distilled water several times .The plant samples were dried in the electric oven at 70^0 C for 48 hours. After that the samples were ground in an electric grinding machine and stored for chemical analysis. The plant samples were collected by avoiding the border area of the plots.

3.12 Collection of data

Data collection were done on the following parameters-

3.12.1 Plant height

The plant height was measured from the ground level to the top of the panicle. Plants of 5 hills were measured from each plot and averaged. It was done at the ripening stage of the crop.

3.12.2 Thousand seed weight

Thousand seed of wheat were counted randomly and then weighed plot wise.

3.12.3 Grain yield

Grains obtained from 1 m^2 area from the center of each unit plot was dried, weighed carefully and then converted into t ha^{-1}.

3.12.4 Straw yield

Straw obtained from each individual plot was dried, weighed carefully and the yield expressed in t ha^{-1}.

3.13 Chemical analysis of the plant, soil and vermicompost samples

3.13.1 Plant sample analysis

The plant samples collected at different growth stages of the crop were digested with conc. HNO_3 and $HClO_4$ mixture for the determination of P, K and S.

3.13.1. a Phosphorous

Phosphorous in the digest was determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a Spectrophotometer (LKB Novaspec, 4049).

3.13.1. b Potassium

Potassium content in plant sample was determined by flame photometer.

3.13.1. c Sulphur

Sulphur content in the digests were determined by turbidimetric method as described by Hunt (1980) using a Spectrophotometer (LKB Novaspac, 4049)

3.13.1. d Nitrogen

Plant samples were digested with 30% H_2O_2, conc. H_2SO_4 and a catalyst mixture (K_2SO_4 : $CuSO_4.5H_2O$: Selenium powder in the ratio 100 : 10 : 1,respectively) for the determination of total nitrogen by Micro-Kjelkal method. Nitrogen in the digests were determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01N H_2SO_4 (Jackson,1973).

3.13.2 Soil sample analysis

3.13.2. a Organic carbon

Soil organic carbon was determined by Walkley and Black's wet oxidation method as outlined by Jackson (1973) from the samples collected before sowing and also after harvesting the crop.

3.13.2. b Organic matter

The organic matter content was calculated by multiplying the percent organic carbon with Van Bemmelen factor 1.73 (Piper, 1950)

3.13.2. c Total nitrogen

Total nitrogen of soil samples were estimated by Micro-Kjeldahl method where soils were digested with 30% H_2O_2 conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Selenium powder in the ratio 100 :10 :1 respectively). Nitrogen in the digests were determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01N H_2SO_4 (Jackson, 1973).

3.13.2. d Available Phosphorous

Available phosphorous was extracted from the soil by Bray-1 method (Bray and Kurtz, 1945). Phosphorous in the extract was determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a Spectrophotometer (LKB Novaspec, 1949).

3.13.2. e Exchangeable potassium

Exchangeable potassium in the soil sample was extracted with 1N neutral ammonium acetate and the potassium content was determined by flame photometer.

3.13.2. f Available sulphur

Available sulphur was extracted from the soil with Ca $(H_2PO_4)_2$. H_2O (Fox, *et al.*, 1964). Sulphur in the extract was determined by the turbidimetric method as described by Hunt (1980) using a Spectrophotometer (LKB Novaspec, 4049).

3.13.3 Vermicompost

Vermicompost was analyzed for organic matter, total N, available P, K and S contents following the methods used for plant and soil analysis. Vermicompost contained 11.03%organic matter, 0.6398% total N, 0.02259% available P, 0.0776% available K and 0.0306% available S.

3.13.4 Statistical analysis

The data obtained from the experiment were analyzed statistically to find out the significance of the difference among the treatments. The mean values of all the characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the differences among pairs of treatment means was estimated by the least significant difference (LSD) test at 5% and 1% level of probability and DMRT was calculated (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

Chapter 4

RESULTS AND DISCUSSION

The results on different yield attributes, yield and nutrient concentrations in the plants and availability of different nutrients in the soil after harvest of wheat are presented in this chapter.

4.1 Effect of vermicompost and NPK on the growth parameters and yield of wheat

4.1.1 Plant height

The effects of vermicompost and NPK fertilizers alone and in combination of two sources on the plant height of wheat are presented in (Table 2 and Appendix Figure 1). Significant variation was observed on the plant height of wheat when the field was incorporated with different doses of vermicompost. Among the different doses of vermicompost, V_3 (3 t ha^{-1}) showed the highest plant height (92.03 cm). On the other hand the lowest plant height (86.37 cm) was observed in the V_0 treatment where no vermicompost was applied and it was closely followed by (88.04 cm) the V_1 (1 t ha^{-1}) treatment (Table 2 and Appendix Figure 1). Vermicompost might have increased the soil moisture content, soil porosity and other plant growth enhancing characters and for that reason increasing dose of vermicompost increased plant height. Similar result was reported by Gorlitz (1987). Agrawal *et al.*, (2003) found that the increasing soil organic matter content through the application of FYM in wheat increased plant height.

Table 2Effect of vermicompost on the yield contributing characters and the yield of wheat

Vermicompost	Plant height (cm)	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
V_0	86.37 c	44.14 b	2.44 c	2.75 c
V_1	88.04 bc	45.93 ab	2.72 b	3.04 b
V_2	89.72 ab	46.90 a	2.99 a	3.40 a
V_3	92.03 a	47.02 a	2.95 a	3.39 a
Level of Significance	0.01	0.05	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

Wheat plants showed significant variation in respect of plant height when fertilizers in different doses were applied. Among the different fertilizer doses, F_3 (High NPK) showed the highest plant height (92.95 cm), which was statistically identical with the fertilizer dose F_2 (Medium NPK). On the contrary, the lowest plant height (84.06 cm) was observed in the fertilizer combination F_0 where no fertilizer was applied (Table 3 and Appendix Figure 2).

Table 3 Effect of NPK fertilizer on the yield contributing characters and the yield of wheat

NPK Fertilizer	Plant height (cm)	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
F_0	84.06 c	44.10 b	2.07 d	2.51 d
F_1	88.09 b	45.58 ab	2.45 c	2.91 c
F_2	91.06 a	46.67 a	3.14 b	3.44 b
F_3	92.95 a	47.65 a	3.43 a	3.72 a
Level of Significance	0.01	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

Combined application of different doses of vermicompost and fertilizer had no significant effect on the plant height of wheat (Table 4 and Appendix Figure 3). The lowest plant height (78.31 cm) was observed in the treatment combination of V_0F_0 (No vermicompost and No NPK). On the other hand, the highest plant height (94.37 cm) was recorded with V_3F_3 (High vermicompost + High NPK).

It is evident from the data that vermicompost at the high rate along with high dose of NPK resulted the highest plant height of wheat plants.

Table 4 Combined effect of vermicompost and NPK fertilizer on the yield contributing characters and yield of wheat

Vermicompost × NPK Fertilizer	Plant height (cm)	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
V_0F_0	78.31	42.60	1.93 f	2.20 h
V_0F_1	85.32	43.40	2.15 ef	2.34 h
V_0F_2	90.22	44.30	2.73 d	3.11 de
V_0F_3	91.63	46.27	2.93 cd	3.37 bcd
V_1F_0	84.00	43.57	1.95 f	2.28 h
V_1F_1	87.18	45.10	2.35 e	2.77 fg
V_1F_2	88.38	46.91	3.13 c	3.28 bcd
V_1F_3	92.58	48.15	3.43 b	3.82 a
V_2F_0	85.48	45.22	2.38 e	2.92 ef
V_2F_1	88.58	46.90	2.92 cd	3.40 bc
V_2F_2	91.62	47.25	2.98 c	3.50 b
V_2F_3	93.20	48.24	3.67 a	3.77 a
V_3F_0	88.45	45.02	2.01 f	2.65 g
V_3F_1	91.27	46.92	2.38 e	3.15 cde
V_3F_2	94.02	48.22	3.72 a	3.85 a
V_3F_3	94.37	47.93	3.67 a	3.92 a
Level of Significance	NS	NS	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.1.2 Weight of 1000 grain

Significant variation was observed in the weight of 1000 seeds of wheat when different doses of vermicompost were applied (Table2 and Appendix Figure 1). The highest 1000 seed weight (47.02 g) was recorded in V_3 (3 t ha^{-1}), which was statistically similar with V_2 (2 t ha^{-1}). The lowest 1000 seed weight (44.14 g) was recorded in the V_0 treatment where no vermicompost was applied and it was closely followed by (45.93 g) the V_1 (1 t ha^{-1} vermicompost) treatment. Similar result was reported by Agrawal *et al.* (2003). They found that treatment with 75% vermicompost + 25% farmyard manure resulted in the greatest 1000 seed weight. The increased grain height might be due to favorable effects of vermicompost on the vegetative growth and accumulation of materials that helped proper growth and development of the wheat grain.

Different doses of chemical fertilizers showed significant variations in respect of weight of 1000 grain (Table 3 and Appendix Figure 2). Among the different doses of fertilizers, F_3 (High NPK) showed the highest weight of 1000 seeds (47.65 g), which was statistically identical (46.67 g) with the fertilizer dose of F_2 (Medium NPK). On the contrary, the lowest weight of 1000 seeds (44.10 g) was observed with F_0, where no fertilizer was applied and this was closely followed by the F_1 (Low NPK) fertilizer combination. Jelic *et al.* (1992) found that fertilizer application increased 1000-grain weight by an average of 10.42% with the increase of fertilizer up to a certain level.

The combined effect of different doses of vermicompost and fertilizer on weight of 1000 seeds of wheat was not significant (Table 4 and Appendix Figure 4). But the highest weight of 1000 seed (48.24 g) was recorded with the treatment combination of

V_2F_3 (Medium vermicompost + High NPK). On the other hand, the lowest weight of 1000 seed (42.60 g) was found in V_0F_0 treatment (No vermicompost and No NPK).

4.1.3 Grain yield of wheat

The grain yield as affected by different doses of vermicompost showed a statistically significant variation (Table 2 and Appendix Figure1). Among the different doses of vermicompost the highest grain yield (2.99 t ha^{-1}) was observed in V_2 (2 t ha^{-1}), which was statistically identical (2.95 t ha^{-1}) with V_3 (3 t ha^{-1}). The lowest grain yield (2.44 t ha^{-1}) was recorded in the V_0 treatment where no vermicompost was applied and it was closely followed (2.72 t ha^{-1}) by the V_1 (1 t ha^{-1}) treatment. Probably vermicompost supplied the necessary requirements for the proper vegetative growth that helped in obtaining the highest yield of wheat. Fouda (1989) stated that grain yield of wheat were increased with the increasing rate of compost application.

Application of fertilizers at different treatment doses showed a significant variation on the of grain yield of wheat (Table 3 and Appendix Figure 2). Among the different combinations fertilizer doses, F_3 (High NPK) showed the highest grain yield (3.43 t ha^{-1}), which was closely followed (3.14 t ha^{-1}) by the fertilizer dose F_2 (Medium NPK). On the other hand, the lowest grain yield (2.07 t ha^{-1}) was recorded with F_0 treatment, where no fertilizer was applied , which also closely followed by the F_1 (Low NPK) treatment. Similar results were reported by Kadar and Csatho (1987) and Dang *et al.* (1988). Optimum fertilizer doses increase the vegetative growth and development of wheat that lead to the highest grain yield. Patel *et al.* (1995) showed that grain yield of wheat was increased with increasing rates of NPK fertilizer and the highest yield was obtained with 120: 60: 40 kg NPK ha^{-1} respectively. On the other hand, Sun and Chen (1995) reported from the economic point of view that the application of 10 kg P_2O_5 $m^{-2}$to wheat gave the best results.

Combined effects of different doses of vermicompost and fertilizers on grain yield showed a statistically significant variation (Table 4 and Appendix Figure 5). The highest grain yield (3.72 t ha^{-1}) was recorded in the treatment combination of V_3F_2 (High vermicompost + Medium NPK) and V_2F_3 (Medium vermicompost + High NPK), which was statistically identical with the treatment combination of V_3F_3 (High vermicompost + High NPK). On the other hand, the lowest grain yield (1.93 t ha^{-1}) was found in V_0F_0. Similar result was obtained by Song *et al.* (2001). They found that the application of fertilizer NPK combined with OM enhanced biomass production and the grain yield of wheat.

4.1.4 Straw yield

Significant variation in straw yield of wheat was observed with different doses of vermicompost (Table 2 and Appendix Figure 1). Among the different doses of vermicompost V_2 (2 t ha^{-1}) showed the highest straw yield (3.39 t ha^{-1}), which was statistically identical with the treatment V_3 (3 t ha^{-1}). On the other hand, the lowest straw yield (2.75 t ha^{-1}) was observed in the V_0 treatment, where no vermicompost was applied and it was closely followed (3.04 t ha^{-1}) by the V_1 (1 t ha^{-1}) treatment . Bangar *et al.* (1990) reported that compost increased straw yield significantly.

Straw yield showed significant variation when different doses of fertilizers were applied (Table 3 and Appendix Figure 2). Among the different combinations of fertilizer doses, F_3 (High NPK) showed the highest straw yield (3.72 t ha^{-1}), which was closely followed (3.44 t ha^{-1}) by the fertilizer dose F_2 (Medium NPK). The lowest straw yield (2.51 t ha^{-1}) was observed with F_0 no fertilizer was applied, which was followed by F_1 (Low NPK).

Combined effect of different doses of vermicompost and fertilizer showed a statistically significant effect on the straw yield of wheat (Table 4 and Appendix Figure 6) .The lowest straw yield (2.20 t ha^{-1}) was observed in the treatment combination of V_0F_0 (No vermicompost and No NPK). On the other hand the highest straw yield (3.92 t ha^{-1}) was recorded with V_3F_3 (High vermicompost + High NPK), which was statistically identical with the treatment combinations of V_3F_2 (High vermicompost + Medium NPK) and V_2F_3 (Medium vermicompost + High NPK).

4.1.5 Relationship between the grain and straw yields of wheat.

A linear relationship was observed between the straw yield and grain yield (Figure3).

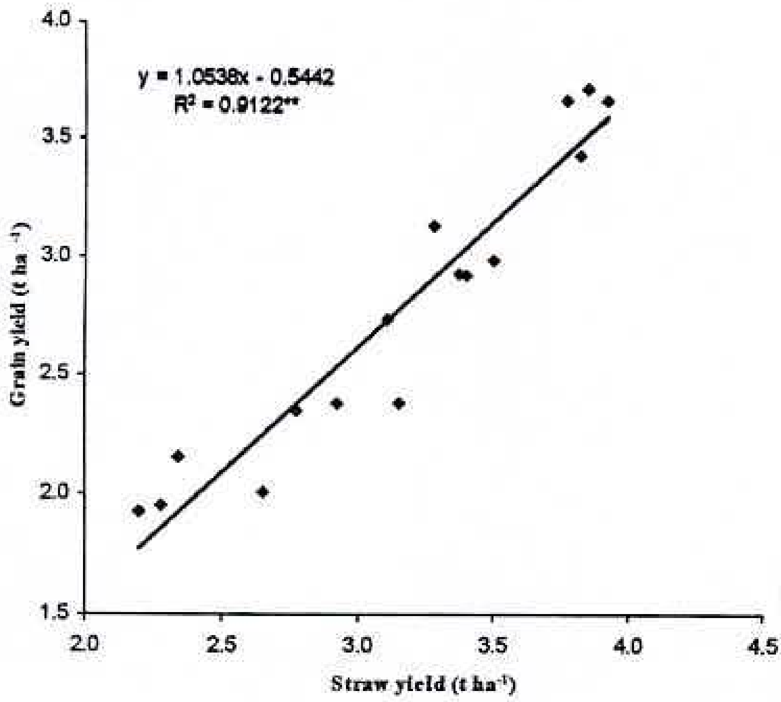


Figure 3 Relationship between the grain and straw yields of wheat.

The estimated regression line between grain yield and straw yield was as follows:

$Y = 1.0538x - 0.5442$

$R^2 = 0.9122$

Y= Grain yield of wheat (t ha^{-1})

X=straw yield of wheat (t ha^{-1})

Figure 3 reveals that the increase in grain yield was due to increament in straw yield. Significant R^2 value also indicated that the proposed linear regression model was adequate to explain the relationship between grain and straw yield of wheat.

4.2 Effect of vermicompost and NPK on the nutrient concentrations in wheat plant

4.2.1 Maximum tillering stage

4.2.1. 1 Nitrogen content

A statistically significant variation was observed in nitrogen concentration in plant at maximum tillering stage of wheat with different doses of vermicompost (Table 5 and Appendix Figure 7). Considering the different doses of vermicompost the highest nitrogen concentration (2.09%) was recorded in V_3 (3 t ha^{-1}), which was significantly higher than V_2 (2 t ha^{-1}) and V_1 (1 t ha^{-1}). On the other hand, the lowest nitrogen concentration (1.84%) was recorded in the V_0 treatment where no vermicompost was applied.

Table 5 Effect of vermicompost on nitrogen, phosphorous, potassium and sulphur concentrations in wheat plant at the maximum tillering stage.

Vermicompost	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0	1.84 c	0.41 c	0.90 c	0.62 d
V_1	1.94 b	0.40 c	0.95 b	0.67 c
V_2	1.98 b	0.48 b	0.95 b	0.75 b
V_3	2.09 a	0.58 a	1.00 a	0.81 a
Level of Significance	0.01	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

The effect of combined applications of different doses of chemical fertilizers showed a statistically significant variation in the nitrogen concentration of wheat plant (Table 6 and Appendix Figure 8). Among the different combinations of fertilizer doses, F_3 (High NPK) showed the highest nitrogen concentration (2.18%) in plant at maximum tillering stage, significantly higher than other treatments. The lowest nitrogen concentration (1.69%) was observed in the fertilizer combination F_0 where any type of fertilizer was not applied which was also closely followed by the F_1 (Low NPK) fertilizer combination.

