EFFECT OF INTEGRATED USE OF INORGANIC FERTILIZERS AND VERMICOMPOST ON THE NUTRIENT CONCENTRATION, UPTAKE, YIELD AND OIL CONTENT OF SOYBEAN

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CERTIFICATE

This is to certify that the thesis entitled, " EFFECT OF INTEGRATED USE OF INORGANIC FERTILIZERS AND VERMICOMPOST ON THE NUTRIENT CONCENTRATION, UPTAKE, YIELD AND OIL CONTENT OF SOYBEAN" 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 SAIKAT CHOWDHURY, Registration No. 26139/00438 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.

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Dedicated to

My

Beloved Parents

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By

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ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka 1207 during the *Rabi* season of 2005-2006 to study the effect of integrated use of inorganic fertilizers and vermicompost on the nutrient concentration, uptake, yield and oil content of soybean (*Glycine max* var. Shohag). The experimental soil was clay loam in texture having pH of 6.3. The treatments used were 4 levels of each of vermicomposts viz. V_0 (0 t ha^{-1}), V_1 (2 t ha^{-1}), V_2 (4 t ha^{-1}), V_3 (6 t ha^{-1}) and chemical fertilizers (N, P_2O_5, K_2O, S) viz. F_0 = (0-0-0-0 kg ha^{-1}), F_1 = low (20-60-40-10 kg ha^{-1}), F_2 = medium (30-80-60-20 kg ha^{-1}), F_3 = high (40-100-80-30 kg ha^{-1}) of N-P_2O_5-K_2O-S in 16 treatment combinations with 3 replications. The results demonstrated that the increasing doses of vermicomposts and chemical fertilizers increased grain and straw yields of soybean significantly. The maximum significant grain yield was obtained with the treatment combination, V_2F_2 and that of straw yield was obtained with the treatment combination, V_3F_3. The highest doses of vermicompost and chemical fertilizers increased N, P, K and S concentrations in soybean plant significantly and also enhanced N, P, K and S uptake significantly at the harvesting stage. The maximum significant N, P and K uptake by soybean grain were obtained with the treatment combination, V_2F_2 and S uptake was obtained with the treatment combination, V_3F_3. The maximum significant oil content in soybean was obtained with the treatment combination, V_3F_0. Application of chemical fertilizers failed to increase organic matter content of post harvest soil, whereas vermicomposts showed a significant positive effect. Vermicompost and chemical fertilizers increased P, S and Zn status significantly and that of N and K appreciably in the soil under study.

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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
Mg	Megagram
mL	Milliliter
mm	Millimeter
MP	Muriate of Potash
N	Nitrogen
NaOH	Sodium Hydroxide
NPKS	Nitrogen, Phosphorus, Potassium and Sulphur
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

INTRODUCTION

Soybean (*Glycine max* (L) Merr.) is one of the world's most important oilseed crops. Soybean is originating from the hot areas of South-East Asia, but more than 50% of its production today comes from the United States and South America. Soybean (*Glycine max*) was first introduced into the United States in 1765 (Soybean Research Advisory Institute, 1984). It has become the leading source of edible oils and fats, constituting about 20% of the world's supply and more than any other single source of these essential food constituents (Singh *et al.*, 1989).

Acute shortage of edible oil has been prevailing in Bangladesh during last several decades. This shortage has inherited from the past. In 1972-73, its production was only 54.6 thousand tons that could meet only 30% of the requirement of the 75 million people leaving a shortage of 70%. At that time, there was no high yielding variety (HYV) or improved cultivation technology of oilseeds. Oils and fats play an important role in human nutrition. As a high energy component of food, edible oil is important for meeting the calorie requirement. This is also important for improving the taste of a number of food items. Oil/fat supplies energy and it provides double the quantity of energy than the same quantity of protein or carbohydrate. Fats and oils act as carrier for fat soluble vitamins (A, D, E and K) in the body and therefore, the presence of some fats/oils in the diet is essential for their absorption. Fats and oils are also the sources of essential fatty acids. The main essential fatty acids of vegetable oils are linoleic and linolenic acids. Fats and oils are used to synthesize phospholipids which are important component of active tissues viz. brain, nerve and liver of human being and other animals. In Bangladesh, sources of edible oils are rapeseed/mustard, sesame, groundnut, soybean, niger, linseed, sunflower and safflower. Although linseed is not considered as an edible oil, but its seed is mixed with mustard and sesame to extract oil and is being used for edible purposes. Nevertheless, linseed and castor oils are used as valuable industrial oils. Soybean is being cultivated in Bangladesh since long but the present production is not sufficient enough to extract oil profitably. In Bangladesh, soybean is not yet popular as a crop but soybean oil is very popular as a cooking oil. Its seed contain 42-45% best quality protein and 20-22% edible oil (Wahhab *et al.*, 2001). However, soybean is an important source of good quality protein and oil and can play an important role in solving the malnutrition problem of Bangladesh.

Soybean, like many other legumes, is capable to fix and utilize atmospheric nitrogen through a symbiotic relationship with *Rhizobium japonicum.* Rhizobia are minor component of the soil micro flora, and while not restricted to rhizosphere soil, reach their maximum numbers in association with plant roots (Reicosky *et al.,* 1985).

Organic farming is the management practice that produces crop of good quality and quantity by using eco-friendly technology, which can co-exist in nature. Such practices exclude the use of chemicals fertilizers, pesticides and weedicides etc. The tussle between population growth and food supply in developing countries like Bangladesh are forced to cultivate repeatedly the high yielding varieties (HYV) of crops that leads to a rapid depletion of the soil nutrient reserve. To get more food, farmers are using chemical fertilizers and pesticides in increasing amount, which are making ecological backlashes, resulting in deterioration of soil health (Yawalkar *et al.*, 1981).

Several researchers have compared vermicompost with the surrounding soils and reported that it has a higher base exchange capacity and is generally rich in total organic matter. Besides, it contains substances which helps in building soil structure, stimulate plant growth particularly that of roots, drilling mud and emulsifiers (Dussere, 1992). Soil organic matter improves the physicochemical properties of the soil and ultimately promotes crop production. Its status in Bangladesh soil is very poor. Evidences from different AEZ of the country have shown a decrease in the content of organic matter by the range of 15 to 30% over the last 20 years (Miah, 1994). Therefore, it would not be wise to depend only on inherent potentials of soils for higher crop production. More recently, attention is focused on the global environmental problems; utilization of organic wastes, FYM, compost, vermicompost and poultry manures as the most effective measure for the purpose.

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

In Bangladesh, the farmers are using the chemical fertilizers continuously without knowing the actual dose and their residual effects on soil properties. Under these imbalanced conditions various beneficial soil microorganisms are being adversely affected. The soil is loosing its fertility as well as productivity day by day. If this trend continues, crop production will be seriously affected in the long run. On the contrary, if only organic matter is used the soil physical properties will be improved but the nutrient demand of the crop can't be satisfied due to relatively low content of nutrients in organic matter.

So, combined applications of both chemical and organic fertilizers need to be applied for the improvement of soil physical properties and requisite supply of essential plant nutrients. Information are limited regarding the combined application of organic and inorganic fertilizers with respect to the soil and crops of Bangladesh under the existing agro-climatic conditions which needs to be studied.

With a view to generate information on this aspect, a field experiment was carried out at Sher-e-Bangla Agricultural University farm with soybean as the test crop to determine the effects of vermicompost (as organic fertilizer) and NPKS fertilizers on the nutrient concentration, uptake, yield and oil content of soybean. Considering the above views the present experiment has been undertaken with the following objectives:

1. To study the effect of vermicompost and NPKS on the yield of soybean.
2. To know the optimum dose of vermicompost and NPKS on the yield of soybean.
3. To find out the measures of improving the soil health (physical properties) as continuous application of chemical fertilizers alone deteriorates the soil health.

Chapter 2

Review of literature

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 NPKS and manure application on soybean

Reddy and Reddy (1998) concluded that the combined use of VC(vermicompost) at 50% level of N with 50% N through inorganic fertilizer is suitable for maintaining good soil health and for obtaining optimum yields in maize- soybean cropping system.

Manna *et al.* (2001) observed, in a 3-year field study (1996–99), the performance of four different composts obtained from legume straw (*Glycine max* Merr.L), cereal straw (*Triticum aestivum*), oilseed straw (*Brassica juncea* L.), city rubbish and compared with chemical fertilizers in terms of degree of maturity, quality of compost, improvement in soil organic matter, biological activities of soil and yields of soybean and wheat. The matured compost increased total P, water soluble P, citrate soluble P, total N and NO_3-N and the application of phosphocompost at the rate of 10 t/ha gave plant growth, dry matter accumulation, seed yield and P uptake by soybean equivalent to single super phosphate at 26.2 kg P/ha.

Vyas *et al.* (2003) reported that combined application of 5 kg Zn and 10 t FYM /ha increased grain yield, NPK contents and uptake by soybean seed. The highest grain yield (1790 kg/ha) was recorded in Zn +FYM treatment with a record of 18.2% increase over control (1515 kg/ha) while the application of B +FYM (13.6%) was on with seed treatment with Na molybdate (13.1%).

A long-term experiment was conducted by Behera (2003) during 1995-2002 under the fine-textured Vertisols at Indore, India to study the effect of combined use of Farm Yard Manure (FYM), poultry manure, vermicompost and biofertilizers (Azotobacter + phosphate solubilizing bacteria) with 50 and 100% NPK on wheat, and residual effect on following soybean. Grain yield of aestivum wheat in the initial 2 years and durum wheat in the later 3 years was significantly increased with 50% NPK + poultry manure @ 2.5 t/ha or FYM @ 10 t/ha compared with 50 or 100% NPK alone. Soybean did not show much response to residual effect of treatments in most years, although the yield were comparatively better under the combined use of 100% NPK +FYM or poultry manure given to wheat.

Reddy *et al.* (2004) conducted a field experiment on a Typic Haplustert from 1992 to 1995 where in the annual treatments included four rates of fertilizer P (0, 11, 22 and 44 kg ha^{-1} applied to both soybean and wheat) in the absence and presence of 16 t ha^{-1} of manure (applied to soybean only). They observed that with regular application of fertilizer P to each crop the level of Olsen P increased significantly and linearly through the years in both manured and unmanured plots. The mean P balance required to raise Olsen P by 1 mg kg^{-1} was 17.9 kg ha^{-1} of fertilizer P in unmanured plots and 5.6 kg ha^{-1} of manure plus fertilizer P in manured plots.

A field experiment was arranged by Ghosh et al. (2004) on deep vertisols of Bhopal, India to evaluate the manural potential of three organic manures: farmyard manure (FYM), poultry manure, phosphocompost vis-à-vis 0%, 75% and 100% recommended dose of fertilizer-NPK and to find out the most productive cropping system at various combinations of organic manures and chemical fertilizers. They found that the seed yield of intercrop soybean (population converted to 100%) was 8.7% less than sole soybean whereas the grain yield of intercrop sorghum was 9.5%more than that of sole sorghum. The productivity in terms of soybean equivalent yield was relatively high in intercropping system. The increasing NPK dose from 0% to 100% significantly improved soybean equivalent yield in sole sorghum and soybean/sorghum intercropping system and the integrated use of organics and inorganics recorded significantly more soybean equivalent yield than inorganics.

Hati *et al.* (2006) found that application of 10 Mg farmyard manure and recommended NPK (NPK + FYM) to soybean for three consecutive years improved the organic carbon content of the surface (0–15 cm) soil from an initial value of 4.4 g kg^{-1} to 6.2 g kg^{-1} and also increased seed yield and water-use efficiency by 103% and 76%, respectively over the control. Root length density (RLD) up to the 30 cm depth was highest in the NPK + FYM plots and it was 31.9% and 70.5% more than NPK and control plots.

Ghosh *et al.* (2006) observed that yield and land equivalent ratio (LER) of the intercrops increased over sole crops though based on aggressivity and relative crowding coefficient (RCC), sorghum is more competitive than soybean. Soybean did not benefit from intercropping to the same degree as sorghum under N–P–K. Nutrient application influenced LER, RCC, and monetary advantage index and was found in the order of N–P–K plus farmyard manure (FYM) > N–P–K plus poultry manure (PM) > N–P–K plus phosphocompost (PC) > N–P–K > control. However, based on competition ratio, yield advantage was greater under N–P–K plus PM.

A long-term (30 years) soybean–wheat experiment was conducted by Kundu *et al.* (2006) at Hawalbagh, Almora and observed that maximum yields of soybean (2.84 Mg ha^{-1}) and residual wheat (1.88 Mg ha^{-1}) were obtained in the plots under NPK + farmyard manure (FYM) treatment, which were significantly higher than yields observed under other treatments.

A field experiment on maize with soybean intercropping system was done by Shil *et al.* (2007) during *rabi* season of 2005-2006. There were 8 treatments comprising 2 sets of planting geometry (PG_1 & PG_2) and 4 doses (NM_1, NM_2, NM_3 and NM_4) of nutrient management package. The interaction effect between planting geometry and nutrient management was statistically non-significant for the main crop (hybrid maize). In case of companion crop (soybean), the highest seed yield (564 and 504 kg/ha) was obtained with NM_3 x PG_2, which was significantly higher over rest of the combinations.

2.2 Effect and importance of NPKS fertilizers on oil and protein contents of soybean

Teixeira *et al.* (1984) conducted an experiment on soybean in Brazil and North-America. They found that the average seed oil content in Brazilian and North-American soybean cultivars were 22.19 and 21.00%, respectively.

Some 94 soyabean (Glycine max) varieties from the local germplasm population of the mid-Yangtze River valley (China) were compared by Song-QiJian *et al.* (1996) for protein content, oil content and yield characteristics by means of correlation and coefficient analyses. They observed that oil content was significantly correlated with days to flowering, days from flowering to maturity, 100-seed weight, plant height, number of branches, number of pods per plant and number of seeds per pod. High oil cultivars were more diverse for these traits than high protein ones, indicating that selection for both high protein content and high oil content was difficult. Number of pods per plant and 100-seed weight had strong direct effects on yield and the same was true for days to flowering and number of branches on number of pods per plant and days to flowering and days from flowering to maturity on 100-seed weight.

Kane *et al.* (1997) reported that delayed planting of soybean increased protein content and linolenic acid levels and reduced oil content and oleic acid levels. The higher seed-fill temperatures associated with early planting were strongly correlated with increased oil content and oleic acid levels and reduced linolenic acid levels.

During 2002 and 2003, a study was carried out by Miladinovic *et al.* (2004) to determine the effects of yield, oil content and growing season duration on protein content in new soybean varieties' seeds. In both years, high negative correlations were found between protein content and the other traits under investigation. Path coefficient analysis showed that only oil content had a significant direct effect on protein content.

The effects of irrigation (40, 60, 80 and 100 mm of water evaporated from a class A pan) and plant density (30, 40, 50 and 60 plants/m^2) on the seed yield, and protein and oil content of soyabean cultivars Hobbit, Williams and Hill were determined in a field experiment conducted in Iran during 2000-01. Grain yield per plant and per hectare, as well as 100-seed weight were highest in cv. Williams and with 60 mm irrigation. Grain yield per plant, 100-seed weight and seed oil content decreased, whereas seed protein content increased with increasing plant density. Seed oil content decreased, whereas seed protein content increased with increasing irrigation regimes. Seed protein content was highest in cv. Hobbit. (Khajouei-Nejad *el al.*, 2004)

Deshmukh *et al.* (2005) reported that application of recommended dose of NPK (20:40:20 kg ha^{-1}) along with FYM (2.5 tonnes ha^{-1}) recorded the highest grain yield of soybean (12.49 q ha^{-1}), energy (183.60 MJ ha^{-1}) and protein (502.30 kg ha^{-1}) yields as compared to other treatments and farmer's practice. Similar trends were also observed in the uptake of N, P and K (118.79, 5.61 and 66.61 kg ha^{-1}, respectively).

2.3 Effect and importance of NPKS fertilizers on soybean

Starling *et al.* (1998) reported that application of starter N decreased the number of nodules per root, but increased plant N concentration and dry matter yield. Grain yield was increased on average by 0.15 Mg/ ha with addition of starter N. In this study, an indeterminate genotype soybean coupled with application of starter N promoted greater soybean growth and yield in a late-planted, double-cropped system.

An experiment was conducted by Kumawat (2000) during the rainy season (*kharif*) of 1993 and 1994 to study the effect of irrigation regimes and nitrogen on yield and quality of soybean [*Glycine max* (L.) Merr.]. The treatments comprised 5 irrigation regimes [irrigation at 0.4, 0.6 and 0.8 irrigation water: cumulative pan evaporation (IW : CPE) ratio and crop growth stages along with control] in 1993 and 4 irrigation regimes (irrigation at 0.6, 0.8 IW : CPE and crop growth stages along with control) in 1994 and 4 nitrogen levels (20, 40, 60 and 80 kg N/ha). The seed, stover, oil and protein yields of soybean were significantly higher under 0.8 IW : CPE ratio. The maximum oil and protein contents in soybean seeds were recorded when the crop was irrigated at 0.8 IW : CPE ratio, while minimum in the control (rainfed). The N and P uptake by seed and stover and the total uptake were maximum under 0.8 IW : CPE ratio. Application of nitrogen up to 60 kg/ha increased seed, stover, oil and protein yields of soybean. However, the oil content of seeds was maximum when the crop was fertilized with 20 kg N/ha, and it decreased at 60 kg N/ha. Conversely, the protein content of the seeds was increased with increasing levels of N up to 60 kg N/ha. The N and P uptake both by seed and stover and total uptake significantly increased with the increase in applied N up to 60 kg/ha.

Singh *et al.* (2002) reported that repeated application of phosphorus (P) as superphosphate either alone or in combination with cattle manure and fertilizer N may affect the P balance and the forms and distribution of P in soil. During 7 years, they monitored 0.5 M $NaHCO_3$ extractable P (Olsen-P) and determined the changes in soil inorganic P (P_i) and organic P (P_o) caused by a yearly dose of 52 kg P ha^{-1} as superphosphate and different levels of cattle manure and fertilizer N application in a soybean-wheat system on Vertisol. In general, the contents of Olsen-P increased with combined use of cattle manure. However, increasing rate of fertilizer nitrogen (N) reduced the Olsen-P due to larger P exploitation by crops.

Taylor *et al.* (2005) reported that in double-cropped soybean [*Glycine max* (L.) Merr.] planting is delayed, with a corresponding decrease in yield associated with photoperiod-induced early flowering and reduced accumulation of dry matter during the vegetative growth period. Application of nitrogen (N) has been shown to improve yield of late-planted soybean. Nitrogen application of 60 to 70 kg ha^{-1} maximized yield and first flowering (R1) dry matter accumulation. N reduced nodule number and mass, but had no effect on R1 plant height, mature plant height, or seed quality, protein and oil content. At current prices for N and soybean, they concluded that N can be a viable input for double-cropped soybean at an optimal economic rate of 59 kg ha^{-1}.

2.4 Effect and importance of vermicompost on crop

Vermicomposting is the managed bioconversion of organic materials through earthworm consumption. 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).

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 dose. 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.

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.

Rao *et al.* (2000) from a field experiment carried out at the Indian Agricultural Research Institute, New Delhi, 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.

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).

An experiment 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 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 were obtained with 50 percent N through green manure plus 50 percent fertilizer N (Tolanur and Badanur, 2003).

2.5 Effect and importance of vermicompost on nutrient status and crop production

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 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).

Vermicompost contain high 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).

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 duration of 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 rate 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.

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.

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.

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).

2.6 Effect and importance of NPKS and manure application on other crops

Ganapathy (2006) reported that integrated use of organic and inorganic manures accelerated the growth and yield components of sunflower compared to inorganic fertilizer application. The growth was more with NPK+FYM compared to 100% NPK. The organic fertilizers in combination with inorganic fertilizer were superior to sole inorganic fertilizer for growth and yield components. Overall application of 75% NPK and FYM @ 10 t/ha recorded highest seed yield and yield attributes (head diameter, number of seeds/head and 100-grain weight of sunflower).

A field experiment was conducted by Bayu *et al.* (2006) to assess the effect of the combined use of farmyard manure and inorganic fertilizer on the growth and yield of sorghum and on soil chemical properties in a semi-arid area in northeastern Ethiopia. The combined application of farmyard manure and inorganic fertilizers increased post-anthesis dry-matter production by 147%–390% and grain yield by 14%–36%. The main effects of farmyard manure and inorganic fertilizers increased stover yield by 8%–21% and 14%–21%, respectively. Farmyard manure application increased total nitrogen (N) uptake by 21%–36%, grain protein yield by 8%–11%, and grain protein concentration by 20%–29%. Application of farmyard manure along with 50% of the recommended inorganic fertilizer rate resulted in a grain yield equivalent to, or greater than that for 100% of the recommended inorganic fertilizer rate, thus affecting a 50% savings of inorganic N and phosphorus (P) fertilizer.

Jat and Ahlawat (2004) reported from a field experiment carried out at the Indian Agricultural Research Institute, New Delhi, India that application of 3 t vermicompost ha^{-1} to chickpea improved dry matter accumulation, grain yield and grain protein content in the crop, 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.

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 highest 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).

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 Jobner, Rajastan, India during the *rabi* season of 1998-99 to determine the effects of FYM and NPK on the yield and nutrient uptake by wheat. 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.

Tolanur and Badanur (2003) observed that the highest grain yield and stover yield of pearl millet was obtained with organic source of nutrients to meet 50% N in conjunction with 50% RDF (recommended dose of fertilizer) over control. N applied in two splits recorded the highest yield (1767 Kg /ha) followed by FYM to meet 50% N with 50% RDF (1744 Kg/ha). They also observed that grain yield of pigeonpea recorded the highest amount (801 Kg/ha) with 50% N through subabul with 50% RDF. They also reported that 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 yield of *rabi* sorghum and chickpea was obtained with 50% N through green manure plus 5% fertilizer N.

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

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 farmer's fields (Kamla Kanwar, 2002).

Song *et al.* (2001) conducted an experiment with winter wheat in China to investigate the effects of application of chemical fertilizers 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 specially farmyard manure at a higher dose had a better yield increase than that obtained through the application of fertilizer NPK alone. It is concluded that the application of fertilizer NPK combined with OM not only make good use of resources, but also enhance wheat yield.

Okalebo *et al.* (1999) observed in the Kenyan highland that maize grain yield ranged between 751 and 6836 kg ha^{-1} with lowest yields observed in the treatment receiving wheat straw alone and higher yields associated with soybean residue incorporation and during the second, wetter growing season. In 1998, crop benefited from more favorable rainfall, providing grain yield increase of 141% above control treatment as a result of combining 2 t ha^{-1} soybean trash and 100 kg N ha^{-1} as urea. Higher yields were obtained when organic and inorganic inputs were applied to soils, particularly when soil moisture was adequate and the organic inputs higher in mineralisable nutrients.

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.

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 in the harvest soil.

In a field experiment on a sandy clay loam in Tamil Nadu, sunflowers were given 0, 10, 20, 30 or 40 kg K_2O/ha basally or foliar application of 1.75% KCl at critical growth stages with 0 or 20 kg P_2O_5/ha. P and K application increased seed yield and seed oil content. The highest seed yield (1.46 t/ha), seed oil content and benefit cost ratio were obtained with 40 kg K_2O + 20 kg P_2O_5. Soyabeans were grown after sunflowers on the same plots either with only residual fertilizers or with freshly applied P and K. Both residual and freshly applied fertilizers benefited the soyabean crop (Annaduri *et al.*, 1994).

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 ha^{-1}, and although yields increased with level of cattle manure, 8 t biogas effluent ha^{-1} gave better results than 16 t cattle manure ha^{-1}. 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).

An experiment was conducted to determine the effects of some of the fertilizer and manure treatments on 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).

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 of the soil. The maximum yield was obtained with 5 t organic wastes plus 100 kg urea ha^{-1}.

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

Chapter 3

Materials and methods

MATERIALS AND METHODS

This chapter includes a brief description of the experimental soil, soybean 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 and S on the nutrient content, yield and oil content of soybean.

3.1 Experimental site

The research work relating to the study of the effect of vermicompost and NPKS on the nutrient content, yield and oil content of soybean was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka 1207 during the *Rabi* season of 2005-2006. The following map shows the specific location 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. Some initial physical and chemical characteristics of the soil are presented in Table 1.

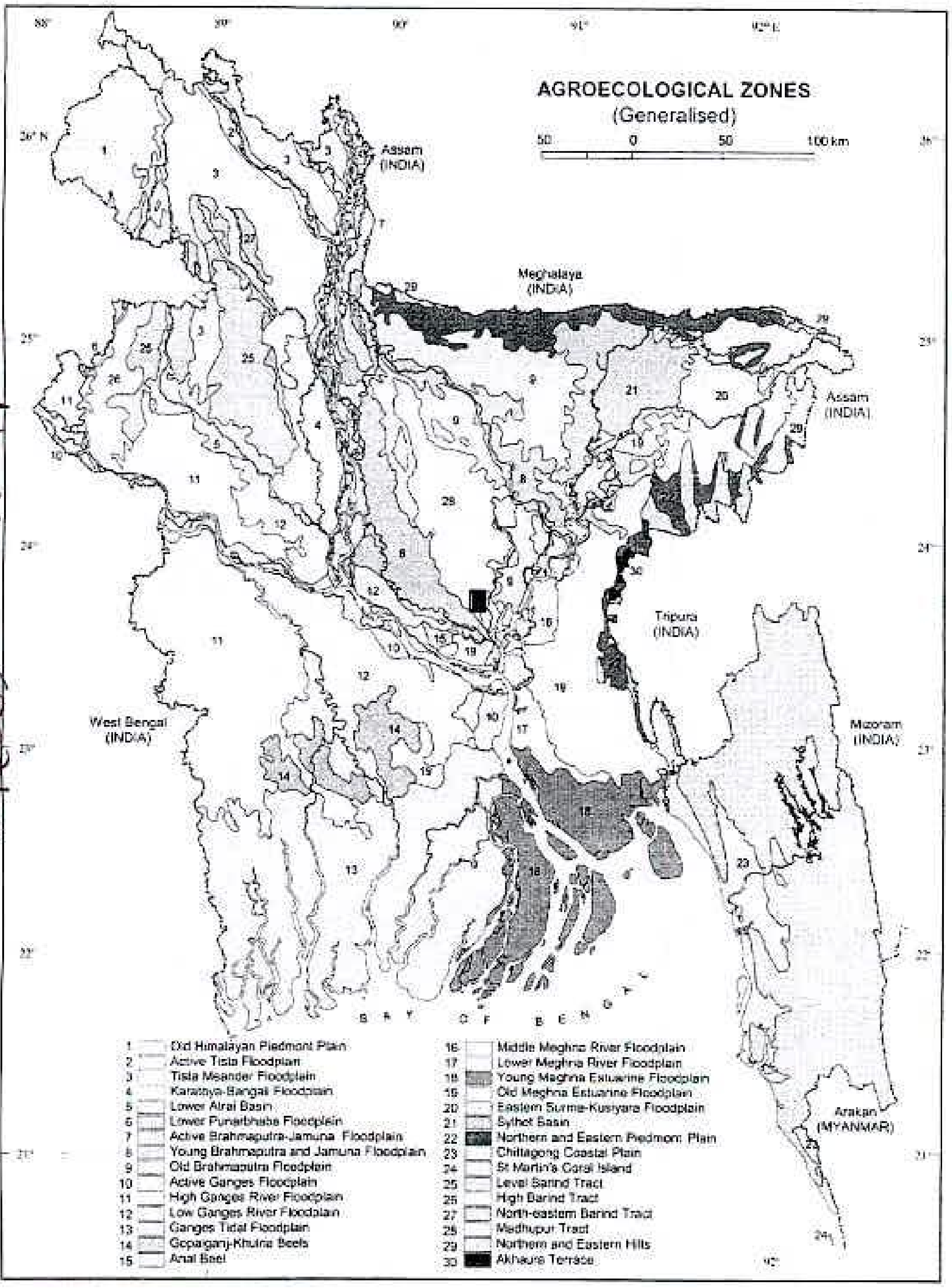


Figure 1. Map showing the experimental site under study ■

Table 1. Initial characteristics of the soil of the experimental field

1. pH		6.3
2. Particle-size analysis of soil	%Sand	30.55
	%Silt	37.29
	%Clay	32.16
3. Textural Class		Clay loam
4. Total N (%)		0.075
5. Organic matter (%)		0.80
6. Phosphorous (%)		0.0016
7. Potassium (%)		0.0015
8. Sulphur (%)		0.0013
9. Zinc (%)		0.00018

3.3 Description of the soybean variety

Sohag (PB-1), a high yielding variety of soybean was used as the test crop in this experiment. This variety was released by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur in 1991. Harvesting of this variety needs 100 to110 days. The variety is resistant to yellow mosaic virus.