Table 6 Effect of NPK fertilizer on nitrogen, phosphorous, potassium and sulphur concentrations in wheat plant at the maximum tillering stage

Fertilizer	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
F_0	1.69 d	0.38 d	0.82 d	0.53 d
F_1	1.92 c	0.44 c	0.87 c	0.65 c
F_2	2.06 b	0.49 b	1.02 b	0.82 b
F_3	2.18 a	0.55 a	1.09 a	0.84 a
Level of Significance	0.01	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

Significant effect of combined application of different doses of vermicompost and fertilizer on the nitrogen concentration was also observed at maximum tillering stage of wheat plant (Table 7 and Appendix Figure 9). The highest nitrogen concentration (2.30%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK) .On the other hand the lowest nitrogen concentration (1.42%) was found in V_0F_0 (No vermicompost+ No NPK). The highest concentration of nitrogen in the plant with the highest dose of vermicompost and fertilizer may be due to the higher supply and subsequent assimilation of this element in the plant.

Table 7 Combined effect of vermicompost and NPK fertilizer on nitrogen, phosphorous, potassium and sulphur concentrations in wheat plant at the maximum tillering stage.

Vermicompost × NPK Fertilizer	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0F_0	1.42 h	0.35 f	0.75	0.50 h
V_0F_1	1.85 ef	0.38 ef	0.82	0.45 I
V_0F_2	1.98 cde	0.40 def	0.98	0.76 e
V_0F_3	2.11 bc	0.52 c	1.06	0.78 de
V_1F_0	1.65 g	0.36 ef	0.82	0.45 I
V_1F_1	1.89 def	0.39 ef	0.83	0.61 g
V_1F_2	2.09 bc	0.41 def	1.05	0.81 d
V_1F_3	2.11 bc	0.42 de	1.10	0.81 d
V_2F_0	1.79 f	0.38 ef	0.85	0.51 h
V_2F_1	1.91 def	0.45 d	0.86	0.78 de
V_2F_2	2.01 cd	0.51 c	1.01	0.85 c
V_2F_3	2.21 ab	0.56 c	1.09	0.86 bc
V_3F_0	1.89 def	0.42 de	0.86	0.66 f
V_3F_1	2.01 cd	0.55 c	0.98	0.78 de
V_3F_2	2.17 ab	0.62 b	1.05	0.88 b
V_3F_3	2.30 a	0.71 a	1.11	0.93 a
Level of Significance	0.05	0.01	NS	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.2.1.2 Phosphorous content

Statistically significant variation of phosphorous concentration in wheat plant at maximum tillering stage was recorded when different doses of vermicompost were applied (Table 5 and Appendix Figure 7). The highest phosphorous concentration (0.58%) was recorded in V_3 (3 t ha^{-1}), significantly higher than V_2 (2 t ha^{-1}). On the other hand, the lowest phosphorous concentration (0.40%) was recorded in the V_1 treatment where 1 t ha^{-1}vermicompost was applied which was closely followed by V_0 (0 t ha^{-1} vermicompost).

Application of different doses of chemical fertilizers showed significant variation in respect of phosphorous concentration in wheat plant at the maximum tillering stage of its growth (Table 6 and Appendix Figure 8). Among the different doses of fertilizers, F_3 (High NPK) showed the highest phosphorous concentration (0.55%) in plant, which was significantly higher than by the fertilizer dose, F_2 (Medium NPK). The lowest phosphorous concentration in plant (0.38%) was recorded in the treatment F_0 where no fertilizer was applied (Table 6 and Appendix Figure 8) which was also closely followed by the F_1(Low NPK) treatment.

The combined effects of different doses of vermicompost and fertilizer resulted a significant change in the phosphorous concentration at the maximum tillering stage of wheat (Table 7 and Appendix Figure 10). The highest phosphorous concentration (0.71%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK) and the lowest phosphorous concentration (0.35%) was found in V_0F_0 (No vermicompost + No NPK). This may be due to the fact that the combined effect of both vermicompost and NPK played a positive effect on phosphorus concentration in wheat plant.

It is evident from the data that combined application of vermicompost and NPK had distinct positive effect on the concentration of plant phosphorous when compared with the concentrations of plant phosphorous obtained with either vermicompost or NPK fertilizer alone.

4.2.1.3 Potassium content

Application of different doses of vermicompost showed a significant variation in potassium concentration in wheat plant at the maximum tillering stage (Table 5 and Appendix Figure 7). The highest potassium concentration (1.00%) was recorded in V_3 (3 t ha^{-1}), which was significantly higher than by V_2 (2 t ha^{-1}) and V_1 (1 t ha^{-1}). On the other hand, the lowest potassium concentration (0.90%) was recorded in the V_0 treatment where no vermicompost was applied

Application of chemical fertilizers at different doses also showed significant variation in respect of potassium concentration in wheat plant (Table 6 and Appendix Figure 8). Among the different doses of fertilizers, F_3 (High NPK) showed the highest potassium concentration (1.09%) in wheat plant at maximum tillering stage, which was closely followed by the fertilizer dose F_2 (Medium NPK) and the lowest potassium concentration (0.82%) was recorded in F_0 where no fertilizer was applied.

Combined application of different doses of vermicompost and fertilizer showed no significant effect on the potassium concentration at the maximum tillering stage of wheat (Table 7 and Appendix Figure 11).

4.2.1.4 Sulphur content

Significant variation in sulphur concentration in plant at maximum tillering stage of wheat was observed when different doses of vermicompost were applied (Table 5 and Appendix Figure 7). The highest sulphur concentration (0.81%) was recorded in V_3 (3 t ha^{-1}), which was significantly higher than that obtained with V_2 (2 t ha^{-1}). On the other hand, the lowest sulphur concentration (0.62%) was recorded in the V_0 treatment where no vermicompost was applied which was closely followed by V_1 (1 t ha^{-1}).

Different doses of chemical fertilizers applied in different combinations showed significant variation in respect of sulphur concentration in wheat plant (Table 6 and

Appendix Figure 8). Among the different doses, F_3 (High NPK) showed the highest sulphur concentration (0.84%) in plant at maximum tillering stage, which was closely followed by the fertilizer dose F_2 (Medium NPK). The lowest sulphur concentration (0.53%) was recorded in F_0 treatment where no fertilizer was applied which was also closely followed by the F_1(Low NPK) fertilizer combination.

Different doses of vermicompost and fertilizer at different combinations resulted in a significant variation in the sulphur concentration in plant at maximum tillering stage of wheat (Table 7 and Appendix Figure 12). The highest sulphur concentration (0.93%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK) and the lowest sulphur concentration (0.45%) was found in V_0F_1 (No vermicompost + Low NPK). The result might be due to higher rate of application of vermicompost and NPK in V_3F_3 treatment.

4.2.2 Flowering stage

4.2.2.1 Nitrogen content

Statistically significant variation in nitrogen concentration in plant at the flowering stage of wheat was recorded when different doses of vermicompost were applied (Table 8 and Appendix Figure 13). The highest nitrogen concentration (1.82%) was recorded in V_3 (3 t ha^{-1}), which was statistically identical with V_1 (1 t ha^{-1}). The lowest nitrogen concentration (1.66%) was recorded in the V_0 treatment where no vermicompost was applied and was statistically similar with V_2 (2 t ha^{-1}). Probably, higher dose of vermicompost helped to increase the nitrogen content in plant.

Table 8 Effect of vermicompost on nitrogen, phosphorous, potassium and sulphur concentrations in wheat plant at the flowering stage

Vermicompost	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0	1.66 b	0.47 b	0.91 c	0.57 d
V_1	1.77 a	0.39 c	0.98 b	0.64 c
V_2	1.70 b	0.46 b	0.96 b	0.72 b
V_3	1.82 a	0.51 a	1.04 a	0.77 a
Level of Significance	0.01	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

Different doses of chemical fertilizers showed a statistically significant variation in respect of nitrogen concentration in wheat plant at its flowering stage (Table 9 and Appendix Figure 14). Among the different combination of fertilizer doses, F_3 (High NPK) showed the highest nitrogen concentration (1.93%), which was significantly higher than that obtained by the fertilizer dose F_2 (Medium NPK). The lowest nitrogen concentration (1.45%) was recorded in the F_0 treatment where no fertilizer was applied which was significantly lower than (1.74%) by the F_1 (Low NPK) fertilizer combination. Probably NPK application at higher doses helped to increase the N content in wheat plant.

Table 9 Effect of NPK fertilizer on nitrogen, phosphorous, potassium and sulphur concentrations in wheat plant at flowering stage

Fertilizer	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
F_0	1.45 d	0.35 d	0.84 d	0.48 d
F_1	1.74 c	0.44 c	0.90 c	0.62 c
F_2	1.82 b	0.54 a	1.03 b	0.79 b
F_3	1.93 a	0.50 b	1.13 a	0.82 a
Level of Significance	0.01	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

Table10 Combined effect of vermicompost and NPK fertilizer on nitrogen, phosphorous, potassium and sulphur concentrations in wheat plant at the flowering stage

Vermicompost × NPK Fertilizer	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0F_0	1.24 g	0.32 f	0.75 f	0.40 k
V_0F_1	1.68 d	0.38 e	0.83 e	0.41 jk
V_0F_2	1.73 cd	0.39 e	0.96 bc	0.72 f
V_0F_3	1.98 a	0.49 ef	1.09 a	0.76 e
V_1F_0	1.43 f	0.35 ef	0.81 ef	0.42 j
V_1F_1	1.72 cd	0.37 e	0.86 de	0.58 h
V_1F_2	1.95 a	0.41 e	1.12 a	0.78 d
V_1F_3	1.98 a	0.41 ef	1.14 a	0.79 cd
V_2F_0	1.51 ef	0.36 d	0.89 cde	0.49 i
V_2F_1	1.82 bc	0.48 d	0.92 bcd	0.76 e
V_2F_2	1.72 cd	0.48 d	0.93 bcd	0.81 bc
V_2F_3	1.75 cd	0.51 cd	1.10 a	0.84 b
V_3F_0	1.62 de	0.38 e	0.92 bcd	0.62 g
V_3F_1	1.75 cd	0.51 cd	0.98 b	0.72 f
V_3F_2	1.89 ab	0.56 b	1.09 a	0.82 b
V_3F_3	2.01 a	0.58 a	1.17 a	0.89 a
Level of Significance	0.01	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

Combined application of different doses of vermicompost and fertilizer resulted a significant variation on the nitrogen concentration in plant at flowering stage of wheat (Table 10 and Appendix Figure 15). The highest nitrogen concentration (2.01%) was recorded in the treatment combination of V_3F_3 , which was statistically identical with V_1F_2 and V_1F_3 . On the other hand, the lowest nitrogen concentration (1.24%) was observed in V_0F_0 (No vermicompost + No NPK). The higher nitrogen content in the plant might be due to higher rate of application of vermicompost and NPK.

4.2.2.2 Phosphorous content

Statistically significant variation was observed in phosphorous concentration in plant at the flowering stage when different doses of vermicompost were applied (Table 8 and Appendix Figure 13). Among the different doses of vermicompost the highest phosphorous concentration (0.51%) was recorded in V_3 (3 t ha^{-1}), which was significantly higher than the V_2 (2 t ha^{-1}) and V_0 (0 t ha^{-1}). On the other hand, the lowest phosphorous concentration (0.39%) at the flowering stage was recorded in the V_1 treatment where 1 t ha^{-1} vermicompost was applied.

Different doses of chemical fertilizer application for the cultivation of wheat showed significant variation in respect of phosphorous concentration in wheat plant at the flowering stage (Table 9 and Appendix Figure 14). Among the different combination of fertilizer doses F_2 (Medium NPK) showed the highest phosphorous concentration (0.54%) in wheat plant, which was significantly higher than the fertilizer dose F_3 (High NPK). On the other hand, the lowest phosphorous concentration (0.35%) was recorded in the F_0 treatment where no fertilizer was applied that was also closely followed by the F_1 (Low NPK) treatment.

When the combined effect of different doses of vermicompost and fertilizer was considered a significant variation was recorded in the case of phosphorous concentration at the flowering stage of wheat (Table 10 and Appendix Figure 16). The highest phosphorous content (0.58%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK) and the lowest phosphorous concentration (0.32%) was observed in V_0F_0 treatment (No vermicompost + No NPK). It was observed that nitrogen content increased due to higher rate of application of vermicompost and NPK.

4.2.2.3 Potassium content

Statistically significant variation was recorded in potassium concentration in plant at the flowering stage of wheat when different doses of vermicompost were applied (Table 8 and Appendix Figure 13). Among the different doses of vermicompost the highest potassium concentration (1.04%) was recorded in V_3 (3 t ha^{-1}), which was significantly higher than the V_2 (2 t ha^{-1}) and V_1 (1 t ha^{-1}). The lowest potassium concentration (0.91%) was recorded in the V_0 treatment where no vermicompost was applied. It was observed that potassium content increased at flowering stage due to higher rate of application of vermicompost.

Application of different doses of chemical fertilizers showed a significant variation in respect of potassium concentration in wheat plant at its flowering stage (Table 9 and Appendix Figure 14). Among the different combinations of fertilizer doses, F_3 (High NPK) showed the highest potassium concentration (1.13%), which was closely followed by the fertilizer dose F_2 (Medium NPK). On the other hand, the lowest potassium concentration at the flowering stage (0.84%) was recorded in the F_0 treatment where no fertilizer was applied and that was also closely followed by the F_1 (Low NPK) treatment.

The different doses of vermicompost and fertilizer in combination resulted a significant variation in the potassium concentration at the flowering stage of wheat (Table 10 and Appendix Figure 17). The highest potassium concentration (1.17%)

was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK). On the other hand, the lowest potassium concentration (0.75%) was observed in V_0F_0 (No vermicompost + No NPK) treatment. This may be due to the application of vermicompost and NPK at higher rates of their application which helped to increase the content of more potassium in wheat plant.

4.2.2.4 Sulphur content

A statistically significant variation was recorded in sulphur concentration in plant at the flowering stage of wheat when different doses of vermicompost were applied (Table 8 and Appendix Figure 13). The highest sulphur concentration (0.77%) was recorded in V_3 (3 t ha^{-1}), which was closely followed by the V_2 (2 t ha^{-1}). The lowest sulphur concentration (0.57%) at flowering stage was recorded in the V_0 treatment where no vermicompost was applied which was closely followed by V_1 (1 t ha^{-1}). It was observed that sulphur content increased at flowering stage due to higher rate of application of vermicompost.

Combined application of different doses of chemical fertilizers resulted in a significant variation in sulphur concentration in wheat plant at flowering stage (Table 9 and Appendix Figure 14). Fertilizer dose F_3 (High NPK) showed the highest sulphur concentration (0.82%) in wheat plant, which was closely followed by the fertilizer dose F_2 (Medium NPK). On the other hand, the lowest sulphur concentration at the flowering stage (0.48%) was recorded in the fertilizer combination F_0 where no fertilizer was applied which was also closely followed by the F_1 (Low NPK) treatment combination. Increased doses of NPK application increased the content of sulphur in wheat plant.

Application of different doses of vermicompost and fertilizer in various combinations resulted significant effect on the sulphur concentration at flowering stage of wheat (Table 10 and Appendix Figure 18). The highest sulphur content (0.89%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK). On the other hand, the lowest sulphur concentration at the flowering stage (0.40%) was observed in V_0F_0 (No vermicompost + No NPK) treatment. Such variation might be due to higher rates of application of vermicompost and NPK in V_3F_3 treatment.

4.2.3 Ripening stage (harvest)

4.2.3.1 Nitrogen content

A statistically significant variation was observed in nitrogen concentration in wheat plant after harvest when different doses of vermicompost were applied (Table 11 and Appendix Figure 19). The effect of different doses of vermicompost revealed that the highest nitrogen concentration (1.74%) was recorded in V_3 (3 t ha^{-1}), which was closely followed by V_2 (2 t ha^{-1}) and the lowest nitrogen concentration (1.46%) was recorded in the V_0 treatment which was statistically similar with V_1 (1 t ha^{-1}). It was observed that nitrogen content increased due to higher rate of application of vermicompost.

Table 11 Effect of vermicompost on nitrogen, phosphorous, potassium and sulphur concentrations in wheat plant at harvest

Vermicompost	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0	1.46 c	0.37 c	0.98 c	0.55 d
V_1	1.51 c	0.35 c	1.02 b	0.59 c
V_2	1.62 b	0.44 b	0.99 bc	0.66 b
V_3	1.74 a	0.47 a	1.07 a	0.74 a
Level of Significance	0.01	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

Application of different doses of chemical fertilizers showed a statistically significant variation in respect of nitrogen concentration in wheat plant after harvest (Table 12 and Appendix Figure 20). Among the different combinations of fertilizer doses, F_3 (High NPK) showed the highest nitrogen concentration (1.81%), which was followed by the fertilizer dose F_2 (Medium NPK). Again, the lowest nitrogen concentration (1.39%) was recorded in the fertilizer combination F_0 where none of the fertilizers was applied and that was closely followed by the F_1 (Low NPK) treatment in wheat plant. Probably, more NPK application helped to enhance nitrogen content in wheat plant.

Table 12 Effect of NPK fertilizer on nitrogen, phosphorous, potassium and sulphur concentrations in wheat plant at harvest.