3.4 Preparation of the field

The plot selected for the experiment was opened by power tiller driven rotovator on the 14th December 2005, 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 numbers of plots were 48, each measuring 4 m × 2.5 m (10 m^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 100 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 = 2 t ha^{-1} (Low vermicompost)

V_2 = 4 t ha^{-1} (Medium vermicompost)

V_3 = 6 t ha^{-1} (High vermicompost)

Factor B: Fertilizer

F_0 = 0 kg N ha^{-1} + 0 kg P_2O_5 ha^{-1} + 0 kg K_2O ha^{-1} + 0 kg S ha^{-1} (No NPKS)

F_1 = 20 kg N ha^{-1} + 60 kg P_2O_5 ha^{-1} + 40 kg K_2O ha^{-1} + 10 kg S ha^{-1} (Low NPKS)

F_2 = 30 kg N ha^{-1} + 80 kg P_2O_5 ha^{-1} + 60 kg K_2O ha^{-1} + 20 kg S ha^{-1} (Medium NPKS)

F_3 = 40 kg N ha^{-1} + 100 kg P_2O_5 ha^{-1} + 80 kg K_2O ha^{-1} + 30 kg S ha^{-1} (High NPKS)

Treatment combination

V_0F_0 = Control (No vermicompost + No NPKS)

V_0F_1 = (No vermicompost + Low NPKS)

V_0F_2 = (No vermicompost + Medium NPKS)

V_0F_3 = (No vermicompost + High NPKS)

V_1F_0 = (Low vermicompost + No NPKS)

V_1F_1 = (Low vermicompost + Low NPKS)

V_1F_2 = (Low vermicompost + Medium NPKS)

V_1F_3 = (Low vermicompost + High NPKS)

V_2F_0 = (Medium vermicompost + No NPKS)

V_2F_1 = (Medium vermicompost + Low NPKS)

V_2F_2 = (Medium vermicompost + Medium NPKS)

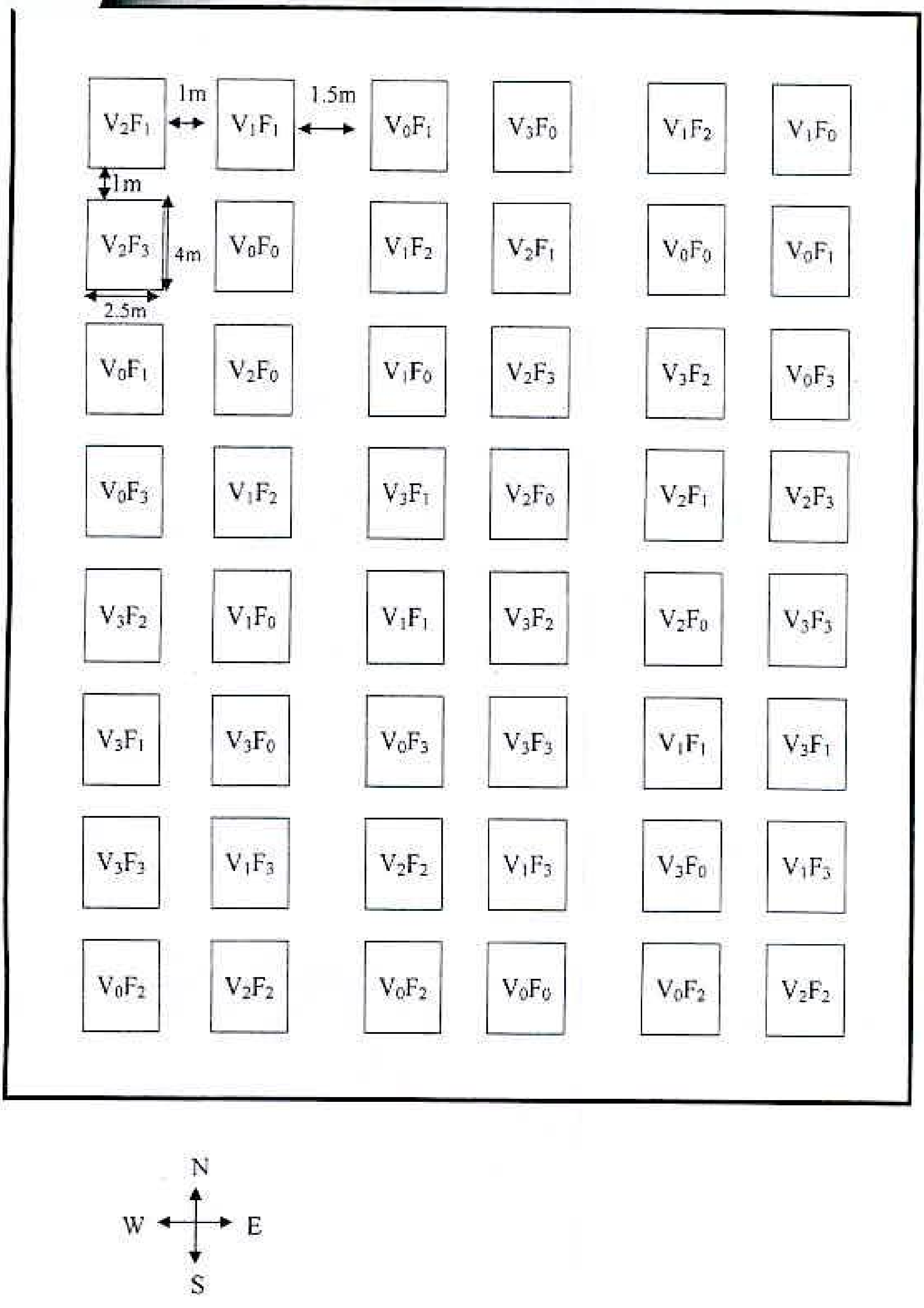
V_2F_3 = (Medium vermicompost + High NPKS)

V_3F_0 = (High vermicompost + No NPKS)

V_3F_1 = (High vermicompost + Low NPKS)

V_3F_2 = (High vermicompost + Medium NPKS)

V_3F_3 = (High vermicompost + High NPKS)



Plot size: 4m x 2.5m ($10m^2$)
Plot to plot distance: 1m
Block to block distance: 1.5 m

Figure 2. Layout of the experimental field

3.7 Application of vermicompost and fertilizers

The required amount of P , K and S fertilizers (Triple superphosphate , Muriate of Potash and Gypsum, respectively) were applied at a time during final land preparation. 50% of N (urea) was applied during the final land preparation. The remaining 50% of N (urea) was applied after first irrigation. The required amounts of vermicompost as per treatment combinations were applied uniformly in the canals opened for sowing the seeds of soybean in lines.

3.8 Seed sowing

Soybean seeds were sown on the 15th December 2005 in lines following the recommended line to line distance of 30 cm and plant to plant distance of 5 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 cutworm, which was removed by applying Malathion. Special care was taken to protect the crop from birds especially after sowing and germination stages.

The field was irrigated twice- one at 35 and the other at 60 days of sowing seed.

3.10 Harvesting

The crop was harvested at maturity on 7th April 2006. 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

Post harvest soil samples were collected from each plot at 0-15 cm depth on 8th April 2006. 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 the harvesting stage of the crop. 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 plant. 10 plants were measured randomly from each plot and averaged. It was done at the ripening stage of the crop.

3.12.2 Number of leaves /plant

Number of leaves were counted at the maximum vegetative stage. 10 plants were selected randomly from each plot and averaged.

3.12.3 Number of primary branches/plant

Number of primary branches were counted at the maximum vegetative stage. 10 plants were selected randomly from each plot and averaged.

3.12.4 Number of pods /plant

Pods were counted at the ripening stage and 10 plants were selected from each plot and averaged.

3.12.5 Number of seeds / plant

It was done after harvesting. At first, number of seeds / pod were counted and averaged. Then it was multiplied with number of pods /plant. 10 plants were selected and averaged.

3.12.6 Thousand seed weight

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

3.12.7 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}.

3.12.8 Straw yield

Straw remained after collection of grain (1 m^2 of each individual plot) was dried, weighed carefully and the yield was 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.

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).

b) Potassium

Potassium content in the digested plant sample was determined by flame photometer.

c) Sulphur

Sulphur content in the digest was determined by turbidimetric method as described by Hunt (1980) using a Spectrophotometer (LKB Novaspec, 4049)

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-Kjeldal method. Nitrogen in the digest was 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).

e) Protein

Protein content of grain was estimated by multiplying percentage of nitrogen with 6.25.

f) Oil

Oil content of soybean seed was estimated by Swedish soxlet method. (As described by South Combe, 1926)

3.13.2 Soil sample analysis

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.

b) Organic Matter

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

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 digest was 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).

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).

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.

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).

g) Available Zinc

Zinc in the extract was determined by the DTPA extracting solution method as described by Lindsay *et al.* (1978) using a Atomic Absorbing Spectrophotometer.

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 11.06% organic matter, 0.6298% total N, 0.02249% available P, 0.07826% available K and 0.0313% 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

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 soybean are presented in this chapter.

4.1 Effect of vermicompost and NPKS fertilizers on the growth parameters and yield of soybean

4.1.1 Plant height

The effects of vermicompost and NPKS fertilizers alone and in combination of two sources on the height of soybean plant are presented in Table 2. Significant variation was observed in plant height of soybean when the field was incorporated with different doses of vermicompost. Among the different doses of vermicompost, V_3 (6 t ha^{-1}) showed the highest plant height (86.67 cm). On the other hand, the lowest plant height (78.29 cm) was observed in the V_0 treatment where no vermicompost was applied. Vermicompost might have increased the soil physical properties particularly soil porosity, structure, water holding capacity and supplied other plant growth promoting substances 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 increase in soil organic matter content through the application of FYM in wheat increased plant height.

Table 2. Effect of vermicompost on the yield contributing characters and the yield of soybean

Vermicompost	Plant height (cm)	1000 seed weight (g)	Seed yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)
V_0	78.29 c	49.12 b	1.52 c	1.41 c
V_1	83.28 b	52.35 a	1.62 bc	1.60 b
V_2	83.72 b	51.72 ab	1.73 b	1.67 b
V_3	86.67 a	52.47 a	1.93 a	1.99 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

Table 3. Effect of NPKS fertilizers on the yield contributing characters and the yield of soybean

NPKS Fertilizer	Plant height (cm)	1000 seed weight (g)	Seed yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)
F_0	78.05 d	47.02 b	1.31 c	1.18 c
F_1	79.39 c	49.87 b	1.55 b	1.62 b
F_2	85.97 b	54.58 a	1.98 a	1.90 a
F_3	88.55 a	54.19 a	1.95 a	1.98 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

Soybean plants showed significant variation in respect of plant height when fertilizers in different doses were applied (Table 3). Among the different fertilizer doses, F_3 (High NPKS) showed the highest plant height (88.55 cm), which was not statistically identical with the fertilizer dose F_2 (Medium NPKS). On the contrary, the lowest plant height (78.05 cm) was observed in F_0 treatment where no fertilizer was applied (Table 3). Song *et al.* (2001) found that application of fertilizer NPK increased the height of wheat plant compared with control treatment.

Combined application of different doses of vermicompost and fertilizer had significant effect on the plant height of soybean (Table 4). The lowest plant height (69.77 cm) was observed in the treatment combination of V_0F_0 (No vermicompost and No NPKS). On the other hand, the highest plant height (95.17 cm) was recorded withV_2F_3 (Medium vermicompost + High NPK). Similar result was reported by Song *et al.* (2001). They found that application of fertilizer NPK combined with various sources of OM increased the plant height in wheat compared with the control treatment.

It is evident from the data that vermicompost at the medium rate along with high dose of NPKS resulted the highest plant height of soybean.

Table 4. Effect of vermicompost and NPKS fertilizers on the yield contributing characters and the yield of soybean

Vermicompost × NPKS Fertilizer	Plant height (cm)	1000 seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})
V_0F_0	69.77 g	42.40 d	1.33 h	0.94 f
V_0F_1	72.70 f	46.80 bcd	1.31 fgh	1.06 ef
V_0F_2	81.83 d	54.00 a	1.77 cde	1.81 bcd
V_0F_3	88.87 b	53.27 ab	1.88 bcd	1.82 bcd
V_1F_0	81.20 d	49.13 abc	1.22 gh	1.20 ef
V_1F_1	81.00 d	50.33 abc	1.51 efg	1.6 cd
V_1F_2	89.40 b	53.93 a	1.76 cde	1.62 cd
V_1F_3	81.53 d	56.00 a	2.00 abc	1.98 abc
V_2F_0	79.17 e	45.87 cd	1.33 fgh	1.15 ef
V_2F_1	77.87 e	50.33 abc	1.53 efg	1.67 cd
V_2F_2	85.50 c	56.00 a	2.25 a	2.01 abc
V_2F_3	95.17 a	54.67 a	1.79 cde	1.86 abc
V_3F_0	82.07 d	50.67 abc	1.57 def	1.42 de
V_3F_1	86.00 c	52.00 abc	1.85 bcde	2.13 ab
V_3F_2	89.97 b	54.40 a	2.15 ab	2.16 ab
V_3F_3	88.63 b	52.83 ab	2.13 ab	2.26 a
Level of Significance	0.01	0.05	0.05	0.05

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 seeds

Significant variation was observed in the weight of 1000 seeds of soybean when different doses of vermicompost were applied (Table 2). The highest 1000 seed weight (52.47 g) was recorded in V_3 (6 t ha^{-1}), and the lowest 1000 seed weight (49.12 g) was recorded in the V_0 treatment where no vermicompost was applied Similar result was reported by Agarwal *et al.* (2003). They found that treatment with 75% vermicompost + 25% farmyard manure resulted in the maximum 1000 seed weight of wheat. The increased grain weight might be due to favorable effects of vermicompost on the vegetative growth and accumulation of materials that helped proper growth and development of the soybean seed.

Different doses of chemical fertilizers showed significant variations in respect of weight of 1000 seeds resulting about 14% increase over the control (Table 3). Among the different doses of fertilizers, F_2 (Medium NPKS) showed the highest weight of 1000 seeds (54.58 g), which was statistically identical (54.19 g) with the fertilizer dose of F_3 (High NPKS). On the contrary, the lowest weight of 1000 seeds (47.02 g) was observed with F_0, where no fertilizer was applied and this was closely followed by the F_1 (Low NPKS) fertilizer combination. Jelic *et al.* (1992) found that higher doses of 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 soybean was significant (Table 4). But the highest weight of 1000 seeds (56.00 g) was recorded with the treatment combination of V_2F_2 (Medium vermicompost + Medium NPKS). On the other hand, the lowest weight of 1000 seeds (42.40 g) was found in V_0F_0 treatment (No vermicompost and No NPKS). Ganapathy

(2006) reported that combined application of 75% NPK and FYM @ 10 t/ha recorded highest 100 grain weight of sunflower.

4.1.3 Seed yield of soybean

The seed yield as improved by different doses of vermicompost showed a statistically significant variation (Table 2). Among the different doses of vermicompost the highest grain yield (1.93 t ha^{-1}) was observed in V_3 treatment (6 t ha^{-1}), which was not statistically identical (1.73 t ha^{-1}) with V_2 treatment (4 t ha^{-1}). The lowest seed yield (1.52 t ha^{-1}) was recorded in the V_0 treatment where no vermicompost was applied and it was closely followed (1.62 t ha^{-1}) by the V_1 (2 t ha^{-1}) treatment. Probably vermicompost supplied the necessary requirements for the proper vegetative growth that helped in obtaining the highest yield of soybean. Ranwa and Sing (1999) reported that the application of vermicompost (7.5 t/ha) improved grain yield of wheat. Fouda (1989) stated that grain yield of wheat were increased with the increasing rate of compost application.

Application of different doses of fertilizers at different treatments showed a significant variation on the seed yield of soybean (Table 3). Among the different combinations of fertilizer doses, F_2 (Medium NPKS) showed the highest seed yield (1.98 t ha^{-1}), which was closely followed (1.95 t ha^{-1}) by the fertilizer dose F_3 (High NPKS). On the other hand, the lowest seed yield (1.31 t ha^{-1}) was recorded with F_0 treatment, where no fertilizer was applied. 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 seed yield showed a statistically significant variation (Table 4). The highest seed yield (2.25 t ha^{-1}) was recorded in the treatment combination of V_2F_2 (Medium vermicompost + Medium NPKS) which was statistically similar with the treatment combination of V_3F_2 (High vermicompost + Medium NPKS) and V_3F_3 (High vermicompost + High NPKS). On the other hand, the lowest seed yield (1.33 t ha^{-1}) was found in V_0F_0. It is observed that the application of fertilizer NPKS combined with organic matter (OM) not only make good use of resources, but also enhance soybean yield. Similar result was obtained by Deshmukh *et al.* (2005). They found that the application of recommended dose of fertilizer NPK combined with FYM recorded the maximum seed yield of soybean. Similar views were reported by Song *et al.* (2001). They found that the application of fertilizer NPK combined with organic matter (OM) enhanced biomass production and the grain yield of wheat. Vasanti and Kumaraswamy (1999) reported that vermicompost at 5 t/ha would be sufficient for rice crop when applied with recommended levels of N, P and K.

4.1.4 Straw yield

Significant variation in straw yield of soybean was observed with different doses of vermicompost (Table 2). Among the different doses of vermicompost V_3 (6 t ha^{-1}) showed the highest straw yield (1.99 t ha^{-1}). On the other hand, the lowest straw yield (1.41 t ha^{-1}) was observed in the V_0 treatment, where no vermicompost was applied. Bangar *et al.* (1990) reported that compost increased straw yield of wheat significantly.

Straw yield showed significant variation when different doses of fertilizers were applied (Table 3). Among the different combinations of fertilizer, F_3 (High NPKS) showed the highest straw yield (1.98 t ha^{-1}), which was closely followed (1.90 t ha^{-1}) by the fertilizer dose F_2 (Medium NPKS). The lowest straw yield (1.18 t ha^{-1}) was observed with F_0 treatment, where no fertilizer was applied. Similar result was obtained by Starling *et al.* (1998). They found that the application of starter N decreased the number of nodules per root, but increased dry matter yield of soybean.

Combined effect of different doses of vermicompost and fertilizer showed a statistically significant effect on the straw yield of soybean (Table 4) .The lowest straw yield (0.94 t ha^{-1}) was observed in the treatment combination of V_0F_0 (No vermicompost and No NPKS). On the other hand, the highest straw yield (2.26 t ha^{-1}) was recorded with V_3F_3 (High vermicompost + High NPKS), which was statistically identical with the treatment combinations of V_3F_2 (High vermicompost + Medium NPKS) and V_3F_1 (high vermicompost + Low NPKS). Song *et al.* (2001) found similar results with the application of fertilizer NPK combined with OM which enhanced biomass and grain yield of wheat.

4.1.5 Number of pods/plant

Significant variation was observed in the number of pods/plant of soybean when different doses of vermicompost were applied (Table 5). The highest number of pods/plant (58.58) was recorded in V_3 (6 t ha^{-1}), and the lowest number of pods/plant (46.33) was recorded in the V_0 treatment where no vermicompost was applied. The increased number of pods/plant may be due to favorable effects of vermicompost on the vegetative growth and accumulation of materials that helped proper growth and development of the soybean pod.

Table 5. Effect of vermicompost on the yield contributing characters of soybean

Vermicompost	No. of pods/plant	No. of seeds/plant	No. of leaves/plant	No. of primary branches/plant
V_0	46.33 b	137.3 c	16.58 b	4.25 b
V_1	47.42 b	140.2 c	19.17 a	5.83 a
V_2	56.92 a	165.9 b	18.83 a	5.75 a
V_3	58.58 a	173.0 a	19.50 a	5.42 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

Table 6. Effect of NPKS fertilizers on the yield contributing characters of soybean

NPKS Fertilizer	No. of pods/plant	No. of seeds/plant	No. of leaves/plant	No. of primary branches/plant
F_0	48.83 d	143.2 c	15.42 c	4.42 b
F_1	50.75 c	149.7 b	17.92 b	5.50 a
F_2	56.67 a	168.1 a	20.75 a	5.92 a
F_3	53.00 b	155.5 b	20.00 a	5.42 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 significant variations in respect of number of pods/plant (Table 6). Among the different doses of fertilizers, F_2 (Medium NPKS) showed the highest number of pods/plant (56.67. On the contrary, the lowest number of pods/plant (48.83) was observed with F_0

The combined effect of different doses of vermicompost and fertilizer on number of pods/plant of soybean was significant (Table 7). The highest number of pods/plant (63.33) was recorded with the treatment combination of V_2F_2 (Medium vermicompost + Medium NPKS). On the other hand, the lowest number of pods/plant (38.67) was found in V_0F_0 treatment (No vermicompost and No NPKS).

Table 7. Combined effect of vermicompost and NPKS fertilizers on the yield contributing characters of soybean

Vermicompost × NPKS Fertilizer	No. of pods/plant	No. of seeds/plant	No. of leaves/plant	No. of primary branches/plant
V_0F_0	38.67 g	115.0 h	11.00 e	2.33 d
V_0F_1	40.00 g	119.3 h	15.33 d	4.00 c
V_0F_2	58.00 bc	172.7 b	20.00 abc	5.67 ab
V_0F_3	48.67 e	142.3 efg	18.00 c	5.00 abc
V_1F_0	48.33 e	143.0 efg	18.33 bc	5.67 ab
V_1F_1	48.00 e	140.0 fg	18.33 bc	5.67 ab
V_1F_2	44.33 f	132.0 g	20.00 abc	6.00 ab
V_1F_3	49.00 e	145.7 def	20.00 abc	6.00 ab
V_2F_0	55.67 cd	159.7 c	14.00 d	5.00 abc
V_2F_1	54.00 d	159.3 c	19.33 abc	6.33 a
V_2F_2	63.33 a	187.0 a	21.00 ab	6.33 a
V_2F_3	54.67 cd	157.7 cd	22.00 a	5.33 abc
V_3F_0	52.67 d	155.0 cde	18.33 bc	4.67 bc
V_3F_1	61.00 ab	180.0 ab	18.67 bc	6.00 ab
V_3F_2	61.00 ab	180.7 ab	20.00 abc	5.67 ab
V_3F_3	59.67 ab	176.3 ab	21.00 ab	5.33 abc
Level of Significance	0.01	0.01	0.01	0.05

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

4.1.6 Number of seeds/plant

The number of seeds/plant as affected by different doses of vermicompost showed a statistically significant variation (Table 5). Among the different doses of vermicompost the highest number of seeds/plant (173.0) was observed in V_3 (6 t ha^{-1}), which was not statistically identical (165.9) with V_2 (4 t ha^{-1}). The lowest number of seeds/plant (137.3) was recorded in the V_0 treatment where no vermicompost was applied and it was closely followed (140.2) by the V_1 (2 t ha^{-1}) treatment. Probably vermicompost supplied the necessary requirements for the proper vegetative growth that helped in obtaining the highest number of seeds/plant of soybean. Fouda (1989) stated that grain yield of wheat were increased with the increasing rate of compost application.

Application of fertilizers at different doses showed a significant variation on the number of seeds/plant of soybean (Table 6). Among the different combinations fertilizer doses, F_2 (Medium NPKS) showed the highest number of seeds/plant (168.1). On the other hand, the lowest number of seeds/plant (143.2) was recorded with F_0 treatment, where no fertilizer was applied. Similar results were reported by Kadar and Csatho (1987) and Dang *et al.* (1988). Optimum fertilizer doses increase the vegetative growth and development of soybean that lead to the formation of the highest number of seeds/plant.

Combined effects of different doses of vermicompost and fertilizers on number of seeds/plant showed a statistically significant variation (Table 7). The highest number of seeds/plant (187.0) was recorded in the treatment combination of V_2F_2 (Medium vermicompost + Medium NPKS). On the other hand, the lowest number of seeds/plant (115.0) was found in V_0F_0.

4.1.7 Number of leaves/plant

Significant variation was observed in the number of leaves/plant of soybean when different doses of vermicompost were applied (Table 5). The highest number of leaves/plant (19.50) was recorded in V_3 (6 t ha^{-1}), which was statistically identical with V_1 (2 t ha^{-1}) and V_2 (4 t ha^{-1}) and the lowest number of leaves/plant (16.58) was recorded in the V_0 treatment where no vermicompost was applied. . Similar results were reported by Agrawal *et al.* (2003) for wheat. The increased number of leaves/plant may be due to favorable effects of vermicompost on the vegetative growth and accumulation of materials that helped proper growth and development of the soybean leaf.

Different doses of chemical fertilizers showed significant variations in respect of number of leaves/plant (Table 6). Among the different doses of fertilizers, F_2 (Medium NPKS) showed the highest number of leaves/plant (20.75) which was statistically identical with F_3 (High NPKS). On the contrary, the lowest number of leaves/plant (15.42) was observed with F_0 (No NPKS).

The combined effect of different doses of vermicompost and fertilizer on number of leaves/plant of soybean was significant (Table 7). The highest number of leaves/plant (22.0) was recorded with the treatment combination of V_2F_3 (Medium vermicompost + High NPKS). On the other hand, the lowest number of leaves/plant (11.0) was found in V_0F_0 treatment (No vermicompost and No NPKS).

4.1.8 Number of primary branches /plant

The number of primary branches /plant as improved by different doses of vermicompost showed a statistically significant variation (Table 5). Among the different doses of vermicompost the highest number of primary branches /plant (5.83) was observed in V_1 (2 t ha^{-1}), which was statistically identical (5.75 & 5.42) with V_2 (4 t ha^{-1}) and V_3 (6 t ha^{-1}), respectively. The lowest number of primary branches /plant (4.25) was recorded in the V_0 treatment where no vermicompost was applied. Probably vermicompost supplied the necessary requirements for the proper vegetative growth that helped in obtaining the highest number of primary branches /plant of soybean.

Application of fertilizers at different doses showed a significant variation on the number of primary branches /plant of soybean (Table 6). Among the different combinations fertilizer doses, F_2 (Medium NPKS) showed the highest number of primary branches /plant (5.92), which was statistically identical (5.50 & 5.42) with F_1 (Low NPKS) and F_3 (High NPKS), respectively. On the other hand, the lowest number of primary branches /plant (4.42) was recorded with F_0 treatment, where no fertilizer was applied. Optimum fertilizer doses increased the vegetative growth and development of soybean that lead to the creation highest number of primary branches /plant.

Combined effects of different doses of vermicompost and fertilizers on the number of primary branches /plant showed a statistically significant variation (Table 7). The highest number of primary branches /plant (6.33) was recorded in the treatment combination of V_2F_2 (Medium vermicompost + Medium NPKS) which was statistically identical with the treatment combination of V_2F_1 (Medium vermicompost + Low NPKS). On the other hand, the lowest number of primary branches /plant (2.33) was found in V_0F_0.

4.2 Effect of vermicompost and NPKS fertilizers on the nutrient concentrations in soybean plant

4.2.1 Nitrogen content

A statistically significant variation was observed in nitrogen concentration in soybean plant after harvest when different doses of vermicompost were applied (Table 8). The effect of different doses of vermicompost revealed that the highest nitrogen concentration (1.06%) was recorded in V_3 (6 t ha^{-1}) and the lowest nitrogen concentration (0.88%) was recorded in the V_0 treatment which was statistically similar with V_1 (2 t ha^{-1}). It was observed that nitrogen content increased due to higher rate of application of vermicompost. Jat and Ahlawat (2004) reported that application of vermicompost to chickpea improved N and P uptake by the cropping system over no vermicompost treatment.

Application of different doses of chemical fertilizers showed a statistically significant variation in respect of nitrogen concentration in soybean plant after harvest (Table 9). Among the different combinations of fertilizer doses, F_3 (High NPKS) showed the highest nitrogen concentration (1.16%) and the lowest nitrogen concentration (0.82%) 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 NPKS) treatment in soybean plant. This may be due to more NPKS application which helped to enhance nitrogen content in soybean plant.

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 soybean crop (Table 10). The highest nitrogen concentration (1.4%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPKS). On the other hand, the lowest nitrogen concentration (0.76%) was found in V_0F_0 (No vermicompost +No NPKS) treatment combination. The application of highest rate of vermicompost with NPKS showed the highest nitrogen content in shoot.

Table 8. Effect of vermicompost on the NPKS concentrations in soybean plant

Vermicompost	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0	0.88 b	0.18 b	0.73 b	0.35
V_1	0.94 b	0.20 ab	0.90 a	0.37
V_2	0.96 ab	0.20 ab	0.91 a	0.39
V_3	1.06 a	0.22 a	0.98 a	0.40
Level of Significance	0.05	0.05	0.01	NS

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

Table 9. Effect of NPKS fertilizers on the NPKS concentrations in soybean plant

Fertilizer	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
F_0	0.82 c	0.17 c	0.61 d	0.33 b
F_1	0.84 c	0.19 b	0.78 c	0.37 ab
F_2	1.03 b	0.21 ab	0.97 b	0.40 a
F_3	1.16 a	0.23 a	1.16 a	0.41 a
Level of Significance	0.01	0.01	0.01	0.05

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

4.2.2 Phosphorous content

Significant variation was recorded with phosphorous concentration in soybean shoot after harvest when vermicompost was applied at different doses (Table 8). Considering the effect of different doses of vermicompost, the highest phosphorous concentration (0.22%) was recorded in V_3 (6 t ha^{-1}) and the lowest phosphorous concentration (0.18%) was recorded in the V_0 treatment where no vermicompost was applied. It was observed that phosphorous content increased due to higher rate of application of vermicompost.

Table 10. Combined effect of vermicompost and NPKS fertilizers on the NPKS concentrations in soybean plant

Vermicompost × NPKS Fertilizer	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0F_0	0.76 d	0.15 e	0.50 h	0.31
V_0F_1	0.76 d	0.17 de	0.70 fgh	0.32
V_0F_2	1.03 bc	0.18 bcde	0.80 ef	0.38
V_0F_3	0.98 bcd	0.21 abcd	0.93 cde	0.39
V_1F_0	0.80 cd	0.16 de	0.53 gh	0.32
V_1F_1	0.84 cd	0.20 abcde	0.80 ef	0.39
V_1F_2	0.99 bcd	0.21 abcd	1.10 abc	0.40
V_1F_3	1.13 b	0.23 abc	1.17 ab	0.39
V_2F_0	0.86 cd	0.17 cde	0.67 fgh	0.34
V_2F_1	0.87 cd	0.19 abcde	080 ef	0.39
V_2F_2	0.98 bcd	0.20 abcde	0.93 cde	0.41
V_2F_3	1.13 b	0.24 a	1.23 ab	0.42
V_3F_0	0.86 cd	0.18 abcde	0.73 efg	0.36
V_3F_1	0.87 cd	0.21 abcd	0.83 def	0.40
V_3F_2	1.11 b	0.23 ab	1.03 bcd	0.42
V_3F_3	1.40 a	0.24 a	1.30 a	0.43
Level of Significance	0.05	0.01	0.05	NS

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 resulted a significant variation in phosphorous concentration in soybean plant at the harvest (Table 9). Among the different combinations of fertilizer doses, F_3 (High NPKS) showed the highest phosphorous concentration (0.23%) in plant, and the lowest phosphorous concentration (0.17%)

was recorded in the plants of the F_0 treatment. It was observed that phosphorous content increased due to higher rate of application of NPKS.

The effect of different doses of vermicompost and fertilizer at various combinations on the phosphorous concentration in soybean plant was statistically significant (Table 10). The highest phosphorous concentration (0.24%) was recorded in the treatment combination of V_2F_3 (Medium vermicompost + High NPKS) which was statistically identical with V_3F_3 treatment combination. On the other hand, the lowest phosphorous concentration (0.15%) was found in V_0F_0 (No vermicompost + No NPKS) treatment combination. The highest content of the nutrient in the plant might be due to application of optimum rate of vermicompost and higher doses of NPKS in V_2F_3 treatment.

4.2.3 Potassium content

Statistically significant variation was recorded in potassium concentration in soybean plant after harvest when different doses of vermicompost were added (Table 8). The highest potassium concentration (0.98%) was recorded in V_3 (6 t ha^{-1}), which was closely followed by V_2 (4 t ha^{-1}) and V_1 (2 t ha^{-1}) treatments and the lowest potassium concentration (0.73%) was recorded in the V_0 treatment where no vermicompost was applied.

Application of different doses of chemical fertilizers resulted a significant variation in potassium concentration in soybean plant after harvest (Table 9). Among the different combinations of fertilizer, F_3 (High NPKS) showed the highest potassium concentration (1.16%) in wheat plant. On the other hand, the lowest potassium concentration (0.61%) was recorded with F_0 where no fertilizer was applied.

Combined application of vermicompost and fertilizers at different levels showed significant effect on potassium concentration in soybean plant after harvest (Table 10). The highest potassium concentration (1.3%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPKS). On the other hand, the lowest potassium concentration (0.5%) was found in V_0F_0 (No vermicompost + No NPKS) treatment combination.

4.2.4 Sulphur content

Statistically significant variation was not recorded in sulphur concentration in soybean plant after harvest when the effects of different doses of vermicompost were compared (Table 8). Considering the effect of different doses of vermicompost, the highest sulphur concentration (0.40%) was recorded in V_3 (6 t ha^{-1}), and the lowest sulphur concentration (0.35%) 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 soybean plant after harvest (Table 9). Fertilizer dose, F_3 (high NPKS) yielded highest sulphur concentration (0.41%) in plant which was statistically identical with F_2 treatment and the lowest sulphur concentration (0.33%) was recorded in F_0 treatment where no fertilizer was applied.