Fertilizer	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
F_0	1.39 d	0.33 d	0.87 d	0.47 d
F_1	1.51 c	0.40 c	0.93 c	0.53 c
F_2	1.63 b	0.44 b	1.06 b	0.76 b
F_3	1.81 a	0.47 a	1.19 a	0.79 a
Level of Significance	0.01	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

The effect of combined applications of different doses of vermicompost and fertilizer resulted significant variations in nitrogen content in plant at the harvest of the wheat crop (Table 13 and Appendix Figure 21). The highest nitrogen concentration (1.92%) was recorded in the treatment combination of V_3F_0 (High vermicompost + No NPK). On the other hand, the lowest nitrogen concentration (1.12%) was found in V_0F_0 (No vermicompost +No NPK) treatment combination. The highest rate of application of vermicompost with NPK showed the highest nitrogen content in straw.

Table 13 Combined effect of vermicompost and NPK fertilizer on nitrogen, potassium, phosphorous and sulphur concentrations in wheat plant at harvest

Vermicompost × NPK Fertilizer	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0F_0	1.12 k	0.30 f	0.74 I	0.38 h
V_0F_1	1.47 gh	0.35 def	0.84 gh	0.39 h
V_0F_2	1.54 fg	0.37 de	1.08 cd	0.72 cd
V_0F_3	1.72 cde	0.45 c	1.24 a	0.74 c
V_1F_0	1.20 jk	0.33 ef	0.83 hi	0.40 h
V_1F_1	1.37 hi	0.31 f	0.99 def	0.44 g
V_1F_2	1.59 fg	0.38 de	1.05 cde	0.72 cd
V_1F_3	1.89 ab	0.39 d	1.19 ab	0.78 b
V_2F_0	1.31 ij	0.35 def	0.93 fg	0.47 f
V_2F_1	1.62 ef	0.46 c	0.93 fg	0.60 e
V_2F_2	1.73 cde	0.46 c	0.97 ef	0.78 b
V_2F_3	1.83 abc	0.49 bc	1.14 bc	0.80 b
V_3F_0	1.92 a	0.33 def	0.97 ef	0.61 e
V_3F_1	1.57 fg	0.47 c	0.96 ef	0.70 d
V_3F_2	1.67 def	0.53 ab	1.13 bc	0.79 b
V_3F_3	1.79 bcd	0.55 a	1.20 ab	0.85 a
Level of Significance	0.01	0.05	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.2.3.2 Phosphorous content

Significant variation was recorded with phosphorous concentration in wheat after harvest when vermicompost was applied at different doses (Table 11 and Appendix Figure 19). Considering the effect of different doses of vermicompost the highest phosphorous concentration (0.47%) was recorded in V_3 (3 t ha^{-1}), which was closely followed by V_2 (2 t ha^{-1}) and the lowest phosphorous concentration (0.35%) was recorded in the V_1 treatment where 1 t ha^{-1} vermicompost was applied which was statistically similar with V_0 (0 t ha^{-1}). It was observed that phosphorous content increased due to higher rate of application of vermicompost.

Different doses of chemical fertilizers resulted a significant variation in phosphorous concentration in wheat plant at the harvest (Table 12 and Appendix Figure 20). Among the different combinations of fertilizer doses, F_3 (High NPK) showed the highest phosphorous concentration (0.47%) in plant, which was closely followed by the fertilizer dose F_2 (Medium NPK) and the lowest phosphorous concentration (0.33%) was recorded in the F_0 treatment and that was followed by the F_1 (Low NPK) fertilizer application. It was observed that phosphorous content increased due to higher rate of application of NPK. Probably more NPK application helped to contain more phosphorus in wheat plant.

The effect of different doses of vermicompost and fertilizer at various combinations on the phosphorous concentration in wheat plant was statistically significant (Table 13 and Appendix Figure 22). The highest phosphorous concentration (0.55%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK). On the other hand, the lowest phosphorous concentration (0.30%) was found in V_0F_0 (No vermicompost + No NPK) treatment combination that was statistically identical with the treatment combination V_1F_1 (Low vermicompost + Low NPK). The highest result might be due to higher rate of application of vermicompost and NPK in V_3F_3 treatment.

4.2.3.3 Potassium content

A statistically significant variation was recorded in potassium concentration in wheat plant after harvest when different doses of vermicompost were added (Table 11 and Appendix Figure 19). When different doses of vermicompost were considered, the highest potassium concentration (1.07%) was recorded in V_3 (3 t ha^{-1}), which was closely followed by V_1 (1 t ha^{-1}) and the lowest potassium concentration (0.98%) was recorded in the V_0 treatment where no vermicompost was applied and was statistically identical with V_2 (2 t ha^{-1}).

Application of different doses of chemical fertilizers resulted a significant variation in potassium concentration in wheat plant after harvest (Table 12 and Appendix Figure 20). Among the different combinations of fertilizer, F_3 (High NPK) showed the highest potassium concentration (1.19%) in wheat plant, which was followed by the fertilizer dose F_2 (Medium NPK). On the other hand, the lowest potassium concentration (0.87%) was recorded with F_0 where no fertilizer was applied (Table 12 and Appendix Figure 20) and that was also closely followed by the F_1 (Low NPK) treatment. Probably more NPK application helped to contain more potassium in wheat plant.

Combined application of vermicompost and fertilizes at different levels showed significant effect on potassium concentration in wheat plant after harvest (Table 13 and Appendix Figure 23). The highest potassium concentration (1.24%) was recorded in the treatment combination of V_0F_3 (No vermicompost + High NPK). On the other hand, the lowest potassium concentration (0.74%) was found in V_0F_0 (No vermicompost + No NPK) treatment combination

4.2.3.4 Sulphur content

Statistically significant variation was recorded in sulphur concentration in wheat plant after harvest when the effects of different doses of vermicompost were compared (Table 11 and Appendix Figure 19). Considering the effect of different doses of vermicompost, the highest sulphur concentration (0.74%) was recorded in V_3 (3 t ha^{-1}), which was followed by V_2 (2 t ha^{-1}) and the lowest sulphur concentration (0.56%) was recorded in the V_0 treatment where no vermicompost was applied.

Significant variation was observed with the application of different doses of chemical fertilizers in respect of sulphur concentration in wheat plant after (Table 12 and Appendix Figure 20). Fertilizer dose, F_3 (High NPK) yielded sulphur concentration (0.79%) in plant, which was closely followed by the fertilizer dose F_2 (Medium NPK) and the lowest sulphur concentration (0.47%) was recorded in F_0 treatment where no fertilizer was applied that was also followed by the F_1 (Low NPK) treatment in wheat crop.

Combined effect the different doses of vermicompost and fertilizer on the sulphur concentration in wheat plant showed statistically significant difference (Table 13 and Appendix Figure 24). The highest sulphur concentration (0.85%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK). On the other hand, the lowest sulphur concentration (0.38%) was found in V_0F_0 (No vermicompost + No NPK) treatment combination that was statistically identical with V_0F_1 (No vermicompost + Low NPK). This might be due to the fact that, the combined effect of both vermicompost and NPK played positive effect on sulphur concentration in wheat plant.

4.3 Effect of vermicompost and NPK on the uptake of nutrients by wheat plant

4.3.1 Nitrogen uptake

The effect of vermicompost on nitrogen uptake by wheat plant showed significant variations (Figure 4 and Appendix Table 1). Nitrogen uptake was maximum in the treatment V_3 (High vermicompost) having 58.70 kg $ha^{-1.}$ The minimum nitrogen uptake by wheat (41.22 kg ha^{-1}) was recorded with control. Baron *et al.* (1995) found that the addition of organic manure has a positive influence on the N uptake by wheat plants.

Application of NPK significantly influenced nitrogen uptake by wheat plants (Figure 6 and Appendix Table 2). Nitrogen uptake ranged from 35.28 to 67.33 kg ha^{-1} with highest in the treatment F_3 (High NPK) and the lowest in control (NPK).

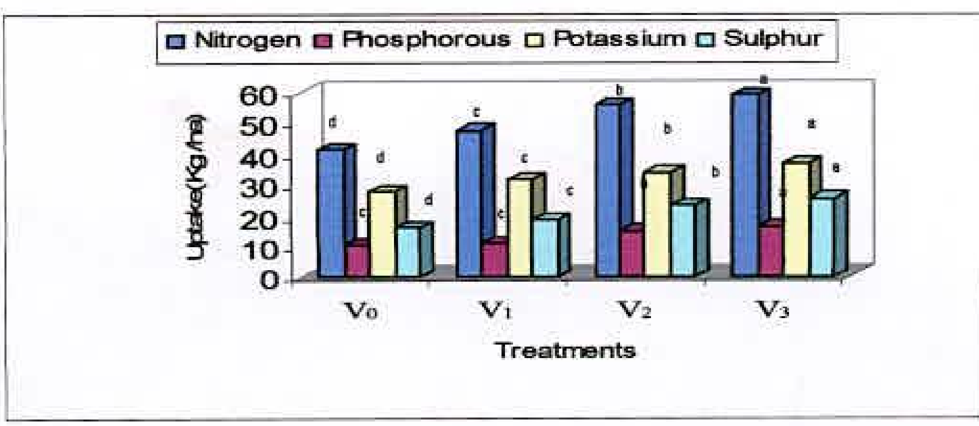


Figure 4 Effect of vermicompost on nitrogen, phosphorous, potassium and sulphur uptake by wheat plant

The combined effect of different doses of vermicompost and fertilizers on nitrogen uptake showed statistically significant variation (Figure 5 and Appendix Table 3). The highest uptake (72.20 kg ha^{-1}) was recorded in the treatment combination of V_1F_3, which was statistically identical with the treatment combination of V_3 F_3 (High vermicompost + High NPK) .On the other hand , the lowest nitrogen uptake (24.64 kg ha^{-1}) was recorded in the control treatment (V_0F_0,) where no vermicompost and no NPK was applied.

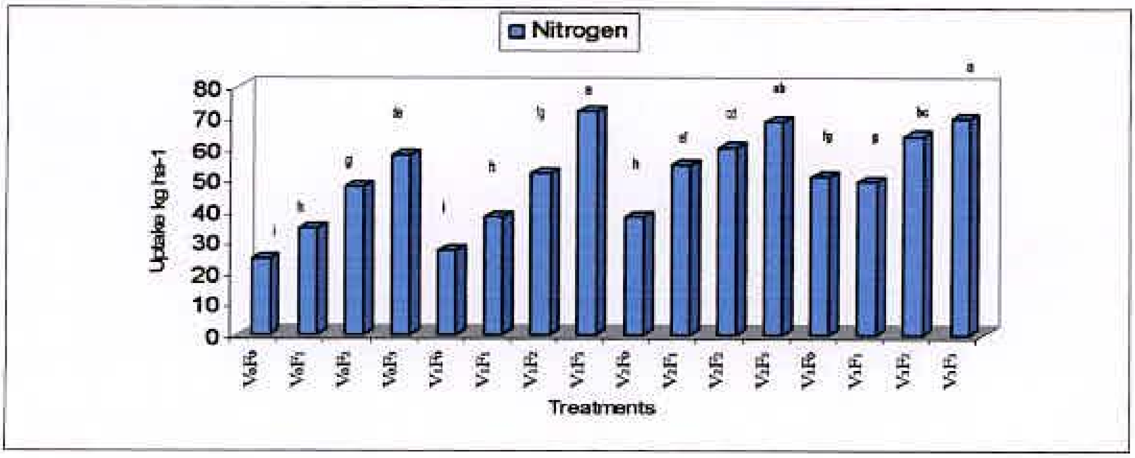


Figure 5 Combined effect of vermicompost and NPK fertilizer on nitrogen uptake by wheat plant

4.3.2 Phosphorus uptake

Phosphorus uptake by wheat was significantly influenced due to the addition of vermicompost (Figure 4 and Appendix Table 1). Phosphorus uptake ranged from 10.36 to 16.38 kg ha^{-1} with maximum in the treatment V_3 (High vermicompost) and minimum in control (V_0). Konov *et al* (1985) also found similar results.

Phosphorus uptake by wheat was significantly influenced due to the application of NPK (Figure 6 and Appendix Table 2). Phosphorus uptake by plant ranged from 8.27 to 17.52 kg ha^{-1}. It was maximum with treatment F_3 (High NPK) and minimum with F_0 treatment where no NPK was applied.

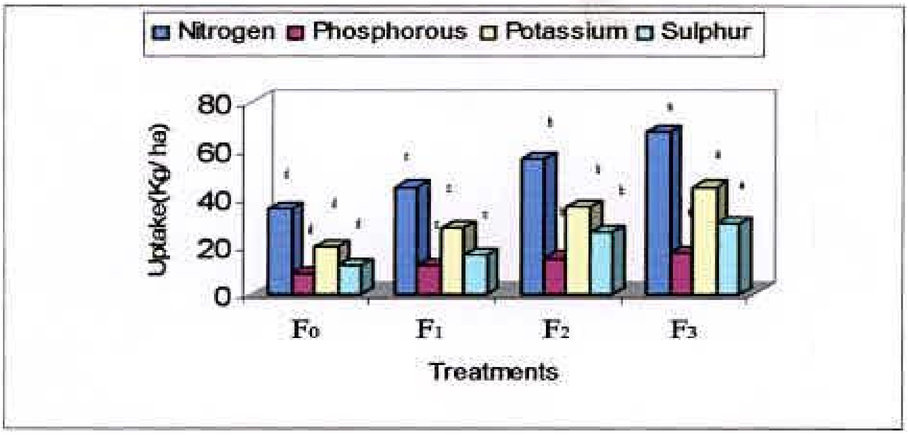


Figure 6 Effect of NPK fertilizer on nitrogen, phosphorous, potassium and sulphur uptake by wheat plant

Combined effect of different doses of vermicompost and fertilizers on phosphorus uptake by wheat showed statistically significant variation (Figure 7 and Appendix Table 3). The highest uptake (21.56 kg ha^{-1}) was recorded in the treatment combination of V_3F_3,.(High vermicompost + High NPK) and the lowest uptake (6.60 kg ha^{-1}) was recorded in the treatment V_0F_0 (No vermicompost + No NPK) treatment.

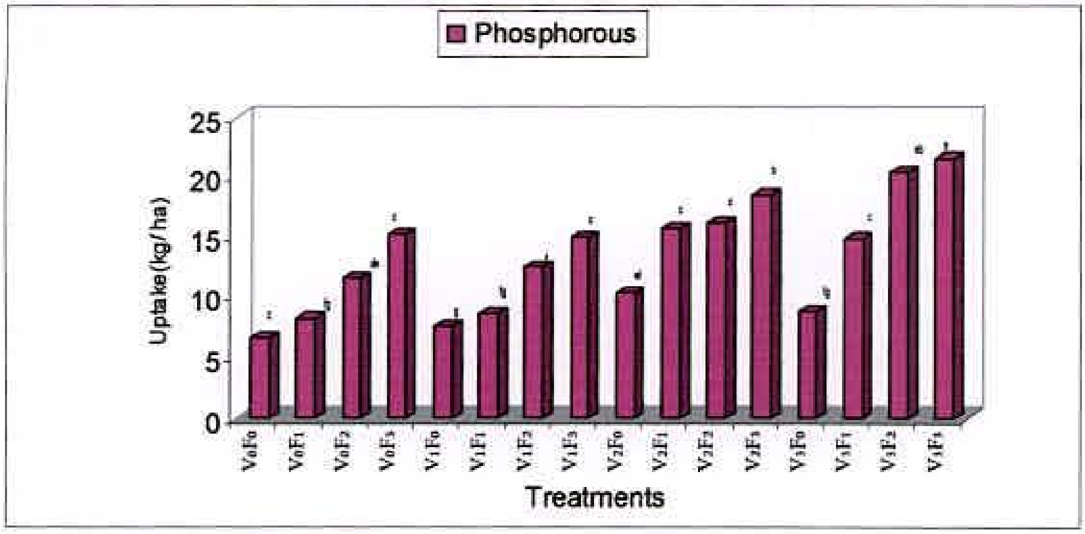


Figure 7 Combined effect of vermicompost and NPK fertilizer on phosphorous uptake by wheat plant

4.3.3 Potassium uptake

The amount of potassium taken up by wheat plant with in a different doses of vermicompost resulted (Figure 4 and Appendix Table 1) significantly higher value over the control. Potassium uptake by straw was maximum in the treatment V_3 (High vermicompost) and minimum in the control. It is evident that vermicompost supplied more potassium and as a consequence its up take was higher with the higher doses.

Application of NPK significantly influenced potassium uptake by wheat. Potassium uptake ranged from 20.01 to 44.31 kg ha^{-1} (Figure 6 and Appendix Table 2). The highest potassium uptake (44.31 kg ha^{-1}) was recorded with the treatment F_3 (High NPK) and the lowest (20.01 kg ha^{-1}) in control (F_0) treatment.

The effect of combined application of different doses of vermicompost and fertilizers on potassium uptake by wheat showed statistically significant variation (Figure 8 and Appendix Table 3). The highest uptake (47.04 Kg ha^{-1}) was recorded in the treatment combination of V_3F_3.(High vermicompost + High NPK).On the other hand , the lowest uptake (16.28) was recorded in the treatment combination of V_0 F_0 (No vermicompost + No NPK).It might be, due to the fact that vermicompost and NPK combined application showed positive effect on potassium uptake by wheat.

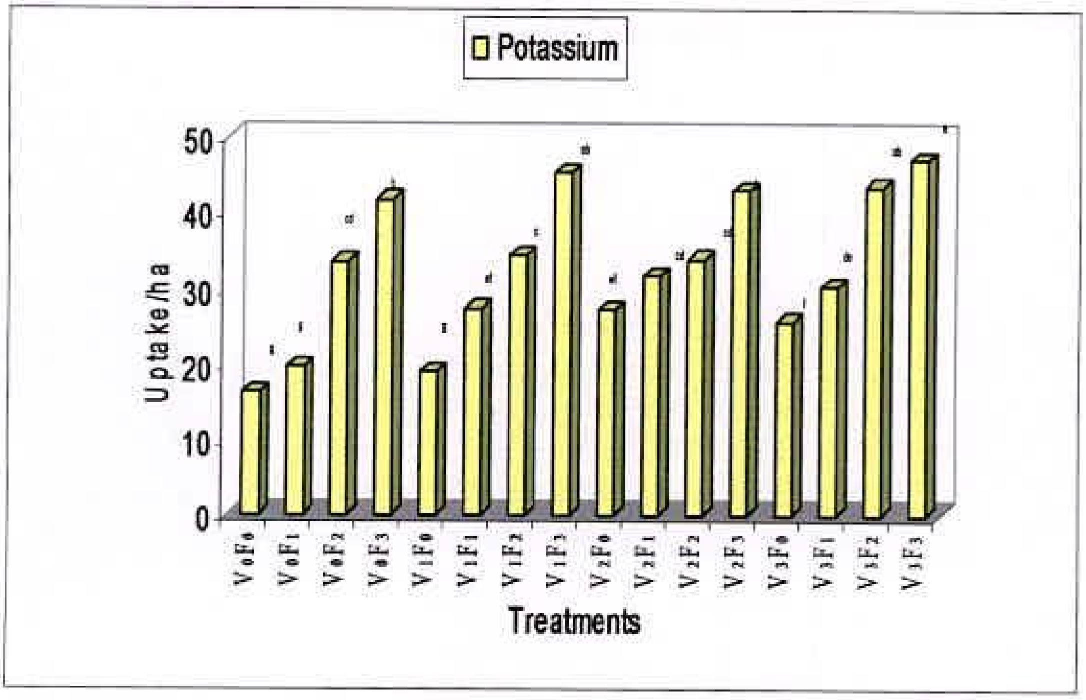


Figure 8 Combined effect of vermicompost and NPK fertilizer on potassium uptake by wheat plant

4.3.4 Sulphur uptake

Sulphur uptake by wheat plant was significantly influenced due to the application of vermicompost (Figure 4 and Appendix Table 1). Sulphur uptake ranged from 16.20 to 25.49 kg ha^{-1}. The maximum value was obtained with the treatment V_3 (High vermicompost) and minimum in control (V_0).

Sulphur uptake by wheat was significantly influenced due to the application of NPK (Figure 6 and Appendix Table 2) and the maximum value was found in the treatment F_3 (High NPK) the lowest value (11.84 kg ha^{-1}) was recorded in F_0 treatment where no NPK was applied.

Combined applications of different doses of vermicompost and fertilizers showed significant variation on sulphur uptake by wheat (Figure 9 and Appendix Table 3).

The highest uptake (33.32 kg ha^{-1}) was recorded in the treatment combination of V_3F_3(High vermicompost + High NPK). On the other hand, the lowest uptake (8.36 kg ha^{-1}) was recorded in the treatment combination where no vermicompost and no fertilizer were added (V_0F_0).

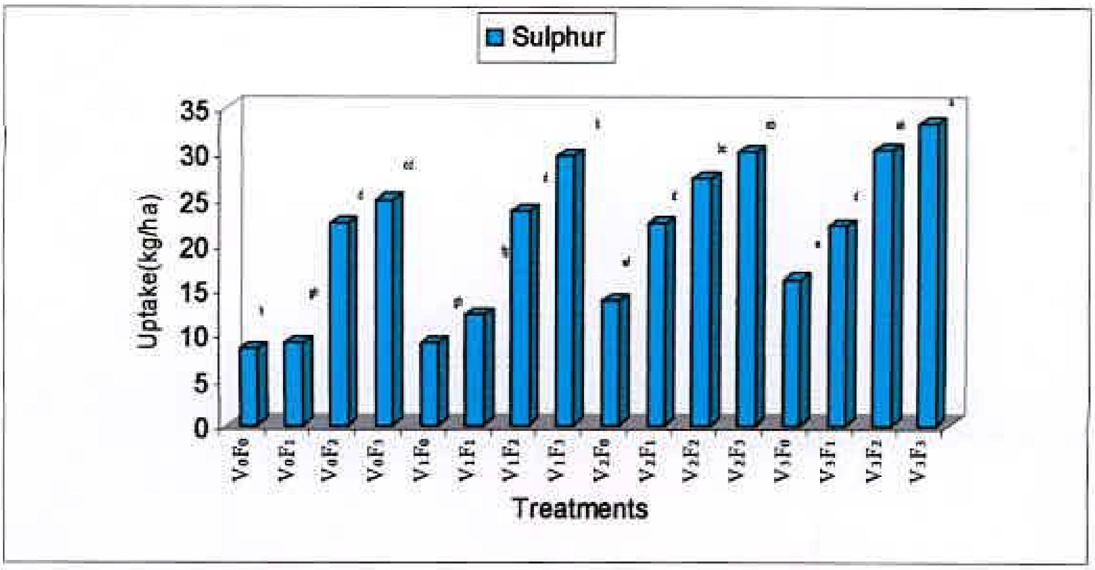


Figure 9 Combined effect of vermicompost and NPK fertilizer on sulphur uptake by wheat plant

4.4 Effect of vermicompost and NPK application on the nutrient status of soil after harvest

4.4.1 Organic matter content of soil

A significant variation was observed on the content of OM after harvest where the vermicompost was incorporated in plots (Table 14 and Appendix Figure 25). Among the different doses of vermicompost, V_3 (3 t ha^{-1}) treatment showed the highest OM content (1.02%) after the harvest of crop. On the other hand the lowest OM content (0.89%) was observed in the V_0 treatment where no vermicompost was applied and it was closely followed (0.92%) by the V_1 (1 t ha^{-1}) treatment . Vermicompost added more organic matter in the soil and as a consequence the residual amount of organic matter showed higher values with the addition of higher amount of vermicompost.

Table 14 Effect of vermicompost on the OM, total N, available P, available K and available S contents in the soil after wheat harvest

Vermicompost	OM (%)	Total N (%)	Available P (%)	Available K (%)	Available S (%)
V_0	0.89 d	0.081 c	0.0017 c	0.0053c	0.0017 b
V_1	0.92 c	0.081 c	0.0018 bc	0.0056b	0.0018 b
V_2	0.96 b	0.084 b	0.0019 ab	0.0057b	0.0020 a
V_3	1.02 a	0.087 a	0.0020 a	0.0059 a	0.0021 a
Level of Significance	0.01	0.01	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

There was no significant variation in the OM content after harvest, when different combinations of fertilizers were applied (Table 15 and Appendix Figure 27). The contents of OM were almost the same (0.94 to 0.96%) in all the fertilizer treated plots after harvest of the crop.

Combined application of different doses of vermicompost and fertilizer showed no significant effect on the OM content of soil after harvest (Table 16 and Appendix Figure 29). The lower OM contents of the soil (0.88 to0.89%) after harvest were recorded in the treatment combinations. On the other hand, the higher OM contents (1.01 to1.03%) were recorded in the treatment combination of the highest vermicompost with fertilizer doses. Andel *et al.* (1994) reported that balanced use of chemical fertilizers such as urea, TSP and MP, with bio-fertilizer, green manure and FYM made significant contribution to conserve soil organic matter status.

Table 15 Effect of NPK fertilizer on the OM, total N, available P, available K and available S in the soil after wheat harvest

NPK Fertilizer	OM (%)	Total N (%)	Available P (%)	Available K (%)	Available S (%)
F_0	0.94	0.079 c	0.0017 b	0.005 c	0.0017 d
F_1	0.94	0.084 ab	0.0018 b	0.0053c	0.0019 c
F_2	0.95	0.083 b	0.0019 a	0.0057 b	0.0020 b
F_3	0.96	0.087 a	0.0021 a	0.0062 a	0.0021 a
Level of Significance	NS	0.01	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

4.4.2 Nitrogen content of soil

Significant variation was recorded on the nitrogen content of wheat field after harvest of the crop when the field was treated with different doses of vermicompost (Table 14 and Appendix Figure 25). Among the different doses of vermicompost, V_3 (3 t ha^{-1}) treatment showed the highest N content (0.087%) and the lowest N content (0.0.081%) was observed in the V_0 treatment where no vermicompost was applied. This was due to the fact that vermicompost added N in soil and reduced the loss of nitrogen and conserved more nitrogen in soil. Bangar *et al.* (1990) found that compost enriched the N content of soil.

Table 16 Combined effect of vermicompost and NPK fertilizer on the organic matter, total N, available P, available K and available S contents in the soil after wheat harvest

Vermicompost × NPK Fertilizer	OM (%)	Total N (%)	Available P (%)	Available K (%)	Available S (%)
V_0F_0	0.88	0.075 f	0.0016	0.0047	0.0016
V_0F_1	0.88	0.088 abc	0.0017	0.0051	0.0017
V_0F_2	0.89	0.075 f	0.0017	0.0053	0.0018
V_0F_3	0.89	0.086 bcd	0.0018	0.006	0.0019
V_1F_0	0.91	0.079 ef	0.0016	0.0055	0.0017
V_1F_1	0.92	0.080 def	0.0017	0.0053	0.0017
V_1F_2	0.92	0.081 de	0.0019	0.0054	0.0018
V_1F_3	0.94	0.083 bcde	0.0020	0.006	0.0019
V_2F_0	0.94	0.081 de	0.0018	0.0053	0.0017
V_2F_1	0.95	0.083 bcde	0.0018	0.0055	0.0019
V_2F_2	0.96	0.085 bcde	0.0020	0.0057	0.0021
V_2F_3	0.97	0.086 bcd	0.0022	0.0061	0.0023
V_3F_0	1.01	0.082 cde	0.0018	0.0057	0.0018
V_3F_1	1.02	0.086 bcd	0.0019	0.0053	0.0020
V_3F_2	1.02	0.089 ab	0.0021	0.0061	0.0021
V_3F_3	1.03	0.092 a	0.0022	0.0067	0.0023
Level of Significance	NS	0.05	NS	NS	NS

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

A significant variation was recorded in the N content of soil after harvest of the wheat crop when different fertilizers in different doses were applied (Table 15 and Appendix Figure 27). In considering the different combinations of fertilizer doses, F_3 (High NPK) showed the highest N content (0.087%), which was statistically identical with the fertilizer dose F_1 (Low NPK). On the other hand, the lowest N content (0.079%) was observed in the F_0 treatment where no fertilizer was applied.

Combined application of different doses of vermicompost and fertilizer showed a significant effect on the N content of soil after harvest (Table 16 and Appendix Figure 30). The highest N content of crop-harvested soil (0.092%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPK). On the other hand, the lowest N content (0.075%) was recorded in V_0F_0 (No vermicompost + No NPK).

4.4.3 Phosphorous content of soil

A significant variation was observed in the P content of soil in the wheat field after harvest where the field was manured with different doses of vermicompost (Table14 and Appendix Figure 26). Among the different doses of vermicompost V_3 (3 t ha^{-1} vermicompost) treatment showed the highest P content (0.0020%) after the harvest of crop. On the other hand the lowest P content (0.0018%) was observed in the V_0 treatment where no vermicompost was applied and it was statistically identical with the V_1 (1 t ha^{-1}) treatment (Table 14 and Appendix Figure 26). Guan (1989) reported that the application of compost increased the availability of P in comparison with the control.

There was a significant variation in the P content of soil after harvest of the crop when different combinations of fertilizers at different doses were applied (Table 15 and Appendix Figure 28). Among the different combinations of fertilizer doses, F_3 (High NPK) showed the highest P content (0.0021%), which was statistically identical with the fertilizer dose F_2 (Medium NPK). The lowest P content (0.0017%) was observed in the F_0 treatment where no fertilizer was applied and it was statistically similar with F_1 (Low NPK) treatment

Combined effect of different doses of vermicompost and fertilizer produced no significant varianon in respect of P content of soil after the harvest of wheat crop. (Table 16 and Appendix Figure 31). The lowest P content of crop harvested soil

(0.0016%) was recorded in the treatment combination of V_0F_0 (No vermicompost + No NPK). On the other hand the highest P content (0.0022%) was recorded in V_3F_3 (High vermicompost + High NPK) and V_2F_3 (Medium vermicompost + High NPK) treatments.

4.4.4 Potassium content of soil

Significant variation was recorded in the K content of soil in the wheat field after harvest of the crop where different doses of vermicompost were applied (Table 14 and Appendix Figure 26). Application of vermicompost at the rate of 3 t ha^{-1} showed the highest K content (0.0059%), which was closely followed by V_2 (2 t ha^{-1}) and V_1 (1 t ha^{-1}). On the other hand, the lowest K content (0.0053%) was observed in the V_0 treatment where no vermicompost was applied.

There was a significant variation in the K content of soil after harvest when different combinations of fertilizers were applied (Table 15 and Appendix Figure 28). Fertilizer dose F_3 (High NPK) showed the highest K content (0.0062%) and the lowest K content (0.0050%) was recorded in the F_0 treatment (No NPK) and that was statistically identical with F_1 treatment (Low NPK).

The effect of combined application of vermicompost and fertilizer showed no significant differences in respect of K content of soil after harvest (Table 16 and Appendix Figure 32). However, the lowest K content of crop-harvested soil (0.0047%) was recorded in the treatment combination of V_0F_0 (No vermicompost+ No NPK) and the highest K content (0.0067%) was recorded with V_3F_3 (High vermicompost + High NPK) treatment combination.

4.4.5 Sulphur content of soil

Significant variation was recorded in the S content of soil after wheat harvest where the plots were incorporated with different doses of vermicompost (Table 14 and Appendix Figure 26). The highest dose of vermicompost, V_3 (3 t ha^{-1}) resulted performed the highest S content (0.0021%) after the harvest of crop and the lowest S content (0.0018%) was observed in the V_0 treatment where no vermicompost was applied and it was statistically similar with the V_1 (1 t ha^{-1}) treatment

Significant variation in the S content of soil after harvest was obtained when different combinations of fertilizers at different doses were applied (Table 15 and Appendix Figure 28). Fertilizer dose, F_3 (High NPK) showed the highest S content (0.0021%), which was closely followed by the fertilizer dose F_2 (Medium NPK). The lowest S content (0.0017%) was observed in the F_0 treatment where no fertilizer was applied and that was closely followed by the treatment F_1 (Low NPK).

The effect of combined application of different doses of vermicompost and fertilizer showed no significant differences in respect of S content of soil after wheat harvest (Table 16 and Appendix Figure 33). However, the lowest S content of crop-harvested soil (0.0016%) was recorded in the treatment combination of V_0F_0 (No vermicompost + No NPK) and the highest S content (0.0021%) was recorded in V_3F_3 (High vermicompost + High NPK) and V_2F_3 (Medium vermicompost + High NPK) treatment combinations. This might be due to the higher rate of application of vermicompost.

Chapter 5

Summary and conclusion

Chapter 5

SUMMARY AND CONCLUSION

An experiment was conducted at the Sher-e-Bangla Agricultural University Farm (SAU Farm), Dhaka 1207 (Tejgaon series under AEZ No.28) during the *Rabi* season of 2004-2005 to study the effect on vermicompost and NPK on the growth, chemical composition and yield of wheat. The soil was silty loam in texture having pH 6.0, organic matter (0.88%). Randomized complete block design was followed with sixteen treatments having unit plot size of 4m x 2.5m (10m^2) replicated thrice. The treatments were V_0F_0 Control (No vermicompost + No NPK), V_0F_1 (No vermicompost + Low NPK), V_0F_2 (No vermicompost + Medium NPK), V_0F_3 (No vermicompost + High NPK), V_1F_0 (Low vermicompost + No NPK), V_1F_1 (Low vermicompost + Low NPK), V_1F_2 (Low vermicompost + Medium NPK), V_1F_3 (Low vermicompost + High NPK), V_2F_0 (Medium vermicompost + No NPK), V_2F_1 (Medium vermicompost + Low NPK), V_2F_2 (Medium vermicompost + Medium NPK), V_2F_3 (Medium vermicompost + High NPK), V_3F_0 (High vermicompost + No NPK), V_3F_1 (High vermicompost + Low NPK), V_3F_2 (High vermicompost + Medium NPK), V_3F_3 (High vermicompost + High NPK). Nitrogen from urea, P_2O_5 from TSP and K_2O from Muriate of potash were used. One third of urea and other chemical fertilizers were used as a basal dose and vermicompost was used in line during sowing and rest of urea was top dressed in two equal splits after 17 and 50 days of seed sowing. Wheat seeds cv. Shatabdi were sown on 10th November, 2004 and the crop was harvested on 7th March 2005. Intercultural operations were done when required. The data were collected plot wise for plant height, weight of 1000 grains, grain and straw yields. The post harvest soil samples were analyzed for organic matter, N, P, K and S contents. All the data were statistically analyzed following F-test and the mean comparison was made by DMRT at 5% level. The salient results of the experiment are stated below.