Combined effect the different doses of vermicompost and fertilizer on the sulphur concentration in soybean plant did not show statistically significant difference (Table 10). The highest sulphur concentration (0.43%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPKS). On the other hand, the lowest sulphur concentration (0.31%) was found in V_0F_0 (No vermicompost + No NPKS) treatment combination. This might be due to the fact that, the combined effect of both vermicompost and NPKS played positive effect on sulphur concentration in soybean plant up to certain limit.

4.3 Effect of vermicompost and NPKS fertilizers on the nutrient concentrations in soybean seed

4.3. 1 Nitrogen content

Statistically significant variation was not observed in nitrogen concentration in soybean seed after harvest when different doses of vermicompost were applied (Table 11). The effect of different doses of vermicompost revealed that the highest nitrogen concentration (5.86%) was recorded in V_3 (6 t ha^{-1}) and the lowest nitrogen concentration (5.40%) was recorded in the V_0 treatment. It was observed that nitrogen content increased due to higher rate of application of vermicompost which is quite natural.

Table 11. Effect of vermicompost on the NPKS concentrations in soybean seed

Vermicompost	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0	5.40	0.51	2.00	0.38 b
V_1	5.63	0.56	1.99	0.42 ab
V_2	5.64	0.57	2.01	0.43 ab
V_3	5.86	0.58	2.06	0.44 a
Level of Significance	NS	NS	NS	0.05

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

Table 12. Effect of NPKS fertilizers on the NPKS concentrations in soybean seed

NPKS Fertilizer	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
F_0	5.19 c	0.49 b	1.88 c	0.38
F_1	5.43 bc	0.55 ab	1.99 b	0.43
F_2	5.92 ab	0.59 a	2.08 ab	0.43
F_3	5.99 a	0.61 a	2.13 a	0.45
Level of Significance	0.05	0.01	0.01	NS

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 soybean seed after harvest (Table 12). Among the different combinations of fertilizer doses, F_3 (High NPKS) showed the highest seed nitrogen concentration (5.99%) and the lowest nitrogen concentration (5.19%) was recorded in the fertilizer combination F_0 where none of the fertilizers was applied in soybean plant. Probably, higher rates of NPKS application helped to enhance nitrogen content in soybean seed.

Table 13. Combined effect of vermicompost and NPKS fertilizers on the NPKS concentrations in soybean seed

Vermicompost × NPKS Fertilizer	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0F_0	4.94 b	0.41 b	1.83 c	0.32 b
V_0F_1	5.38 ab	0.48 ab	2.00 abc	0.39 ab
V_0F_2	5.61 ab	0.56 a	2.07 abc	0.38 ab
V_0F_3	5.66 ab	0.61 a	2.13 ab	0.41 ab
V_1F_0	5.17 ab	0.48 ab	1.84 c	0.40 ab
V_1F_1	5.42 ab	0.57 a	2.00 abc	0.44 ab
V_1F_2	6.00 ab	0.59 a	2.03 abc	0.41 ab
V_1F_3	5.96 ab	0.59 a	2.10 ab	0.44 ab
V_2F_0	5.15 ab	0.51 ab	1.90 bc	0.42 ab
V_2F_1	5.18 ab	0.58 a	1.93 abc	0.44 ab
V_2F_2	6.10 ab	0.59 a	2.10 ab	0.46 ab
V_2F_3	6.11 ab	0.61 a	2.13 ab	0.41 ab
V_3F_0	5.50 ab	0.55 a	1.93 abc	0.37 ab
V_3F_1	5.74 ab	0.56 a	2.03 abc	0.45 ab
V_3F_2	5.95 ab	0.59 a	2.10 ab	0.49 a
V_3F_3	6.23 a	0.61 a	2.17 a	0.51 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 seed at the harvest of the soybean crop (Table 13). The maximum nitrogen concentration (6.23%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPKS). On the other hand, the minimum nitrogen concentration (4.94%) was found in V_0F_0 (No vermicompost +No NPKS) treatment combination. Both the highest rate of application of vermicompost and NPKS showed the highest nitrogen content in soybean seed.

4.3.2 Phosphorous content

Significant variation was not recorded with phosphorous concentration in soybean seed after harvest when vermicompost was applied at different doses (Table 11). Considering the effect of different doses of vermicompost, the highest phosphorous concentration (0.58%) was recorded in V_3 (6 t ha^{-1}) and the lowest phosphorous concentration (0.51%) was found in the V_0 treatment where no vermicompost was applied. It was observed that phosphorous content showed increase due to increasing rates of application of vermicompost.

Different doses of chemical fertilizers resulted a significant variation in phosphorous concentration in soybean seed at the harvest (Table 12). Among the different combinations of fertilizer doses, F_3 (High NPKS) showed the highest phosphorous concentration (0.61%) in seed, which was statically identical with F_2 (Medium NPKS) and the lowest phosphorous concentration (0.49%) was recorded in the F_0 treatment. It was observed that phosphorous content showed an increase due to higher rate of application of NPKS.

The effect of different doses of vermicompost and fertilizer at various combinations on the phosphorous concentration in soybean seed was statistically significant (Table 13). The highest phosphorous concentration (0.61%) was recorded in the treatment combination of V_0F_3 (No vermicompost + High NPKS) and V_3F_3 (High vermicompost + High NPKS). On the other hand, the lowest phosphorous concentration (0.41%) was found in V_0F_0 (No vermicompost + No NPKS) treatment combination. It is observed that all the treatment combination showed statistically similar values of P concentration except the V_0F_0 treatment.

4.3.3 Potassium content

Statistically significant variation was not recorded with potassium concentration in soybean seed as well after harvest when different doses of vermicompost were added (Table 11). When different doses of vermicompost were considered, the highest potassium concentration (2.06%) was recorded in V_3 (6 t ha^{-1}) and the lowest potassium concentration (1.99%) was recorded in the V_1 treatment.

Application of different doses of chemical fertilizers resulted a significant variation in potassium concentration in soybean seed after harvest (Table 12). Among the different combinations of fertilizer, F_3 (High NPKS) showed the highest potassium concentration (2.13%). On the other hand, the lowest potassium concentration (1.88%) was recorded with F_0 where no fertilizer was applied. Probably more NPKS application helped to accumulate more potassium in soybean seed.

Combined application of vermicompost and fertilizes at different levels showed significant effect on potassium concentration in soybean seed after harvest (Table 13). The highest potassium concentration (2.17%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPKS). On the other hand, the lowest potassium concentration (1.83%) was found in V_0F_0 (No vermicompost + No NPKS) treatment combination.

4. 3.4 Sulphur content

Statistically significant variation was recorded in sulphur concentration in soybean seed after harvest when the effects of different doses of vermicompost were compared

(Table 11). Considering the effect of different doses of vermicompost, the highest sulphur concentration (0.44%) was recorded in V_3 (6 t ha^{-1}), and the lowest sulphur concentration (0.38%) was recorded in the V_0 treatment where no vermicompost was applied.

Significant variation was not observed with the application of different doses of chemical fertilizers with respect of sulphur concentration in soybean seed (Table 12). Fertilizer dose, F_3 (High NPKS) yielded maximum sulphur concentration (0.45%) in seed and the minimum sulphur concentration (0.38%) was recorded in F_0 treatment where no fertilizer was applied.

Combined effect the different doses of vermicompost and fertilizer on the sulphur concentration in soybean seed showed statistically significant difference (Table 13). The highest sulphur concentration (0.51%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPKS) which was statistically identical with V_3F_2 (High vermicompost + Medium NPKS). On the other hand, the lowest sulphur concentration (0.32%) was found in V_0F_0 (No vermicompost + No NPKS) treatment combination. This might be due to the fact that, the combined effect of both vermicompost and NPKS played positive effect on sulphur concentration in soybean seed up to certain limit.

4.4 Effect of vermicompost and NPKS fertilizers on the protein and oil contents of soybean

4.4.1 Protein content

Statistically significant variation was not observed in protein content in soybean seed after harvest when different doses of vermicompost were applied (Table14). The effect of different doses of vermicompost revealed that the highest protein content (36.74%) was recorded in V_3 (6 t ha^{-1}) and the lowest protein content (34.41%) was recorded in the V_0 treatment. It was observed that protein content showed an increase due to higher rate of application of vermicompost.

Table 14. Effect of vermicompost on the protein and oil contents in soybean seed

Vermicompost	Content (%)	
	Protein	Oil
V_0	34.41	19.35 c
V_1	35.21	19.21 d
V_2	35.24	19.58 b
V_3	36.74	19.74 a
Level of Significance	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

Application of different doses of chemical fertilizers showed a statistically significant variation in respect of protein content in soybean seed after harvest (Table 15). Among the different combinations of fertilizer doses, F_3 (High NPKS) showed the highest protein content (37.43%) which was statistically identical with F_2 (Medium NPKS) and the lowest protein content (32.42%) was recorded in the fertilizer combination F_0 where none of the fertilizers was applied. Probably, more NPKS application helped to enhance protein content in soybean seed.

Table15. Effect of NPKS fertilizers on the protein and oil contents in soybean seed

Fertilizers	Content (%)	
	Protein	Oil
F_0	32.42 b	19.42 b
F_1	34.62 ab	19.52 a
F_2	37.13 a	19.51 a
F_3	37.43 a	19.42 b
Level of Significance	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 protein content in seed at the harvest of the soybean crop (Table16). The highest protein content (38.92%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPKS). On the other hand, the lowest protein content (30.85%) was found in V_0F_0 (No vermicompost +No NPKS) treatment combination. The highest rate of application of vermicompost with NPKS showed the highest protein content in soybean seed.

4.4.3 Oil content

Statistically significant variation was observed in oil content in soybean seed after harvest when different doses of vermicompost were applied (Table 14). The effect of different doses of vermicompost revealed that the highest oil content (19.74%) was recorded in V_3 (6 t ha^{-1}) and the lowest oil content (19.21%) was recorded in the V_1 (2 t ha^{-1}) treatment. It was observed that oil content increased due to higher rate of application of vermicompost.

Table 16. Combined effect of vermicompost and NPKS fertilizers on the protein and oil contents of soybean.

Vermicompost × NPKS Fertilizer	Concentration (%)	
	Protein	Oil
V_0F_0	30.85 b	18.40 j
V_0F_1	35.73 ab	19.47 g
V_0F_2	35.69 ab	19.73 h
V_0F_3	35.37 ab	18.81 i
V_1F_0	32.23 ab	19.38 h
V_1F_1	33.88 ab	19.33 h
V_1F_2	37.50 ab	19.75 d
V_1F_3	37.25 ab	19.36 h
V_2F_0	32.21 ab	19.50 g
V_2F_1	32.40 ab	19.82 c
V_2F_2	38.15 ab	19.36 h
V_2F_3	38.19 ab	19.63 e
V_3F_0	34.38 ab	20.03 a
V_3F_1	36.48 ab	19.47 g
V_3F_2	37.18 ab	19.57 f
V_3F_3	38.92 a	19.88 b
Level of Significance	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 oil content in soybean seed after harvest (Table 15). Among the different combinations of fertilizer doses, F_1 (Low NPKS) showed the highest oil content (19.52%) which was statistically identical with F_2 (Medium NPKS) and the lowest oil content (19.42%) was recorded in the fertilizer combination, F_0 where none of the fertilizers was applied which was statistically identical with F_3 (High NPKS) in soybean plant. This may be due to the fact that high NPKS application helped to decrease oil content in soybean seed. Miladinovic *et al.* (2004) and Kane *et al.* (1997) observed the similar trend.

The effect of combined applications of different doses of vermicompost and fertilizer resulted significant variations in oil content in seed at the harvest of the soybean crop (Table 16). The highest oil content (20.03%) was recorded in the treatment combination of V_3F_0 (High vermicompost + No NPKS). On the other hand, the lowest oil content (18.40%) was found in V_0F_0 (No vermicompost +No NPKS) treatment combination. The application of highest rate of vermicompost with no NPKS showed the highest oil content in soybean seed under study.

4.5 Effect of vermicompost and NPKS fertilizers on the uptake of nutrients by soybean plant

4.5.1 Nitrogen uptake

The effect of vermicompost on nitrogen uptake by soybean plant showed significant variation (Figure 3 and Appendix Table 1). Nitrogen uptake was maximum in the treatment V_3 (High vermicompost) having 21.58 kg $ha^{-1.}$ The minimum nitrogen uptake by soybean (12.90 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 NPKS significantly influenced nitrogen uptake by soybean plants (Figure 4 and Appendix Table 2). Nitrogen uptake ranged from 9.70 to 23.08 kg ha^{-1} with the highest in the treatment F_3 (High NPKS) and the lowest in control (No NPKS).

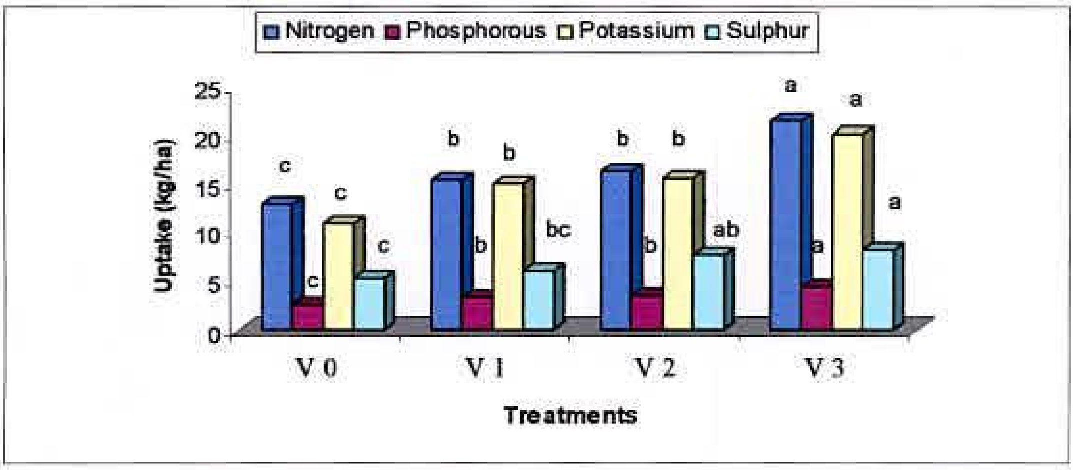


Figure 3. Effect of vermicompost on NPKS uptake by soybean plant

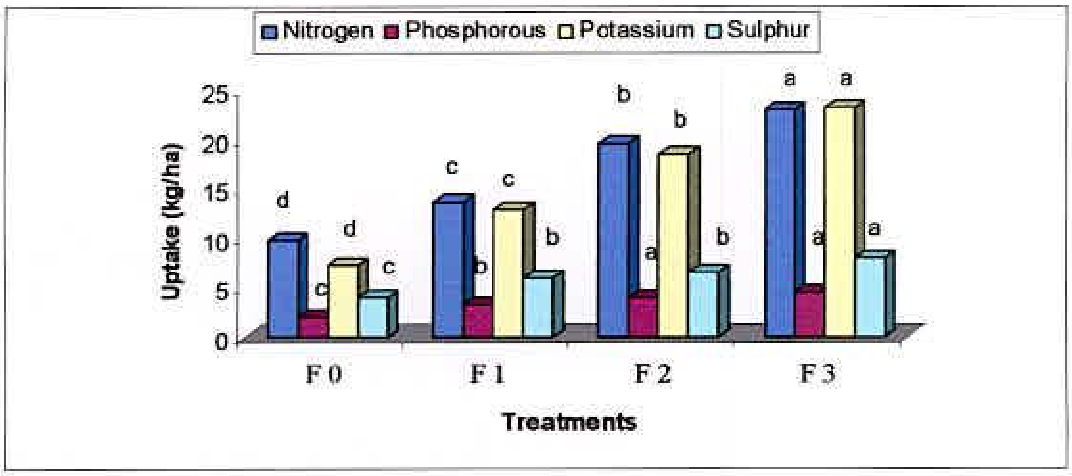


Figure 4. Effect of fertilizer on NPKS uptake by soybean plant

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 (31.39 kg ha^{-1}) was recorded in the treatment combination of $V_3 F_3$ (High vermicompost + High NPKS) .On the other hand , the lowest nitrogen uptake (7.14 kg ha^{-1}) was recorded in the control treatment (V_0F_0), where no vermicompost and no NPKS was applied.