Grain yield of wheat responded significantly to the vermicompost and NPK fertilizer treatments. The highest grain yield of 3.72 t ha $^{-1}$ was obtained in V_3F_2 (High vermicompost + Medium NPK) treatment. However, this yield was not significantly different from the yield (3.67 t ha $^{-1}$) recorded in V_3F_3 (High vermicompost + High NPK). The lowest grain yield (1.93 t ha $^{-1}$) was observed in the control viz.V_0F_0 (No vermicompost + No NPK) which received neither vermicompost nor fertilizer. The result revealed that when vermicompost is applied with NPK fertilizer, the effect is better on yield product rather applying vermicompost or NPK fertilizer alone. Like grain yield the highest straw yield (3.92 t ha $^{-1}$) was recorded in V_3F_3 (High vermicompost + High NPK) treatment and the lowest (2.20 t ha $^{-1}$) in V_0F_0 Control (No vermicompost + No NPK).

The N, P, K and S contents and uptake of these nutrients by wheat straw were influenced significantly by the application of vermicompost and chemical fertilizers. The highest N, P, K and S contents in straw (2.30%, 0.71%, 1.11% and 0.93% at maximum tillering stage,. 2.01%, 0.58%, 1.17% and 0.89% at flowering stage, and 1.79%, 0.55%, 1.20% and 0.85% at after harvest respectively) were recorded in V_3F_3 (High vermicompost + High NPK) treatment. The lowest N, P, K contents 1.42%, 0.35% and 0.75% respectively were obtained with V_0F_0 treatment and the lowest S content 0.45% with V_1F_0 treatment at maximum tillering stage and 1.24% N, 0.32%

P, 0.75% K and 0.40% S at flowering stage and 1.12% N, 0.30% P, 0.74% K and 0.38% S at harvest stage with V_0F_0 control (No vermicompost + No NPK) treatment.

The highest uptake of 70.17, 21.56, 47.04 and 33.32Kg ha^{-1} and the lowest uptake 24.64, 6.61, 6.28 and 8.36 Kg ha^{-1} of N, P, K and S by wheat at harvest stage were found in V_3F_3 (High vermicompost + High NPK) and V_0F_0 Control (No vermicompost + No NPK) treatments, respectively.

Data on nutrients contents of straw showed that the N, P and S was decreased while the crop was going to the maturity but potassium was increased .The soil properties such as organic matter content , total nitrogen , phosphorus , potassium and sulphur were increased due to treatments after the harvest of crop, compared the initial nutrient status of the initial soil.

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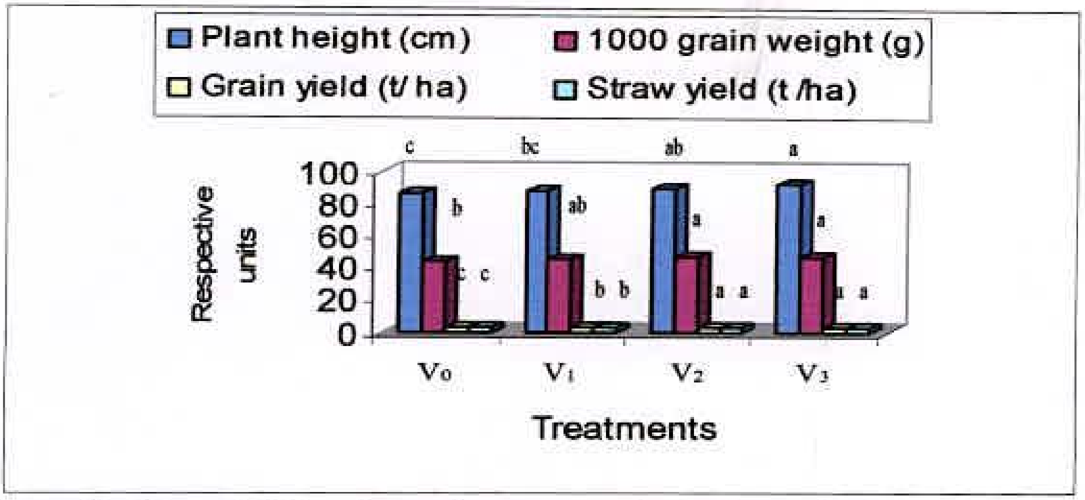
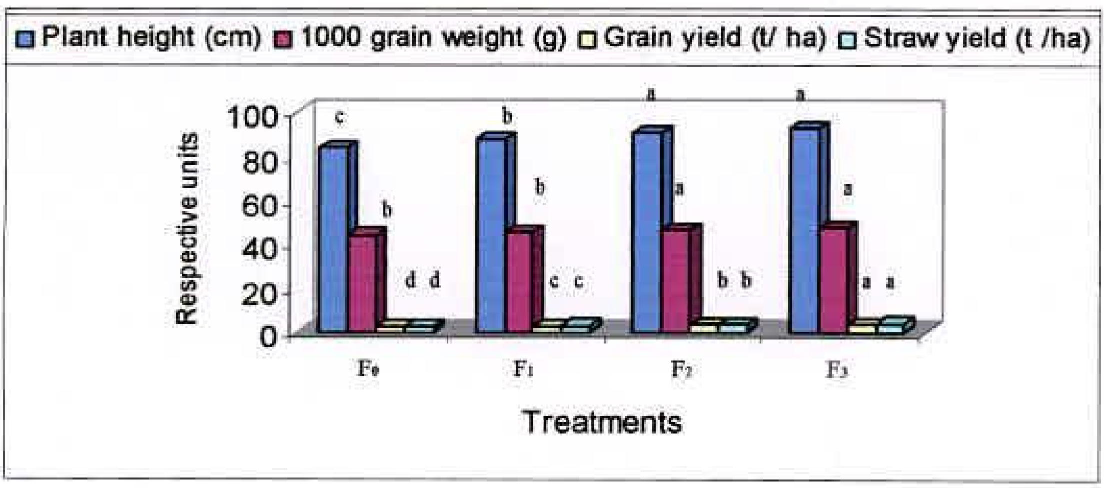
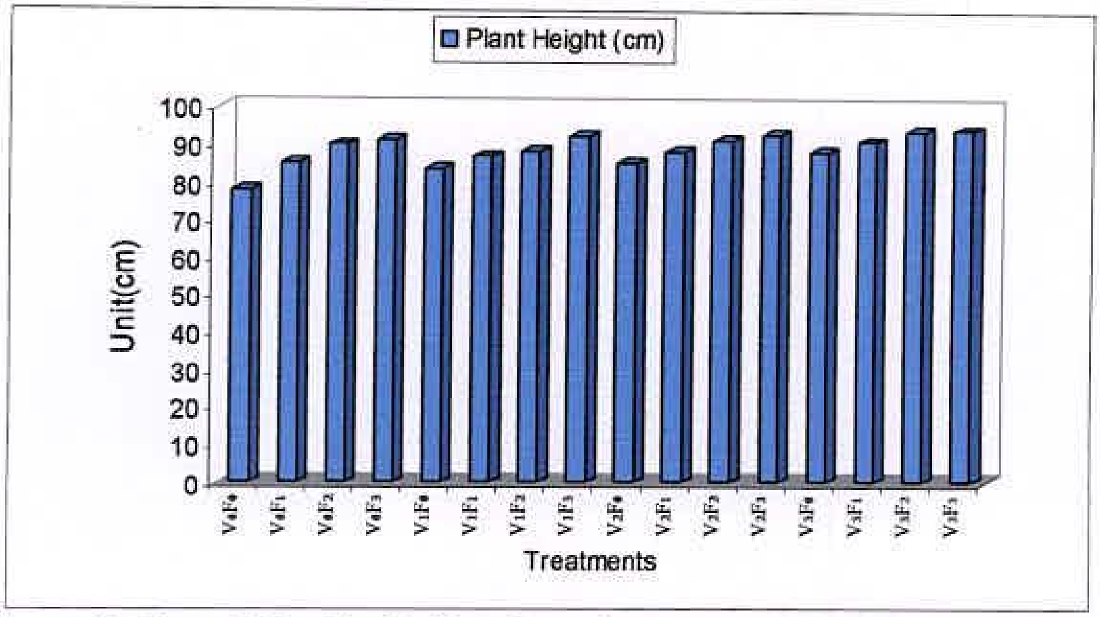
Appendices



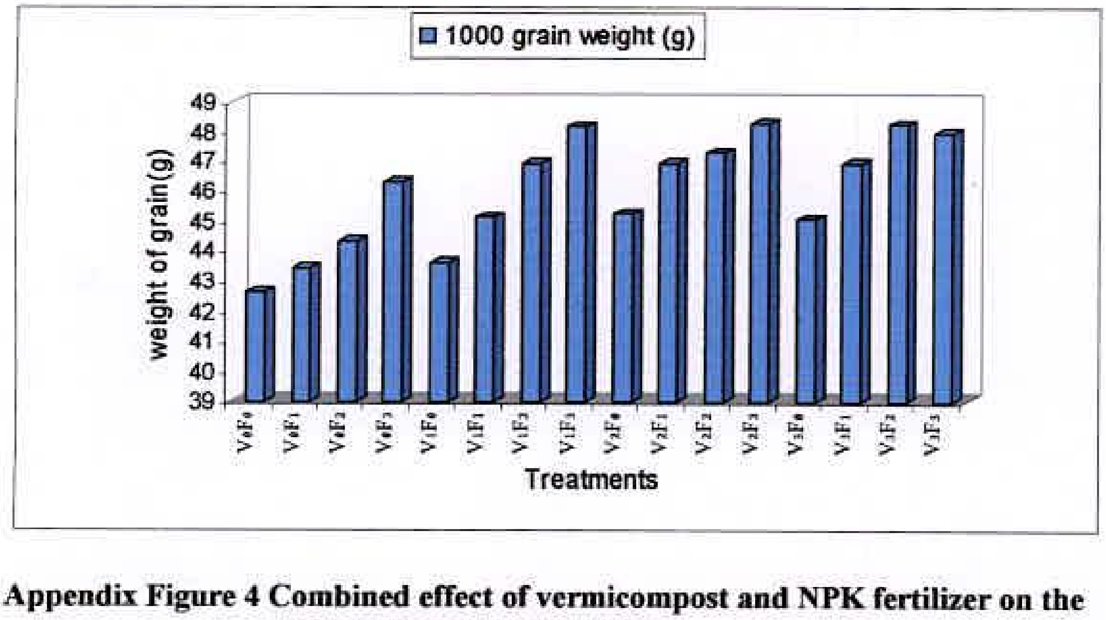
Appendix Figure 1 Effect of vermicompost on the yield contributing and the yield of wheat



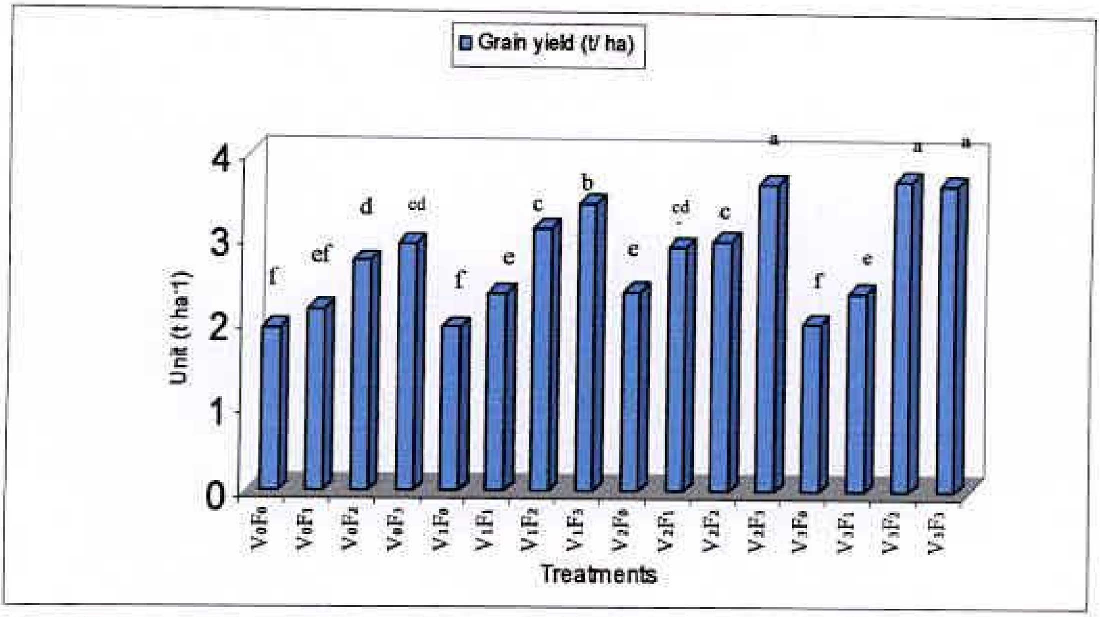
Appendix Figure 2 Effect of NPK on the yield contributing characters and the yield of wheat



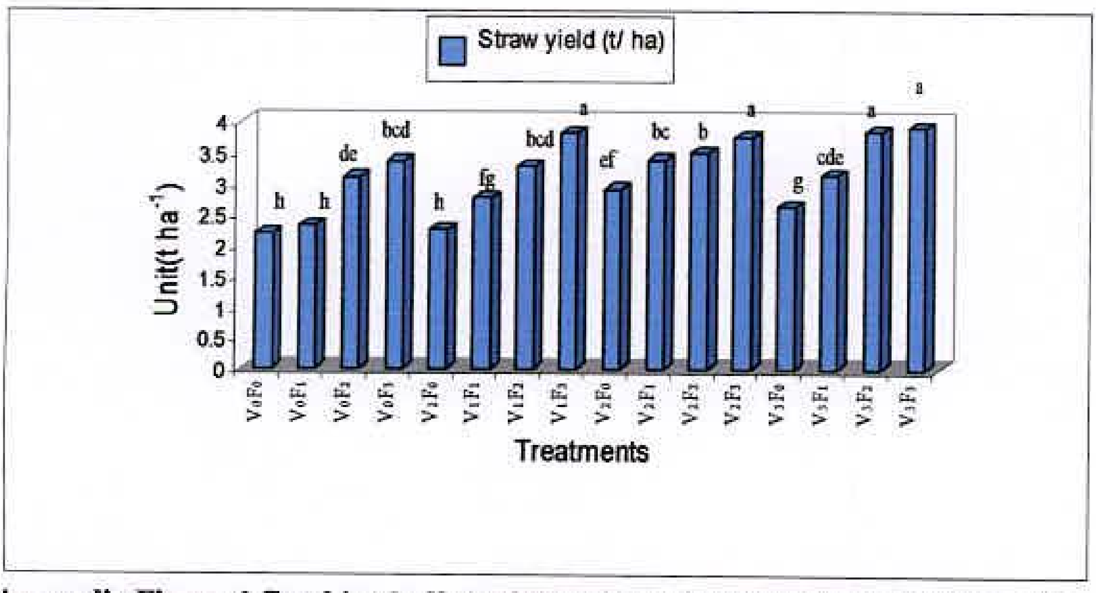
Appendix Figure 3 Combined effect of vermicompost and NPK fertilizer on the plant height of wheat.



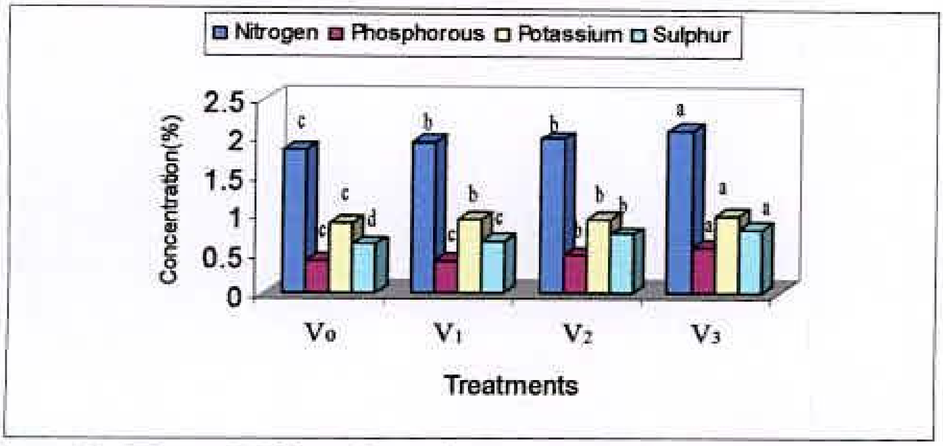
Appendix Figure 4 Combined effect of vermicompost and NPK fertilizer on the 1000 grain weight of wheat



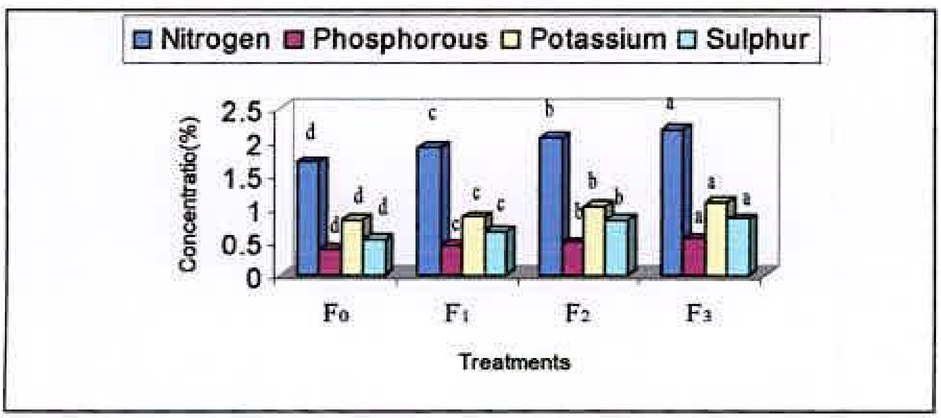
Appendix Figure 5 Combined effect of vermicompost and NPK fertilizer on the grain yield of wheat