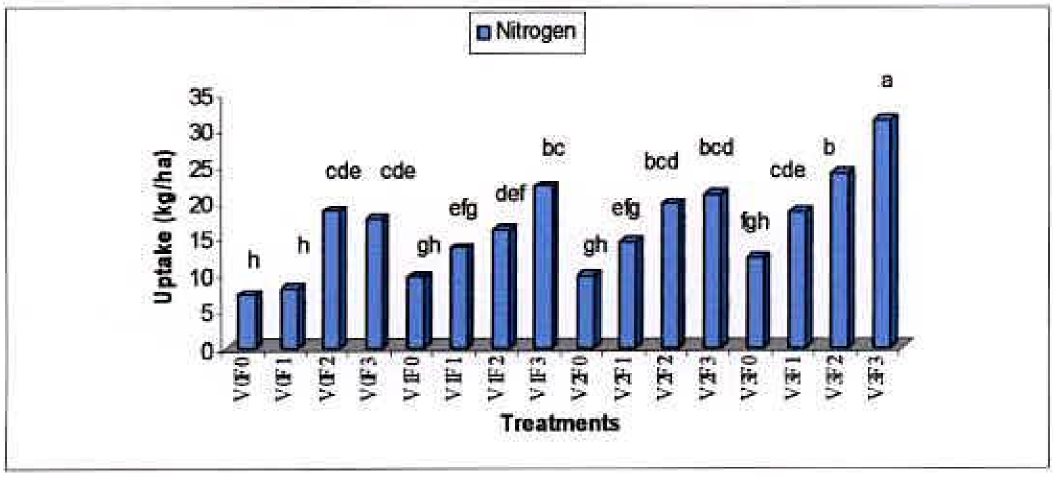


Figure 5. Combined effect of vermicompost and NPKS fertilizers on nitrogen uptake by soybean plant

4.5.2 Phosphorus uptake

Phosphorus uptake by soybean was significantly influenced due to the addition of vermicompost (Figure 3 and Appendix Table 1). Phosphorus uptake ranged from 2.55 to 4.39 kg ha^{-1} with the maximum in the treatment, V_3 (High vermicompost) and the minimum in control (V_0). Konov *et al.* (1985) also found similar results.

Phosphorus uptake by soybean plant was significantly influenced due to the application of NPKS (Figure 4 and Appendix Table 2). Phosphorus uptake by plant ranged from 1.94 to 4.57 kg ha^{-1}. It was maximum with treatment, F_3 (High NPKS) and minimum with F_0 treatment where no NPKS was applied.

Combined effect of different doses of vermicompost and fertilizers on phosphorus uptake by soybean showed statistically significant variation (Figure 6 and Appendix Table 3). The highest P uptake (5.4 kg ha^{-1}) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPKS) and the lowest uptake (1.37 kg ha^{-1}) was recorded in the V_0F_0 (No vermicompost + No NPKS) treatment.

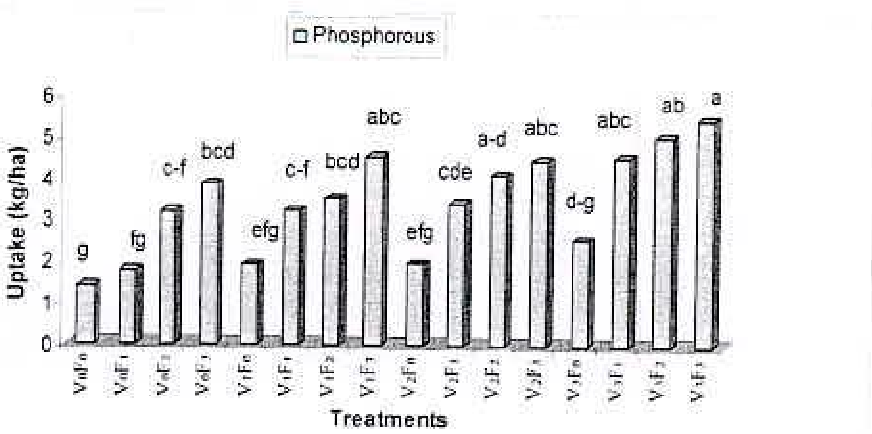


Figure 6. Combined effect of vermicompost and NPKS fertilizers on phosphorous uptake by soybean plant

4.5.3 Potassium uptake

The amount of potassium taken up by soybean plant with different doses of vermicompost resulted significantly higher values over the control(Figure 3 and Appendix Table 1). Potassium uptake by soybean plant was maximum (20.17 kg ha^{-1}) in the treatment V_3 (High vermicompost) and minimum (10.86 kg ha^{-1}) in the control. It is evident that vermicompost possibly supplied more potassium and as a consequence its up take was higher with the higher doses.

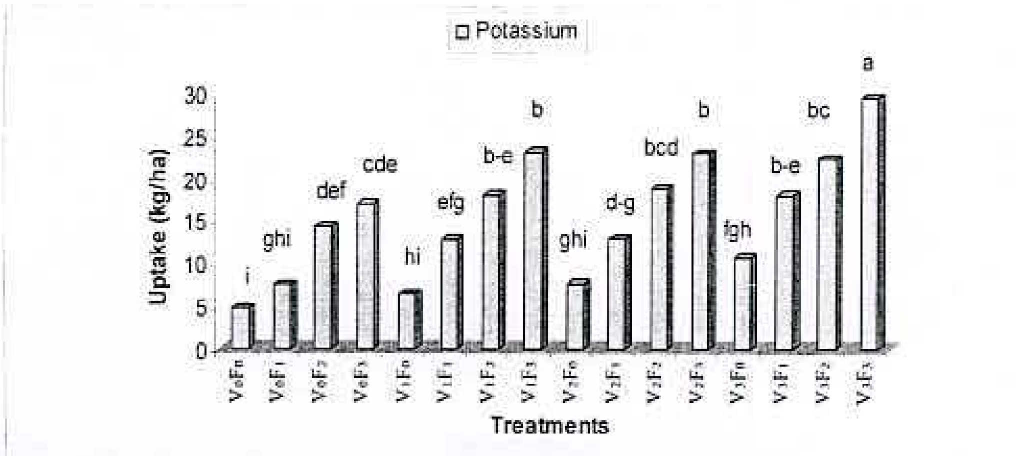


Figure 7. Combined effect of vermicompost and NPKS fertilizers on ptassium uptake by soybean plant

Application of NPKS significantly influenced potassium uptake by soybean. Potassium uptake ranged from 7.30 to 23.18 kg ha^{-1} (Figure 4 and Appendix Table 2). The highest potassium uptake (23.18 kg ha^{-1}) was recorded with the treatment, F_3 (High NPKS) and the lowest (7.30 kg ha^{-1}) in control (F_0) treatment.

The effect of combined application of different doses of vermicompost and fertilizers on potassium uptake by soybean showed statistically significant variation (Figure 7 and Appendix Table 3). The highest uptake (29.53 Kg ha^{-1}) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPKS). On the other hand , the lowest uptake (4.66 Kg ha^{-1}) was recorded in the treatment combination of V_0F_0 (No vermicompost + No NPKS). It might be due to the fact that combined application of vermicompost and NPKS showed positive effect on potassium uptake by soybean.

4.5.4 Sulphur uptake

Sulphur uptake by soybean plant was significantly influenced due to the application of vermicompost (Figure 3 and Appendix Table 1). Sulphur uptake ranged from 5.21 to 8.11 kg ha^{-1}. The maximum value was obtained with the treatment, V_3 (High vermicompost) and that of minimum in control (V_0).

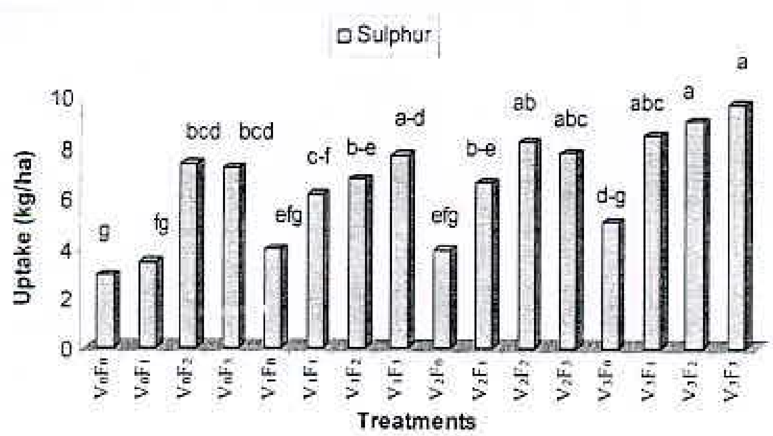


Figure 8. Combined effect of vermicompost and NPKS fertilizers on sulphur uptake by soybean plant

Sulphur uptake by soybean was significantly influenced due to the application of NPKS (Figure 4 and Appendix Table 2) and the maximum value (7.96 Kg ha^{-1}) was found in the treatment, F_3 (high NPKS) the lowest value (3.95 kg ha^{-1}) was recorded in F_0 treatment where no NPKS was applied.

Combined applications of different doses of vermicompost and fertilizers showed significant variation on sulphur uptake by soybean (Figure 8 and Appendix Table 3). The highest uptake (9.72 kg ha^{-1}) was recorded in the treatment combination of V_3F_3(High vermicompost + High NPKS). On the other hand, the lowest uptake (2.89 kg ha^{-1}) was recorded in the treatment combination, V_0F_0 where no vermicompost and no fertilizer were added.

4.6 Effect of vermicompost and NPKS fertilizers on the uptake of nutrients by soybean seed

4.6.1 Nitrogen uptake

The effect of vermicompost on nitrogen uptake by soybean seed showed significant variations (Figure 9 and Appendix Table 4). Nitrogen uptake was maximum in the treatment, V_3 (High vermicompost) having 113.3 kg ha^{-1}. The minimum nitrogen uptake by soybean (83.08 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 grain.

Application of NPKS significantly influenced nitrogen uptake by soybean seed (Figure 10 and Appendix Table 5). Nitrogen uptake ranged from 68.52 to 117.5 kg ha^{-1}

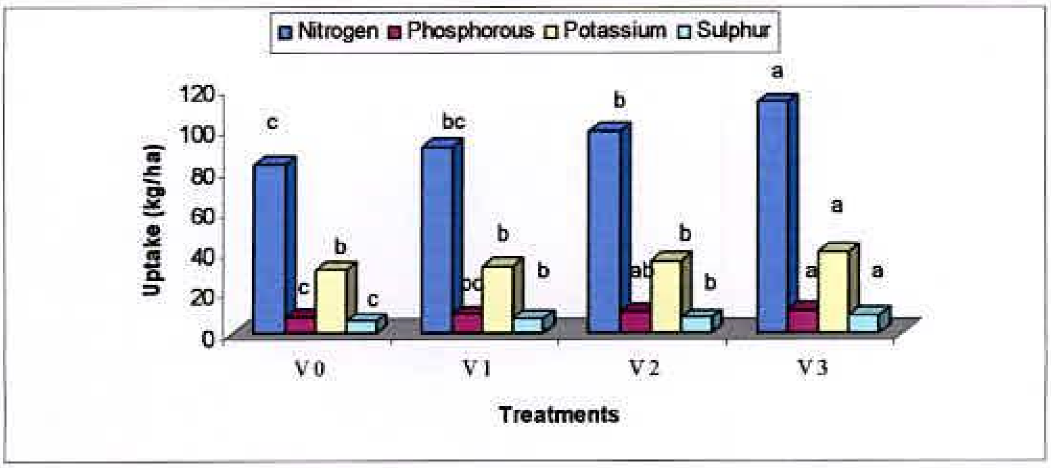


Figure 9. Effect of vermicompost on nitrogen, phosphorous, ptassium and sulphur uptake by soybean seed

with highest in the treatment, F_2 (Medium NPKS) which was statistically identical with F_3 (High NPKS) and the lowest in control (No NPKS).

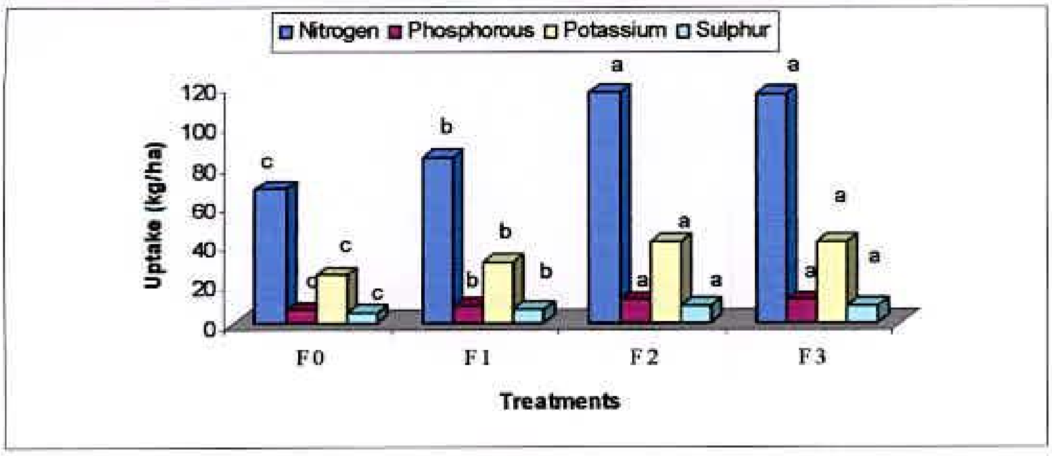


Figure 10. Effect of NPKS fertilizers on nitrogen, phosphorous, ptassium and sulphur uptake by soybean seed

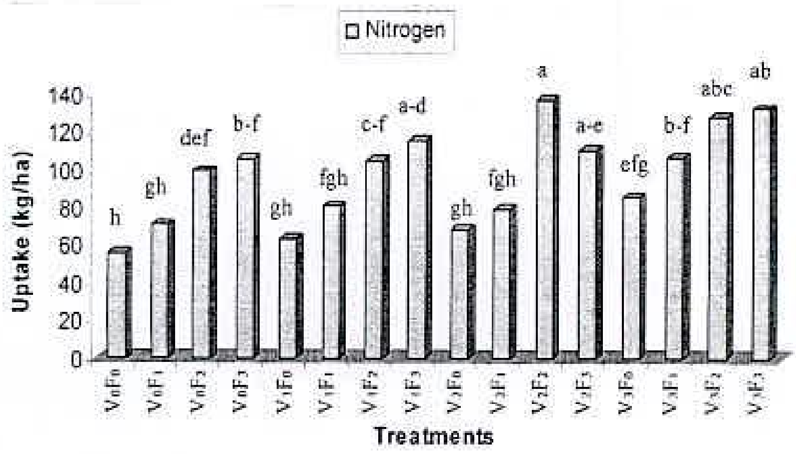


Figure 11. Combined effect of vermicompost and NPKS fertilizers on nitrogen uptake by soybean seed

The combined effect of different doses of vermicompost and fertilizers on nitrogen uptake showed statistically significant variation (Figure11.and Appendix Table 6). The highest uptake (137.2 kg ha^{-1}) was recorded in the treatment combination of V_2 F_2 (Medium vermicompost + Medium NPKS). On the other hand, the lowest nitrogen uptake (56.01 kg ha^{-1}) was recorded in the control treatment (V_0F_0), where no vermicompost and no NPKS were applied.

4.6.2 Phosphorus uptake

Phosphorus uptake by soybean seed was significantly influenced due to the addition of vermicompost (Figure 9 and Appendix Table 4). Phosphorus uptake ranged from 8.10 to 11.16 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.

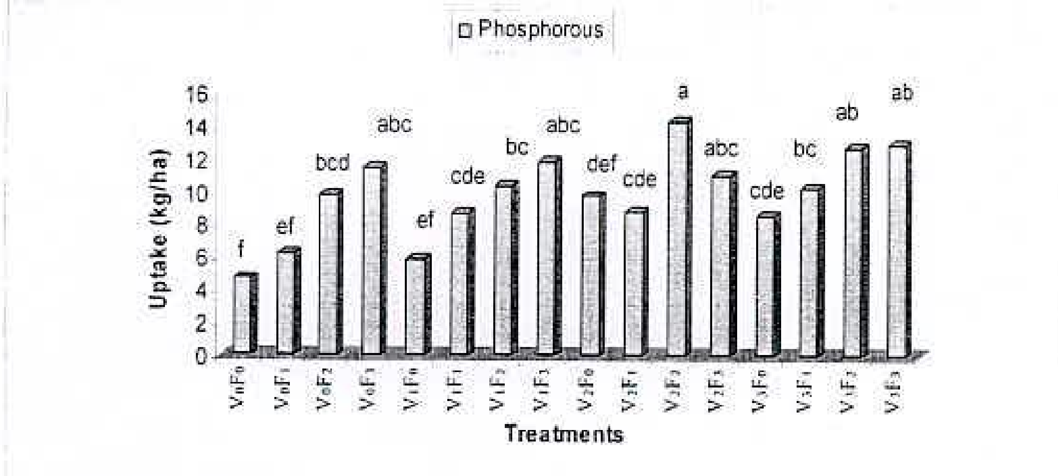


Figure 12. Combined effect of vermicompost and NPKS fertilizers on phosphorous uptake by soybean seed

Phosphorus uptake by soybean seed was significantly influenced due to the application of NPKS fertilizer (Figure 10 and Appendix Table 5). Phosphorus uptake by seed ranged from 6.50 to 11.88 kg ha^{-1}. It was maximum with treatment, F_3 (High NPKS) and minimum with F_0 treatment where no NPKS was applied.

Combined effect of different doses of vermicompost and fertilizers on phosphorus uptake by soybean seed showed statistically significant variation (Figure 12 and Appendix Table 6). The highest uptake (14.34 kg ha^{-1}) was recorded in the treatment combination of V_2F_2 (Medium vermicompost + Medium NPKS) and the lowest uptake (4.74 kg ha^{-1}) was recorded in the treatment combination, V_0F_0 (No vermicompost + No NPKS).

4.6.3 Potassium uptake

The amount of potassium taken up by soybean seed with different doses of vermicompost resulted significantly higher value over the control (Figure 9 and Appendix Table 4). Potassium uptake by soybean seed was maximum (39.98 kg ha^{-1}) in the treatment, V_3 (High vermicompost) and minimum (30.85 kg ha^{-1}) in the control. It is evident that vermicompost supplied more potassium and as a consequence its uptake was higher with the higher doses of the same.

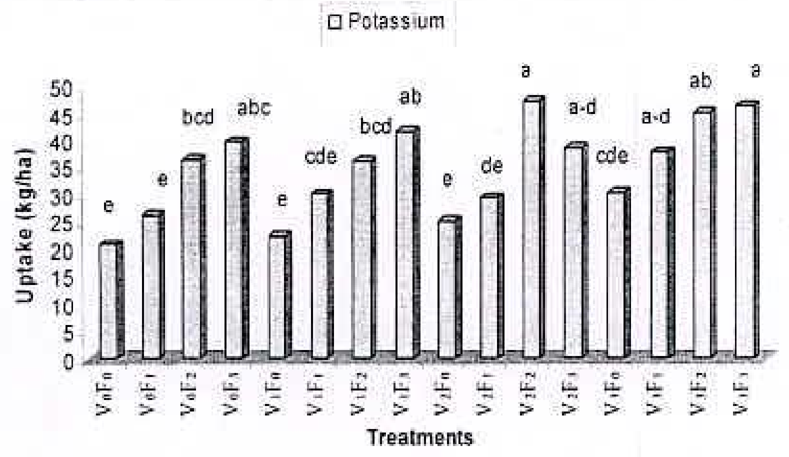


Figure 13. Combined effect of vermicompost and NPKS fertilizers on potassium uptake by soybean seed

Application of NPKS significantly influenced potassium uptake by soybean seed. Potassium uptake ranged from 24.69 to 41.70 kg ha^{-1} (Figure 10 and Appendix Table 5). The highest potassium uptake (41.70 kg ha^{-1}) was recorded with the treatment, F_3 (High NPKS) which was statistically identical with F_2 (Medium NPKS) and the lowest (24.69 kg ha^{-1}) in control (F_0) treatment.

The effect of combined application of different doses of vermicompost and fertilizers on potassium uptake by soybean seed showed statistically significant variation (Figure 13 and Appendix Table 6). The highest uptake (47.46 Kg ha^{-1}) was recorded in the treatment combination of V_2F_2 (Medium vermicompost + Medium NPKS), which was statistically identical with V_3F_3 (High vermicompost + High NPKS). On the other hand, the lowest uptake (20.80 Kg ha^{-1}) was recorded in the treatment combination of V_0F_0 (No vermicompost + No NPKS). It might be due to the fact that vermicompost and NPKS combined application showed positive effect on potassium uptake by soybean.

4.6.4 Sulphur uptake

Sulphur uptake by soybean seed was significantly influenced due to the application of vermicompost (Figure 9 and Appendix Table 4). Sulphur uptake ranged from 5.77 to 8.65 kg ha^{-1}. The maximum value (8.65 kg ha^{-1}) was obtained with the treatment, V_3 (High vermicompost) and minimum (5.77 kg ha^{-1}) in control (V_0).

Sulphur uptake by soybean was significantly influenced due to the application of NPKS (Figure 10 and Appendix Table 5) and the maximum value (8.78 Kg ha^{-1}) was found in the treatment F_3 (High NPKS), which was statistically identical with F_2 (Medium NPKS) and the lowest value (5.09 kg ha^{-1}) was recorded in F_0 treatment where no NPKS was applied.

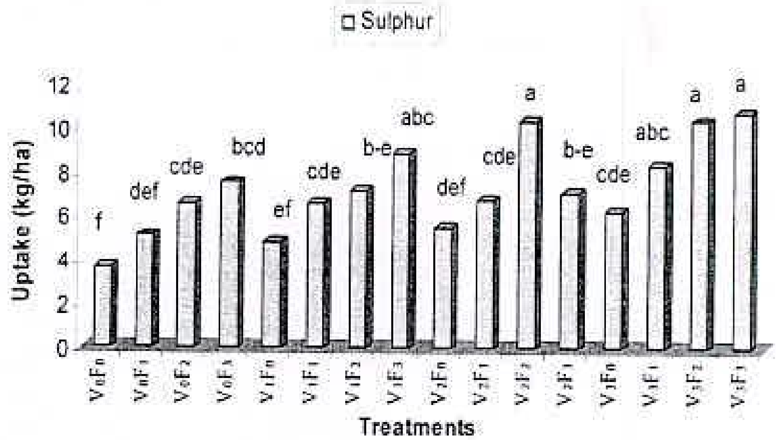


Figure 14. Combined effect of vermicompost and NPKS fertilizers on sulphur uptake by soybean seed

Combined applications of different doses of vermicompost and fertilizers showed significant variation on sulphur uptake by soybean seed (Figure 14 and Appendix Table 6). The highest uptake (10.86 kg ha^{-1}) was recorded in the treatment combination of V_3F_3 (High vermicompost + high NPKS), which was statistically identical with V_3F_2 (high vermicompost + Medium NPKS) and V_2F_2 (Medium vermicompost + Medium NPKS) treatments. On the other hand, the lowest uptake (3.67 kg ha^{-1}) was recorded in the treatment combination where no vermicompost and no fertilizer were added (V_0F_0).

4.7 Effect of vermicompost and NPKS fertilizers application on the nutrient status of soil after harvest

4.7.1 Organic Matter (OM) content of soil

A significant variation was observed on the content of OM after harvest where the vermicompost was incorporated in soil (Table 17). Among the different doses of vermicompost, V_3 (6 t ha^{-1}) treatment showed the highest OM content (1.04%) after the harvest of crop. On the other hand, the lowest OM content (0.83%) was observed in the V_0 treatment where no vermicompost was applied and it was closely followed (0.88% & 0.92%) by the V_1 (2 t ha^{-1}) and V_2 (4 t ha^{-1}) treatments, respectively. 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 17. Effect of vermicompost on the Organic Matter (OM), total N, available P, exchangeable K, available S and Zn contents in the soil after soybean harvest

Vermicompost	OM (%)	Total N (%)	Available P (%)	Available K (%)	Available S (%)	Available Zn (%)
V_0	0.83 b	0.078 d	0.0018 b	0.0013 d	0.0013 c	0.00019 c
V_1	0.88 b	0.081 c	0.0018 b	0.0015 c	0.0014 bc	0.00022 bc
V_2	0.92 b	0.085 b	0.0020 ab	0.0018 b	0.0015 ab	0.00024 b
V_3	1.04 a	0.088 a	0.0022 a	0.0021 a	0.0017 a	0.00028 a
Level of Significance	0.01	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 18). The contents of OM were almost the same (0.89 to 0.94%) 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 19). The lower OM contents of the soil (0.81 to0.84%) after harvest were recorded in the treatment combinations where vermicompost was not applied. On the other hand, the higher OM contents (1.02 to1.05%) 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 18. Effect of NPKS fertilizers on the Organic Matter (OM), total N, available P, exchangeable K, available S and available Zn content in the soil after soybean harvest

NPKS Fertilizer	OM (%)	Total N (%)	Available P (%)	Available K(%)	Available S (%)	Available Zn (%)
F_0	0.89	0.079 c	0.0018 c	0.0014 c	0.0013 c	0.00019 c
F_1	0.91	0.081 c	0.0019 bc	0.0015 c	0.0013 c	0.00021 c
F_2	0.93	0.084 b	0.0020 ab	0.0018 b	0.0015 b	0.00024 b
F_3	0.94	0.087 a	0.0022 a	0.0021 a	0.0017 a	0.00028 a
Level of Significance	NS	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

4.7.2 Nitrogen content of soil

Significant variation was recorded on the nitrogen content of soybean field after harvest of the crop when the field was treated with different doses of vermicompost (Table 17). Among the different doses of vermicompost, V_3 (6 t ha^{-1}) treatment showed the highest N content (0.088%) and the lowest N content (0.0.078%) 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 thus conserved more nitrogen in soil. Bangar *et al.* (1990) found that compost enriched the N content of soil.

A significant variation was recorded in the N content of soil after harvest of the soybean crop when different fertilizers in different doses were applied (Table 18). In considering the different combinations of fertilizer doses, F_3 (High NPKS) showed the highest N content (0.087%) and the lowest N content (0.079%) was observed in the F_0 treatment where no fertilizer was applied which was statistically identical with F_1 (Low NPKS) treatment.

Combined application of different doses of vermicompost and fertilizer showed no significant effect on the N content of soil after harvest (Table 19). The highest N content of crop-harvested soil (0.093%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High NPKS). On the other hand, the lowest N content (0.074%) was recorded in V_0F_0 (No vermicompost + No NPKS). Tolanur and Badanur (2003) reported that soil available nutrients like N, P and K increased significantly with the application of various organic sources of nutrients in combination with fertilizer.

Table 19. Combined effect of vermicompost and NPKS fertilizers on the Organic Matter (OM), total N, available P, exchangeable K, available S and Zn contents in the soil after soybean harvest

Vermicompost × NPKS Fertilizer	OM (%)	Total N (%)	Available P (%)	Available K (%)	Available S (%)	Available Zn (%)
V_0F_0	0.81	0.074	0.0017 c	0.0010	0.0011 d	0.00017 c
V_0F_1	0.82	0.079	0.0018 bc	0.0012	0.0013 cd	0.00018 bc
V_0F_2	0.83	0.076	0.0019 bc	0.0014	0.0013 cd	0.00020 bc
V_0F_3	0.84	0.083	0.0020abc	0.0017	0.0015 bcd	0.00022 bc
V_1F_0	0.87	0.077	0.0017 c	0.0014	0.0011 d	0.00018 bc
V_1F_1	0.87	0.078	0.0018 c	0.0015	0.0013 cd	0.00022 bc
V_1F_2	0.88	0.082	0.0018 bc	0.0016	0.0015 bcd	0.00023 bc
V_1F_3	0.91	0.088	0.0020abc	0.0016	0.0017 abc	0.00025 b
V_2F_0	0.88	0.080	0.0017 c	0.0015	0.0015 bcd	0.00021 bc
V_2F_1	0.91	0.082	0.0018 c	0.0018	0.0012 cd	0.00021 bc
V_2F_2	0.95	0.090	0.0021abc	0.0019	0.0015 bcd	0.00023 bc
V_2F_3	0.96	0.086	0.0024 a	0.0022	0.0018 ab	0.00026 a
V_3F_0	1.02	0.083	0.0020abc	0.0016	0.0014 bcd	0.00021 bc
V_3F_1	1.04	0.085	0.0021abc	0.0018	0.0015 bcd	0.00022 bc
V_3F_2	1.04	0.089	0.0023 ab	0.0022	0.0017 ab	0.00026 a
V_3F_3	1.05	0.093	0.0024 a	0.0025	0.0020 a	0.00028 a
Level of Significance	NS	NS	0.01	NS	0.01	0.05

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

4.7.3 Phosphorous content of soil

A significant variation was observed in the P content of soil in the soybean field after harvest where the field was manured with different doses of vermicompost (Table17). Among the different doses of vermicompost, V_3 (6 t ha^{-1} vermicompost) treatment showed the highest P content (0.0022%) 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 (2 t ha^{-1}) treatment (Table 17). Guan (1989) reported that the application of compost increased the availability of P in soil in comparison with the control treatment.

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 18). Among the different combinations of fertilizer doses, F_3 (High NPKS) showed the highest P content (0.0022%) and the lowest P content (0.0018%) was observed in the F_0 treatment where no fertilizer was applied.

Combined effect of different doses of vermicompost and fertilizer produced significant variarion in respect of P content of soil after the harvest of soybean crop. (Table 19). The lowest P content of crop harvested soil (0.0017%) was recorded in the treatment combination of V_0F_0 (No vermicompost + No NPKS). On the other hand, the highest P content (0.0024%) was recorded in V_2F_3 (Medium vermicompost + High NPKS) and V_3F_3 (High vermicompost + High NPKS) treatments.

4.7.4 Potassium content of soil

Significant variation was recorded in the K content of soil in the soybean field after harvest of the crop where different doses of vermicompost were applied (Table 17). Application of vermicompost at the rate of 6 t ha^{-1} (V_3) showed the highest K content (0.0021%) and the lowest K content (0.0013%) 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 18). Fertilizer dose F_3 (High NPKS) showed the highest K content (0.0021%) and the lowest K content (0.0014%) was recorded in the F_0 treatment (No NPKS) and that was statistically identical with F_1 treatment (Low NPKS).