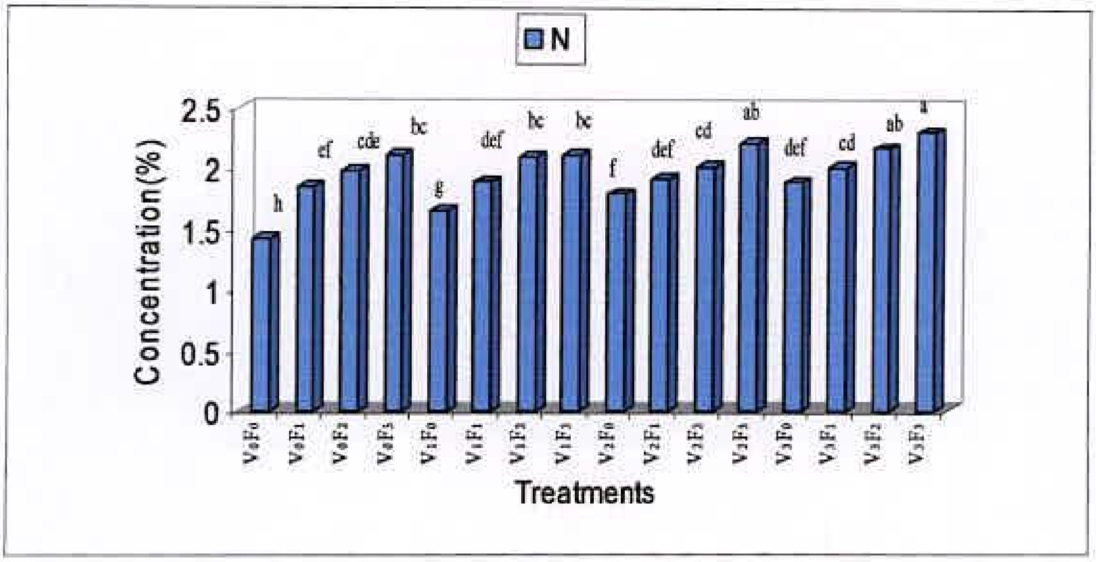
Appendix Figure 6 Combined effect of vermicompost and NPK fertilizer on the straw yield of wheat



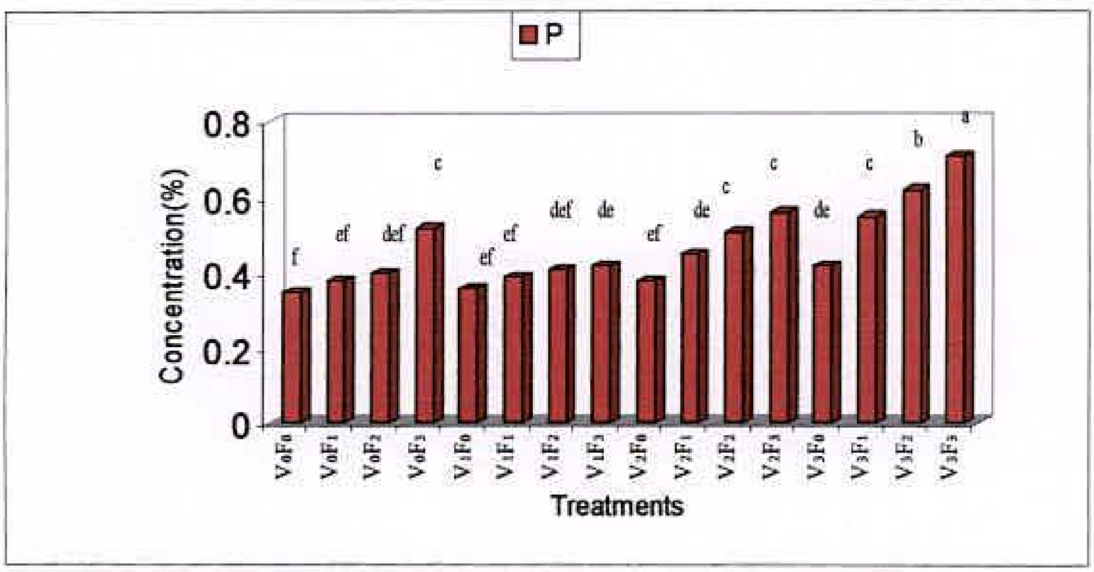
Appendix Figure 7 Effect of vermicompost on nitrogen, phosphorous, potassium and sulphur concentration in wheat plant at the maximum tillering stage



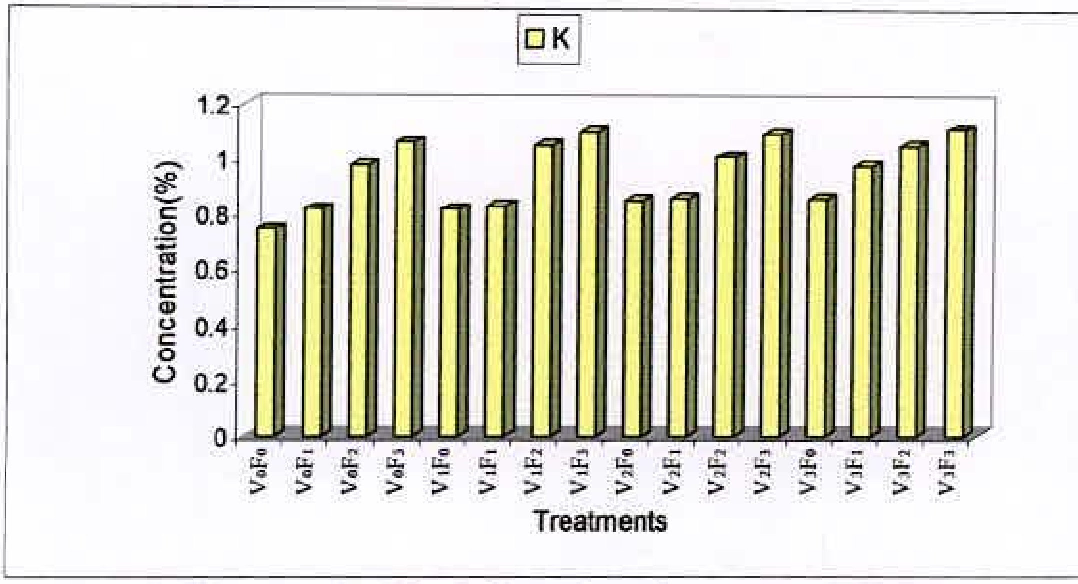
Appendix Figure 8 Effect of vermicompost on nitrogen, phosphorous, potassium and sulphur concentration in wheat plant at the maximum tillering stage



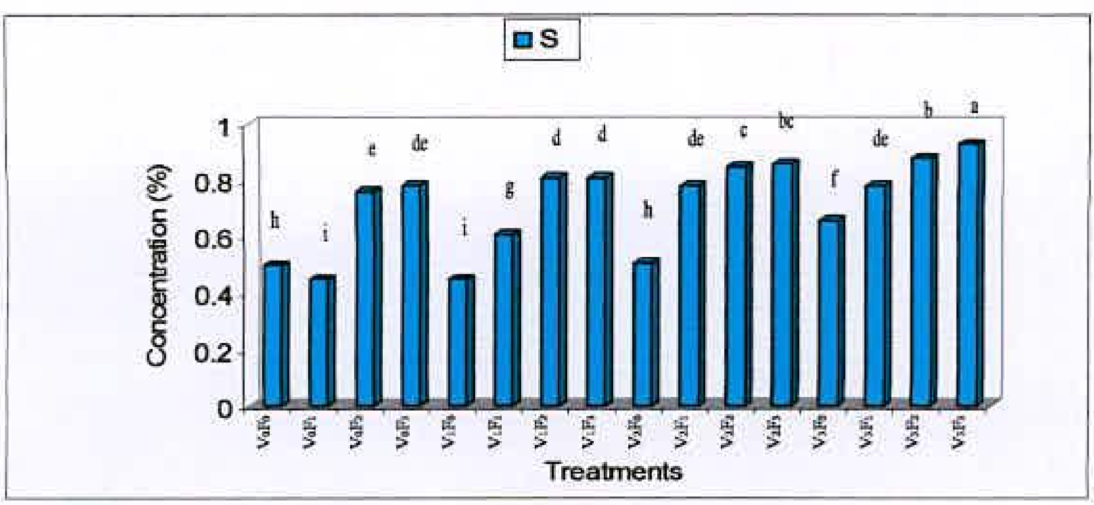
Appendix Figure 9 Combined effect of vermicompost and NPK fertilizer on nitrogen in wheat plant at the maximum tillering stage.



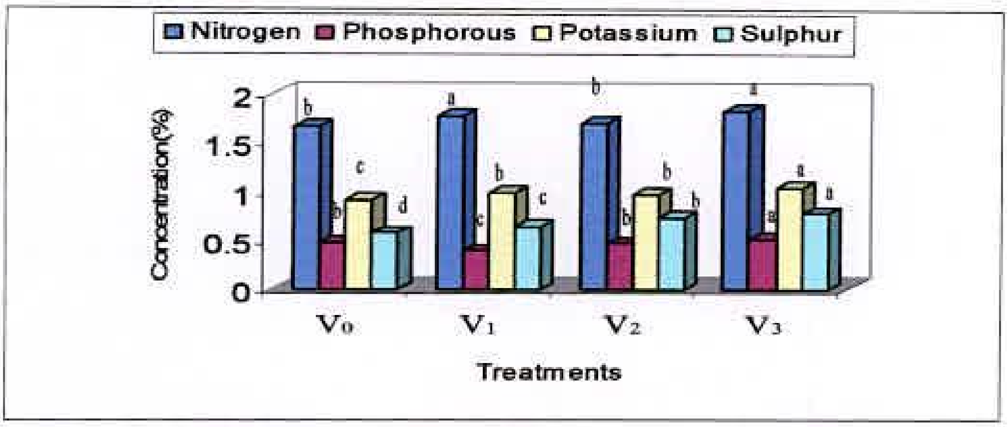
Appendix Figure 10 Combined effect of vermicompost and NPK. fertilizer on phosphorus in wheat plant at the maximum tillering stage



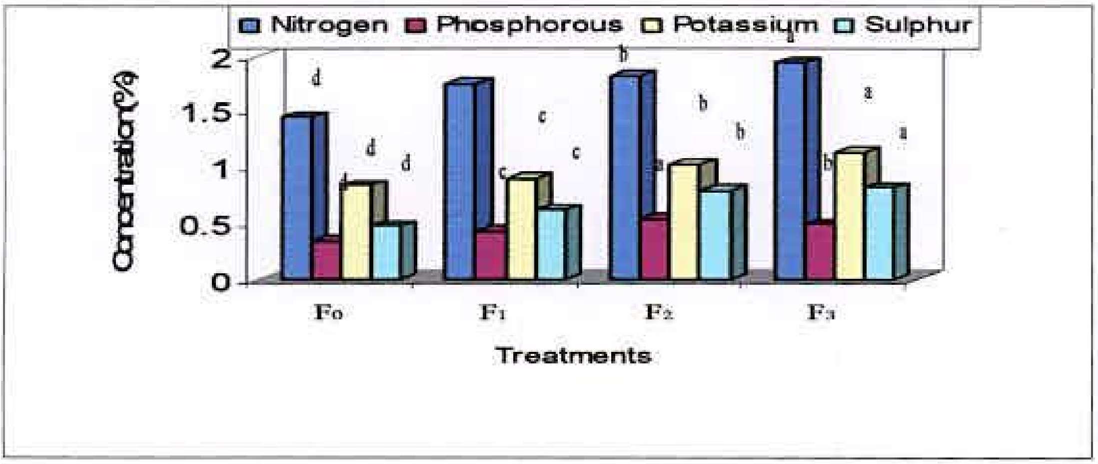
Appendix Figure 11 Combined effect of vermicompost and NPK. fertilizer on potassium in wheat plant at the maximum tillering stage



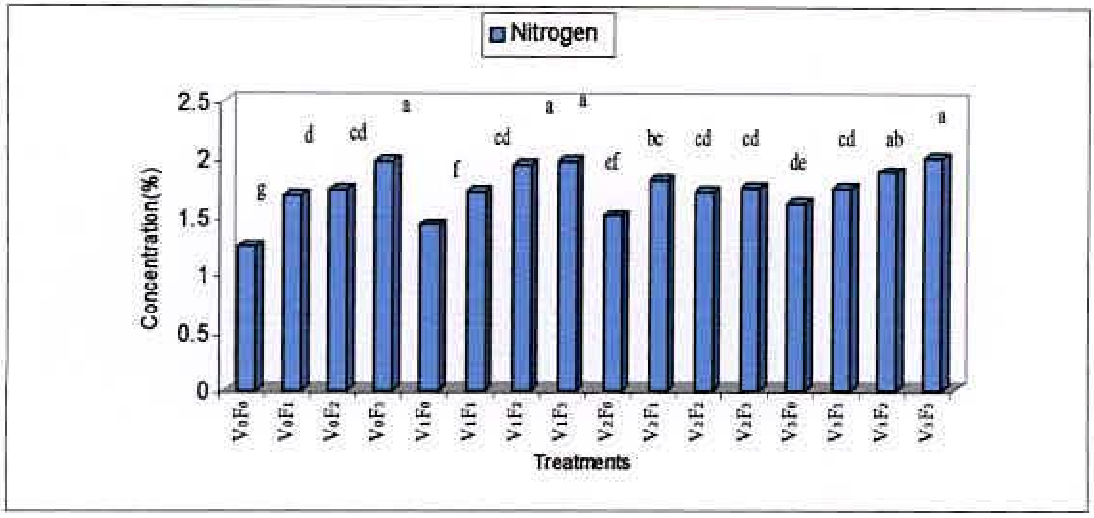
Appendix Figure12 Combined effect of vermicompost and NPK fertilizer on sulphur in wheat plant at the maximum tillering stage



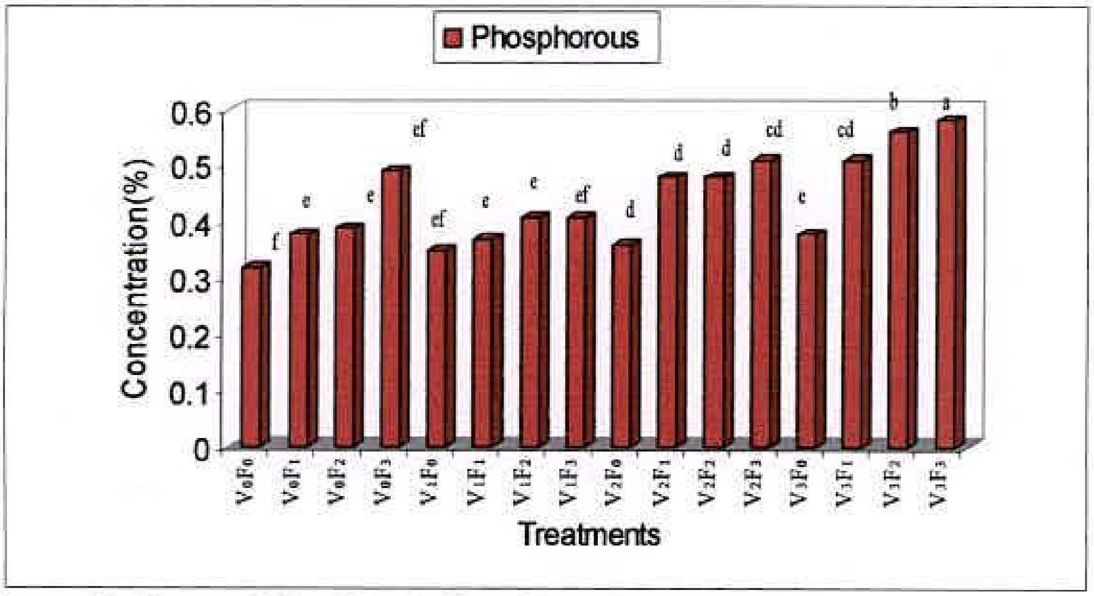
Appendix Figure 13 Effect of vermicompost on nitrogen, phosphorous, potassium and sulphur concentration in wheat plant at the flowering stage



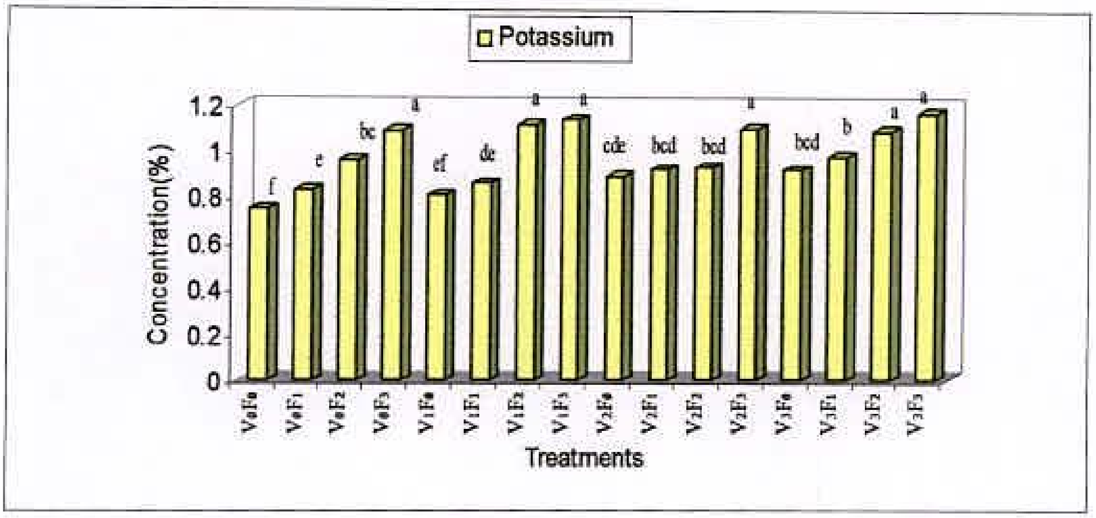
Appendix Figure 14 Effect of NPK on nitrogen, phosphorous, potassium and sulphur concentration in wheat plant at the flowering stage



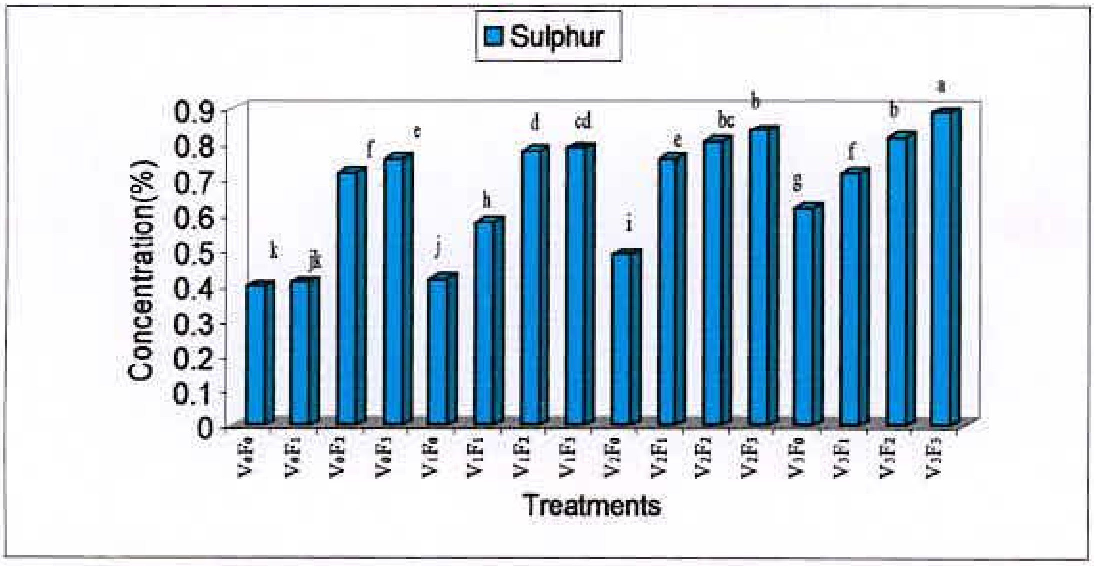
Appendix Figure 15 Combined effect of vermicompost and NPK fertilizer on nitrogen in wheat plant at the flowering stage



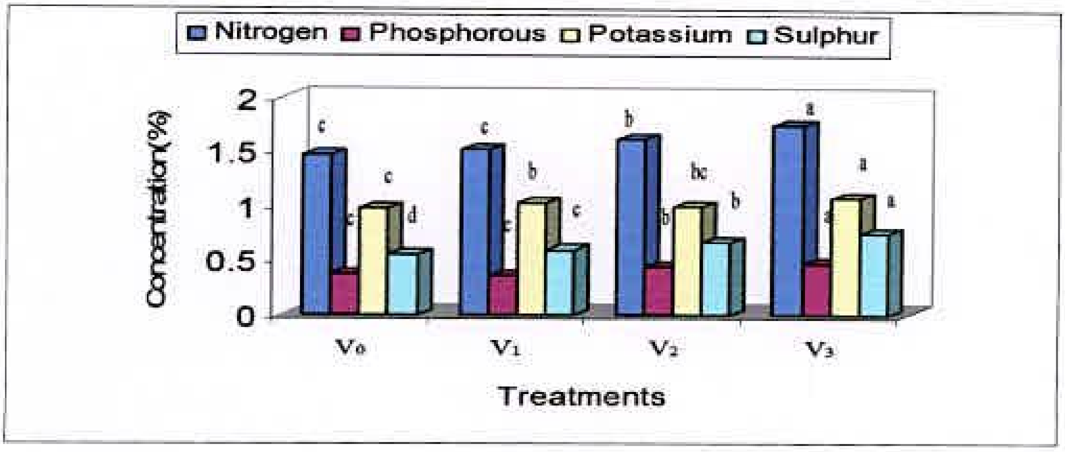
Appendix Figure 16 Combined effect of vermicompost and NPK fertilizer on phosphorous in wheat plant at the flowering stage



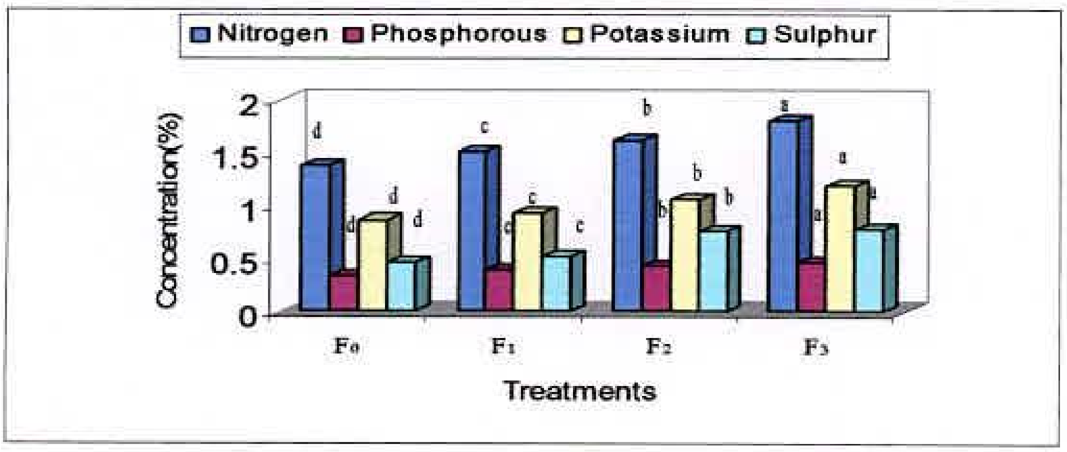
Appendix Figure 17 Combined effect of vermicompost and NPK fertilizer on potassium in wheat plant at the flowering stage



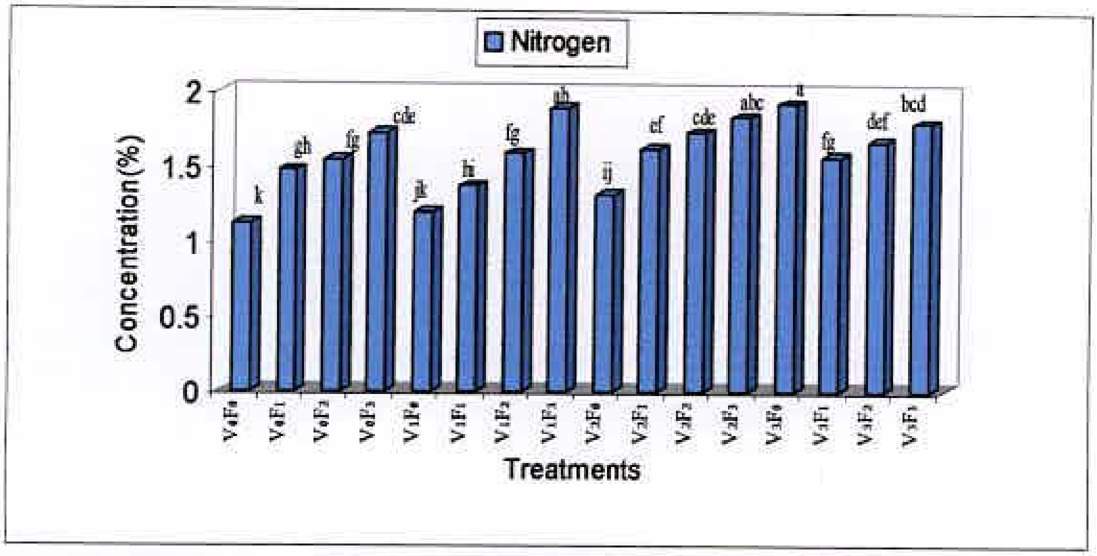
Appendix Figure 18 Combined effect of vermicompost and NPK fertilizer on sulphur concentration in wheat plant at the flowering stage



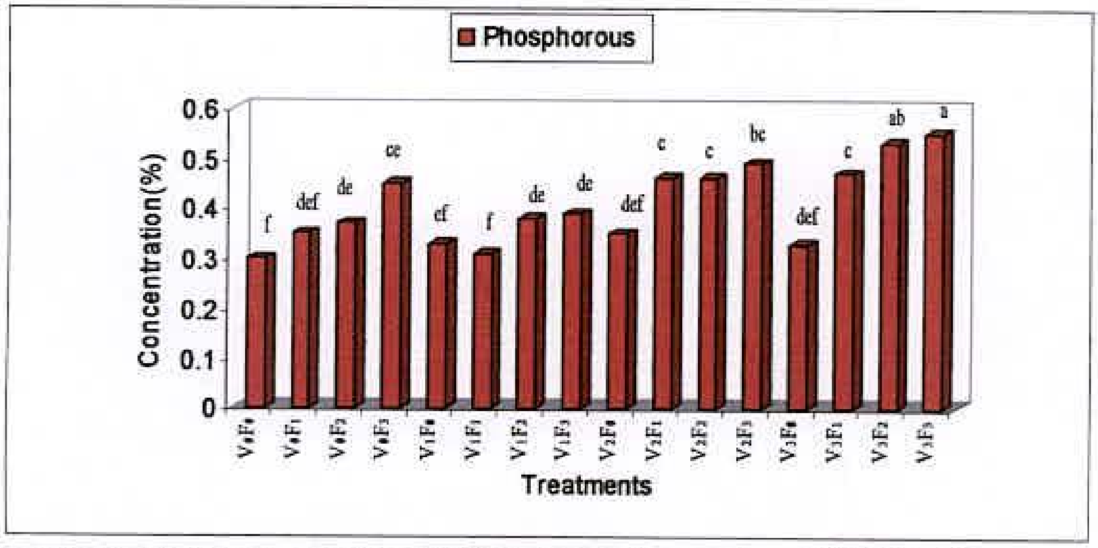
Appendix Figure 19 **Effect of vermicompost on nitrogen, phosphorous, potassium and sulphur concentrations in wheat plant at harvest**



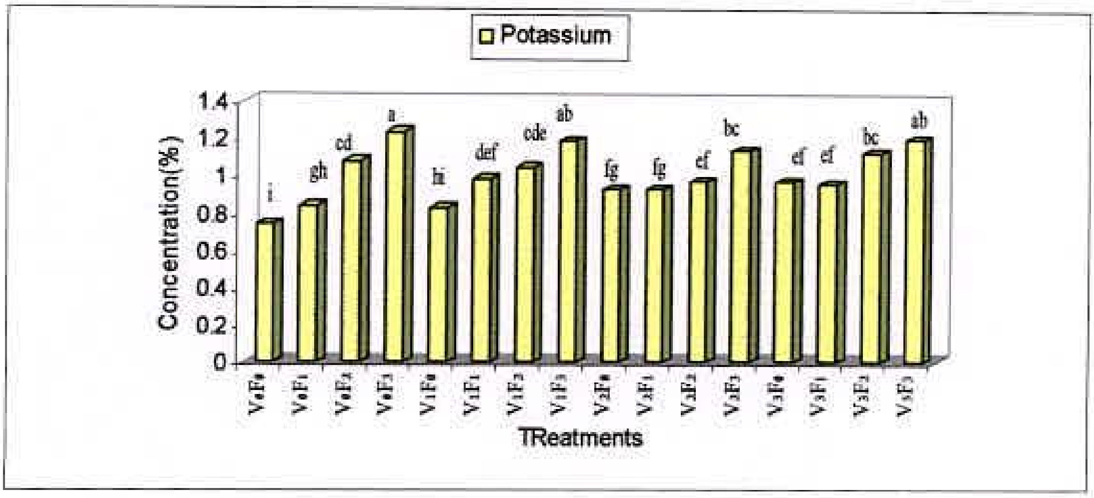
Appendix Figure 20 **Effect of NPK on nitrogen, phosphorous, potassium and sulphur concentrations in wheat plant at harvest**



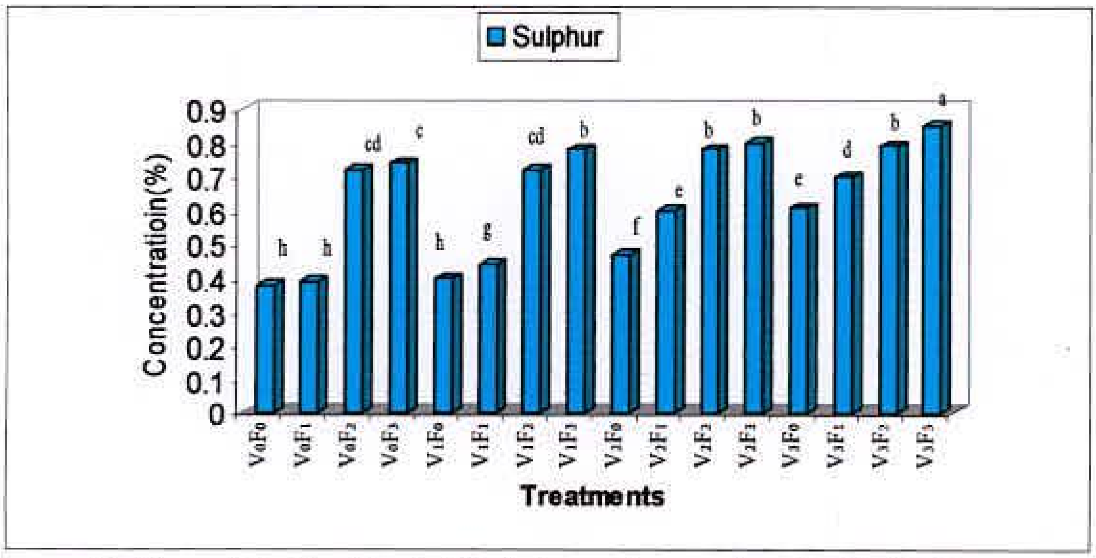
Appendix Figure 21 Combined effect of vermicompost and NPK fertilizer on nitrogen concentrations in wheat plant at harvest



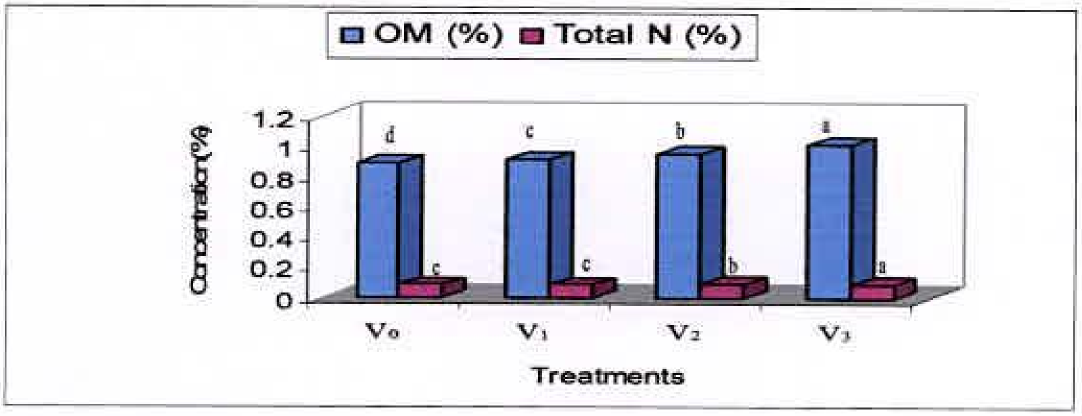
Appendix Figure 22 Combined effect of vermicompost and NPK fertilizer on phosphorus concentrations in wheat plant at harvest



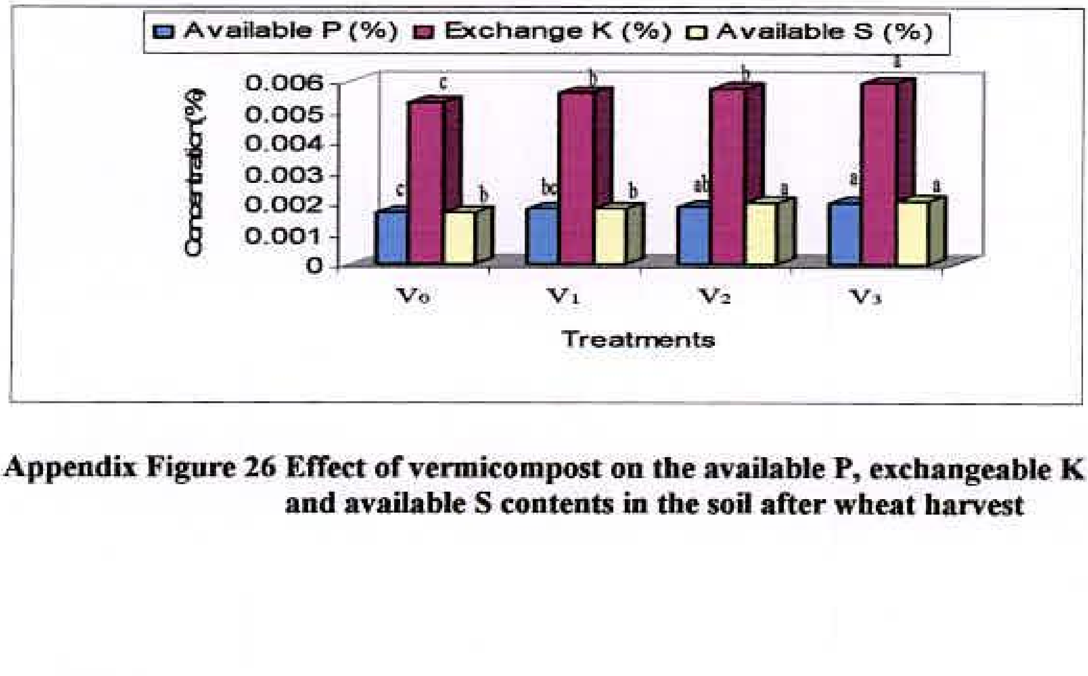
Appendix Figure 23 Combined effect of vermicompost and NPK fertilizer on potassium concentrations in wheat plant at harvest



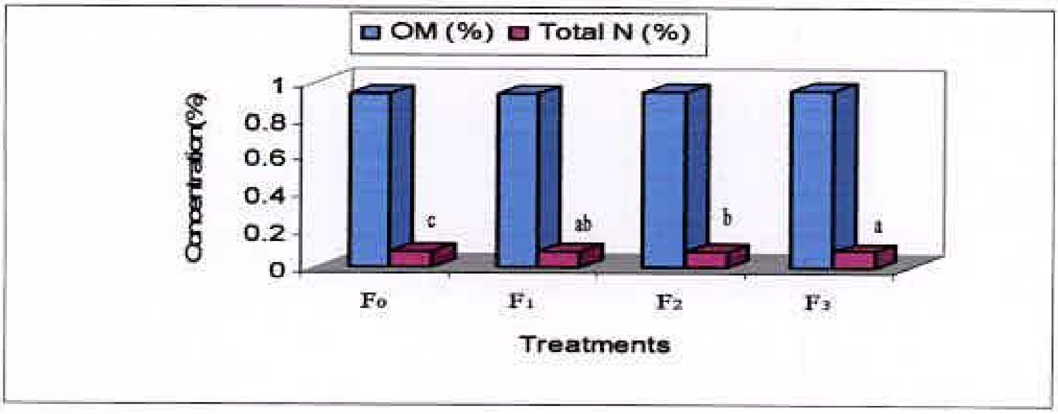
Appendix Figure 24 Combined effect of vermicompost and NPK fertilizer on sulphur concentrations in wheat plant at harvest



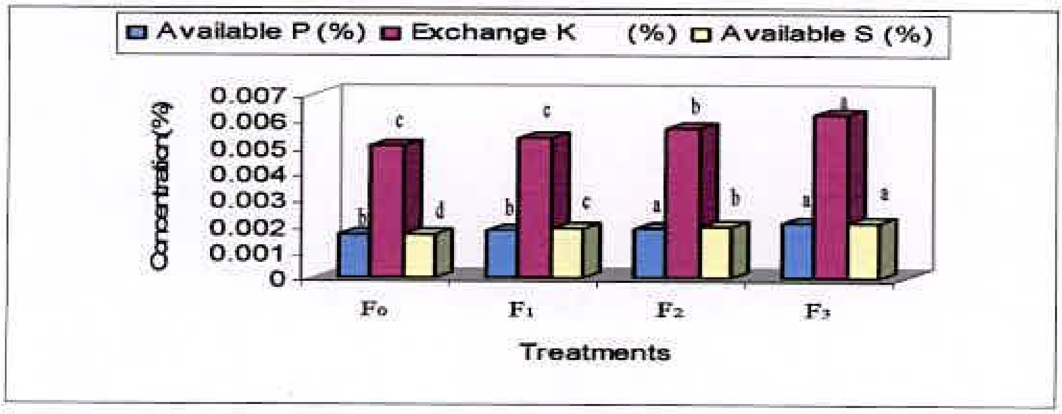
Appendix Figure 25 Effect of vermicompost on the OM content, total N contents in the soil after wheat harvest



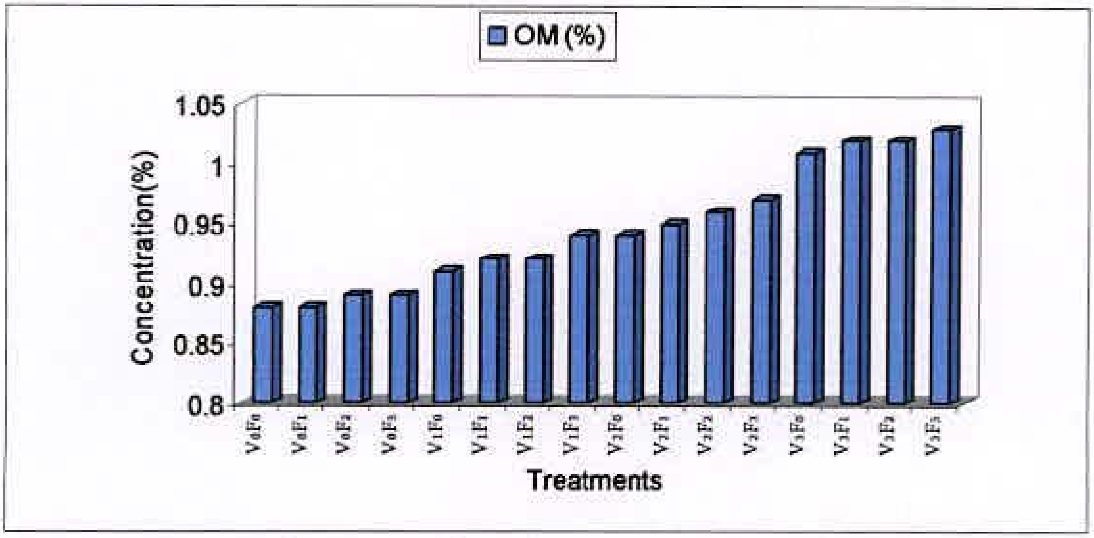
Appendix Figure 26 Effect of vermicompost on the available P, exchangeable K and available S contents in the soil after wheat harvest



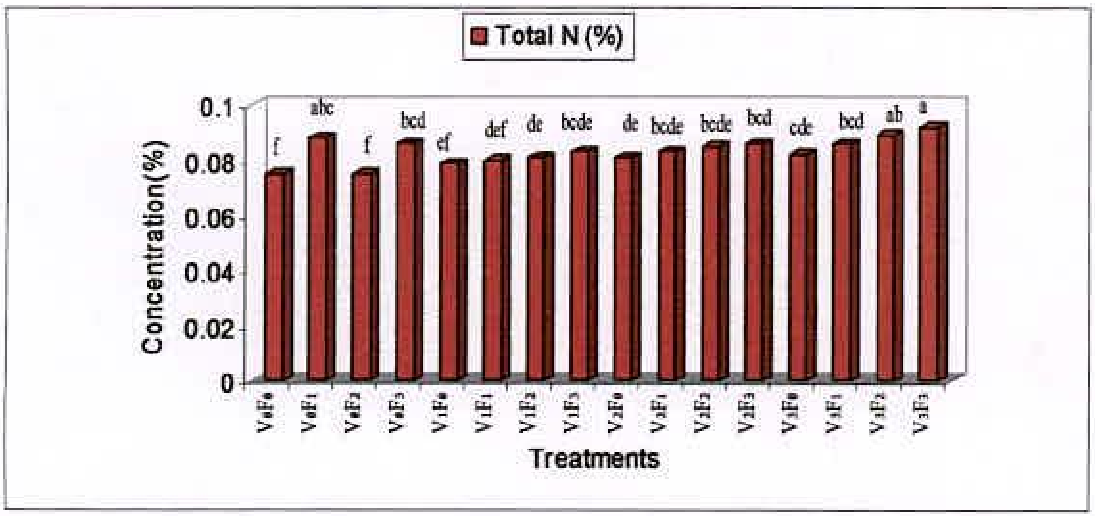
Appendix Figure 27 Effect of NPK on the OM content, total N contents in the soil after wheat harvest



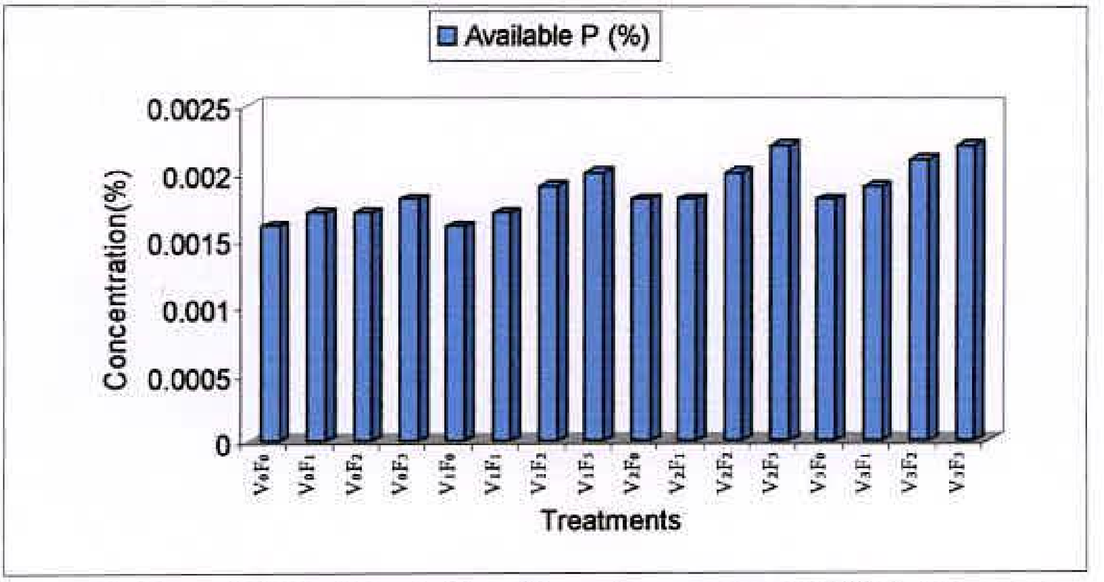
Appendix Figure 28 Effect of NPK on the available P, exchangeable K and available S contents in the soil after wheat harvest



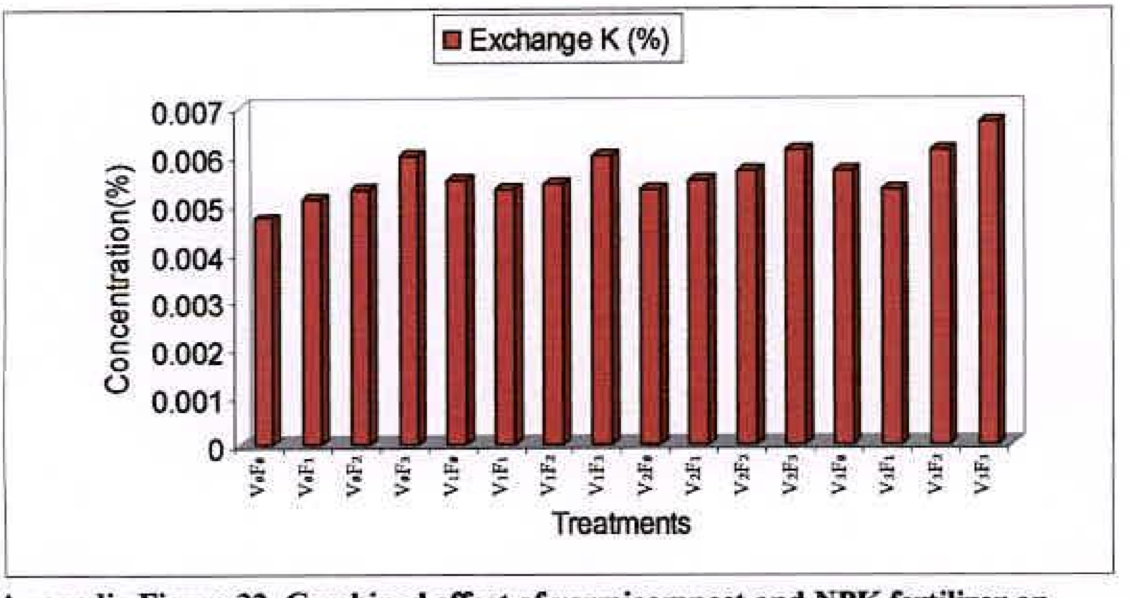
Appendix Figure 29 Combined effect of vermicompost and NPK fertilizer on the organic matter contents in the soil after wheat harvest



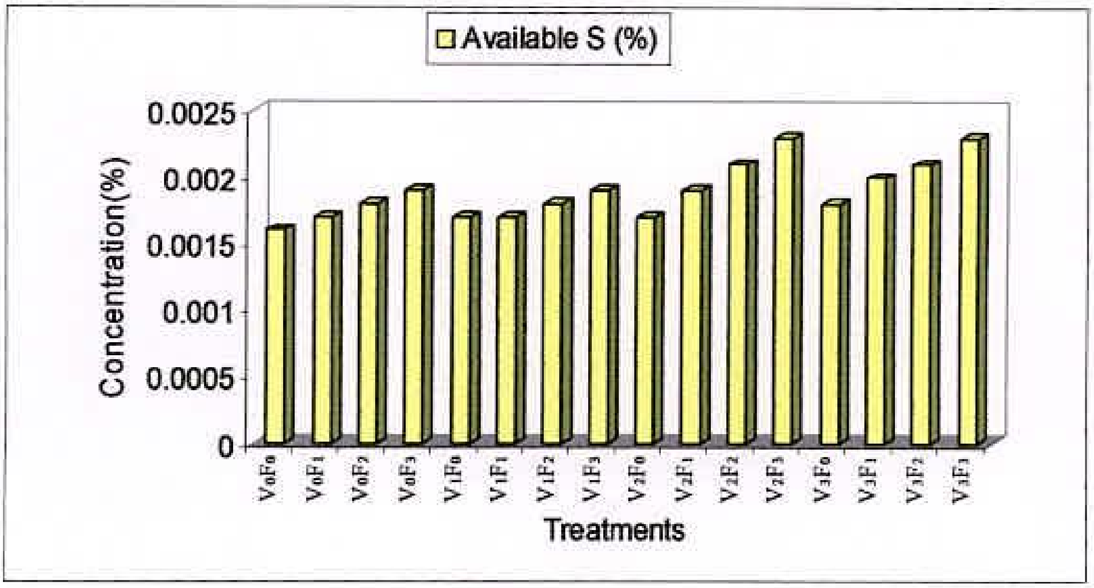
Appendix Figure 30 Combined effect of vermicompost and NPK fertilizer on the total N contents in the soil after wheat harvest



Appendix Figure 31 **Combined effect of vermicompost and NPK fertilizer on the available P contents in the soil after wheat harvest**



Appendix Figure 32 **Combined effect of vermicompost and NPK fertilizer on the exchangeable K contents in the soil after wheat harvest**



Appendix Figure 33 Combined effect of vermicompost and NPK fertilizer on the available S contents in the soil after wheat harvest

Appendix Table1 Effect of vermicompost fertilizer on nitrogen, phosphorous, potassium and sulphur uptake by wheat plant

Vermicompost	Kg ha^{-1}			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0	41.22d	10.36c	27.82d	16.2d
V_1	47.41c	10.86c	31.56c	18.67c
V_2	55.72b	15.11b	33.92b	23.4b
V_3	58.7a	16.38a	36.62a	25.49a
Level of Significance	2.504	1.044	1.811	1.625

Appendix Table 2 Effect of NPK fertilizer on nitrogen, phosphorous, potassium and sulphur uptake by wheat plant

Fertilizer	Kg ha^{-1}			
	Nitrogen	Phosphorous	Potassium	Sulphur
F_0	35.28d	8.27d	20.01d	11.84d
F_1	44.22c	11.8c	27.23c	16.44c
F_2	56.22b	15.12b	36.37b	25.93b
F_3	67.33a	17.52a	44.31a	29.55a
Level of Significance	2.504	1.044	1.811	1.625

Appendix Table 3 Combined effect of vermicompost and NPK fertilizer on nitrogen, potassium, phosphorous and sulphur uptake by wheat plant

Vermicompost x Fertilizer	Kg ha^{-1}			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0F_0	24.64i	6.6g	16.28g	8.36h
V_0F_1	34.39h	8.19fg	19.65g	9.13gh
V_0F_2	47.89g	11.51de	33.58 cd	22.39d
V_0F_3	57.94de	15.16c	41.78b	24.93cd
V_1F_0	27.36i	7.52g	18.92g	9.12gh
V_1F_1	37.94h	8.58fg	27.42ef	12.18fg
V_1F_2	52.15fg	12.46d	34.44c	23.61d
V_1F_3	72.2a	14.89c	45.45ab	29.79b
V_2F_0	38.25h	10.22ef	27.16ef	13.72ef
V_2F_1	55.08ef	15.64c	31.62cd	22.4d
V_2F_2	60.55cd	16.1c	33.95cd	27.3bc
V_2F_3	68.99ab	18.47b	42.97b	30.16ab
V_3F_0	50.88fg	8.74fg	25.7f	16.16e
V_3F_1	49.45g	14.8c	30.24de	22.05d
V_3F_2	64.3bc	20.4ab	43.5ab	30.41ab
V_3F_3	70.17a	21.56a	47.04a	33.32a
Level of Significance	5.009	2.089	3.622	3.250