The effect of combined application of vermicompost and fertilizer showed no significant differences in respect of K content of soil after harvest (Table 19). However, the lowest K content of crop-harvested soil (0.0010%) was recorded in the treatment combination of V_0F_0 (No vermicompost+ No NPKS) and the highest K content (0.0025%) was recorded with V_3F_3 (High vermicompost + High NPKS) treatment combination.

4.7.5 Sulphur content of soil

Significant variation was recorded in the S content of soil after soybean harvest where the plots were incorporated with different doses of vermicompost (Table 17). The highest dose of vermicompost, V_3 (6 t ha^{-1}) resulted the highest S content (0.0017%) after the harvest of crop and the lowest S content (0.0013%) was observed in the V_0 treatment where no vermicompost was applied.

Significant variation in the S content of soil after harvest was obtained when different combinations of fertilizers at different doses were applied (Table 18). Fertilizer dose, F_3 (High NPKS) showed the highest S content (0.0017%) and the lowest S content

(0.0013%) was observed in the F_0 treatment where no fertilizer was applied and that was closely followed by the treatment, F_1 (Low NPKS).

The effect of combined application of different doses of vermicompost and fertilizer showed significant differences in respect of S content of soil after soybean harvest (Table 19). However, the lowest S content of crop-harvested soil (0.0011%) was recorded in the treatment combination of V_0F_0 (No vermicompost + No NPKS) and the highest S content (0.0020%) was recorded in V_3F_3 (High vermicompost + High NPKS) treatment combinations. This might be due to the higher rate of application of vermicompost.

4.7.6 Zinc content of soil

Significant variation was recorded in the Zn content of soil after soybean harvest where the soils were incorporated with different doses of vermicompost (Table 17). The highest dose of vermicompost, V_3 (6 t ha^{-1}) resulted the highest Zn content (0.00028%) in soil after the harvest of crop and the lowest Zn content (0.00019%) was observed in the V_0 treatment where no vermicompost was applied.

Significant variation in the Zn content of soil after harvest was obtained when different combinations of fertilizers at different doses were applied (Table 18). Fertilizer dose, F_3 (High NPKS) showed the highest Zn content (0.00028%) and the lowest Zn content (0.00019%) was observed in the F_0 treatment where no fertilizer was applied and that was closely followed by the treatment, F_1 (Low NPKS).

The effect of combined application of different doses of vermicompost and fertilizer showed significant differences in respect of Zn content of soil after soybean harvest (Table 19). The lowest Zn content of crop-harvested soil (0.00017%) was recorded in the treatment combination of V_0F_0 (No vermicompost + No NPKS) and the highest Zn content (0.00028%) was recorded in V_3F_3 (High vermicompost + High NPKS) treatment combination which was statistically identical with V_3F_2 (High vermicompost + Medium NPKS) and V_2F_3 (Medium vermicompost + High NPKS) treatment combinations. This might be due to application of higher rate of vermicompost and fertilizer.

Chapter 5

Summary and conclusion

SUMMARY AND CONCLUSION

A field 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 2005-2006 to study the effect of integrated use of inorganic fertilizers and vermicompost on the nutrient concentration, uptake, yield and oil content of soybean. The soil was clay loam in texture having pH 6.3, organic matter 0.80%. 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 NPKS), V_0F_1 (No vermicompost + Low NPKS), V_0F_2 (No vermicompost + Medium NPKS), V_0F_3 (No vermicompost + High NPKS), V_1F_0 (Low vermicompost + No NPKS), V_1F_1 (Low vermicompost + Low NPKS), V_1F_2 (Low vermicompost + Medium NPKS), V_1F_3 (Low vermicompost + High NPKS), V_2F_0 (Medium vermicompost + No NPKS), V_2F_1 (Medium vermicompost + Low NPKS), V_2F_2 (Medium vermicompost + Medium NPKS), V_2F_3 (Medium vermicompost + High NPKS), V_3F_0 (High vermicompost + No NPKS), V_3F_1 (High vermicompost + Low NPKS), V_3F_2 (High vermicompost + Medium NPKS) and V_3F_3 (High vermicompost + High NPKS). Nitrogen from urea, P_2O_5 from TSP and K_2O from Muriate of potash (MP) were used. Half of the urea and the whole amount of other chemical fertilizers were used as a basal dose and vermicompost was applied in line during sowing and rest of the urea was top dressed after irrigation (35 days of growth). Soybean seeds cv. Sohag were sown on 15th December, 2005 and the crop was harvested on 7th April 2006. Intercultural operations were done when required. The data were collected plot wise for plant height, number of leaves per plant, number of primary branches per plant, number of pods per plant, number of seeds per plant, weight of 1000 seeds, seed and straw yields. The post harvest soil samples were analyzed for organic matter, N, P, K, S and Zn contents. All the data were statistically analyzed following F-test and the mean comparison was made by DMRT at 5% level. The results of the experiment are stated below.

Grain yield of soybean responded significantly to the vermicompost and NPKS fertilizer treatments. The highest seed yield of 2.25 t ha^{-1} was obtained in V_2F_2 (Medium vermicompost + Medium NPKS) treatment. The lowest seed yield (1.33 t ha^{-1}) was observed in the control viz.V_0F_0, which received neither vermicompost nor fertilizer. The results revealed that when vermicompost was applied in combination with NPKS fertilizers, the effect showed better performance on yield rather than applying vermicompost or NPKS fertilizers alone. The highest straw yield (2.26 t ha^{-1}) was recorded in V_3F_3 (High vermicompost + High NPKS) treatment and the lowest (0.94 t ha^{-1}) in V_0F_0 control (No vermicompost + No NPKS).

The N, P, K and S contents and uptake of these nutrients by soybean plant were influenced significantly by the application of vermicompost and chemical fertilizers. The highest N, P, K and S content in straw (1.4%, 0.24%, 1.3% and 0.43% at after harvest, respectively) were recorded in V_3F_3 (High vermicompost + High NPKS) treatment. The lowest N, P, K and S content (0.76%, 0.15%, 0.5% and 0.31%, respectively) were obtained with V_0F_0 treatment.

The highest uptake of 31.39, 5.46, 29.53 and 9.72 kg ha^{-1} and the lowest uptake 7.14, 1.37, 4.66 and 2.89 kg ha^{-1} of N, P, K and S, respectively by soybean plant at harvest stage were found in V_3F_3 (High vermicompost + High NPKS) and in V_0F_0 control (No vermicompost + No NPKS) treatments.

The N, P, K and S contents and uptake of these nutrients by soybean seed were influenced significantly by the application of vermicompost and chemical fertilizers. The highest N, K and S contents in seed (6.23%, 2.17% and 0.51%, respectively) were recorded in V_3F_3 (High vermicompost + High NPKS) treatment and the highest P content in seed (0.61%) was recorded in V_0F_3, V_2F_3 and V_3F_3 treatment combinations. The lowest N, P, K and S contents in seed (4.94%, 0.41%, 1.83% and 0.32%, respectively) were obtained with V_0F_0 treatment.

The highest uptake of 137.2, 14.34, 47.46 and 10.86 kg ha^{-1} and the lowest uptake 56.01, 4.74, 20.80 and 3.67 kg ha^{-1} of N, P, K and S, respectively by soybean seed were found in V_2F_2 (Medium vermicompost + Medium NPKS) except S (V_3F_3 treatment). The lowest value was obtained with V_0F_0 control (No vermicompost + No NPKS) treatments in every case.

Oil content in soybean seed was influenced significantly by the application of vermicompost and chemical fertilizers. The highest oil content in seed (20.03%) was recorded in V_3F_0 (High vermicompost + No NPKS) and the lowest oil content (18.40%) was obtained with V_0F_0 treatment (No vermicompost + No NPKS).

The soil properties such as organic matter, total nitrogen, phosphorus, potassium, sulphur and zinc contents were increased due to the application of vermicompost and fertilizers after the harvest of the crop as compared to the initial nutrient status of the soil.

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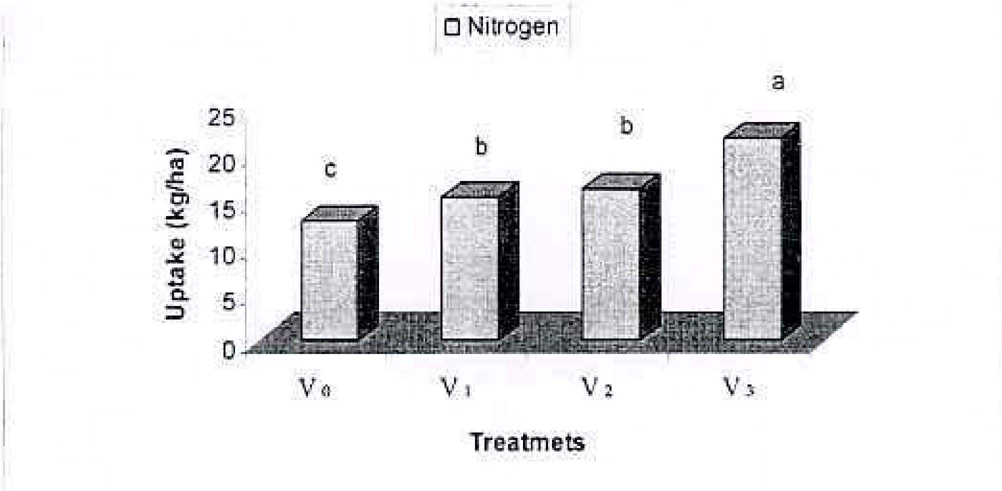
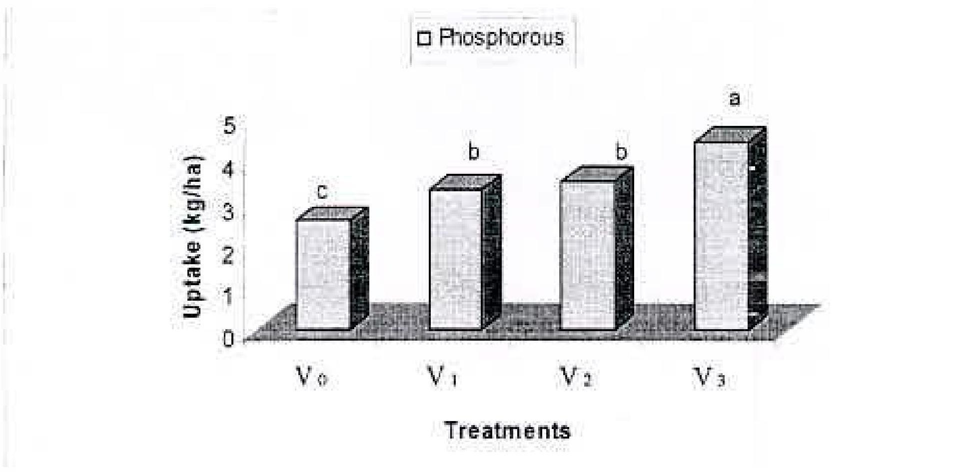
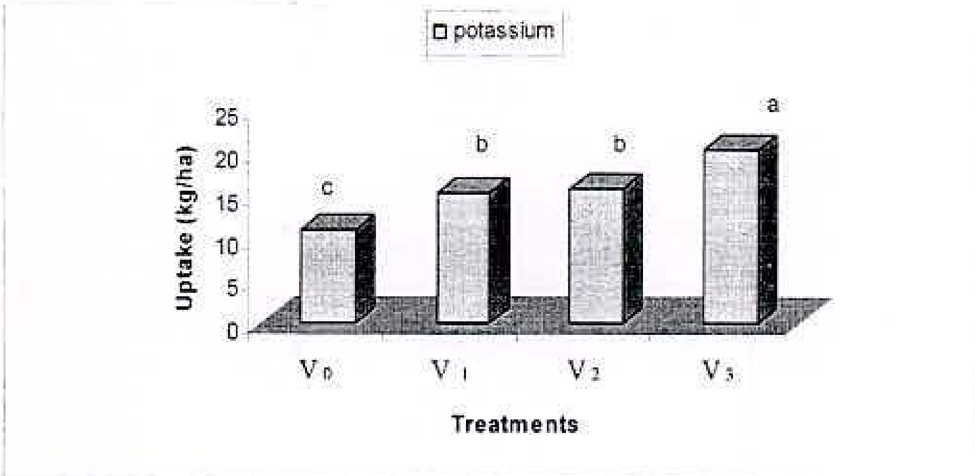
Appendices



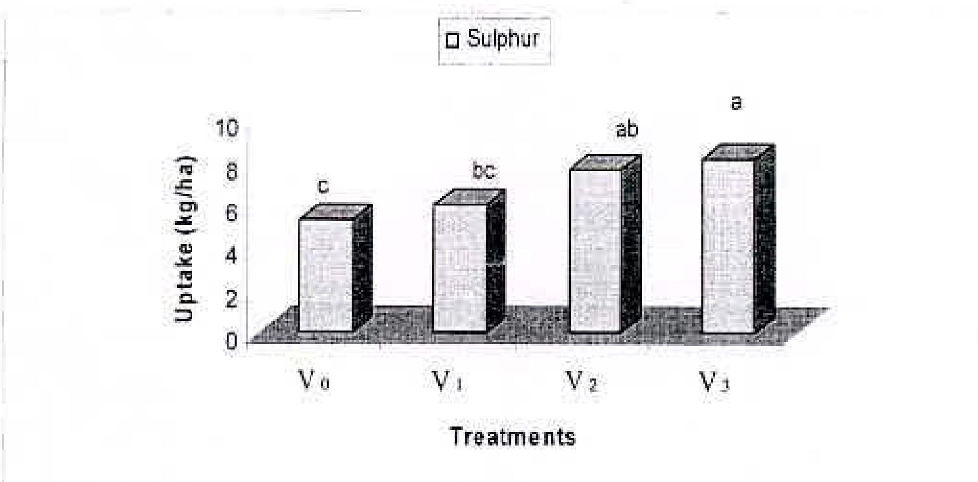
Appendix Figure 1. Effect of vermicompost on nitrogen uptake by soybean plant



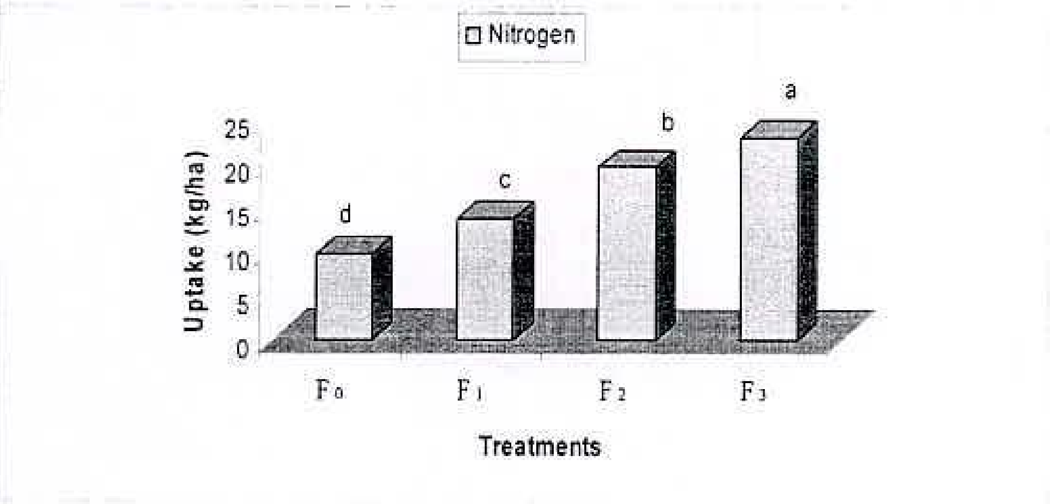
Appendix Figure 2. Effect of vermicompost on phosphorous uptake by soybean plant



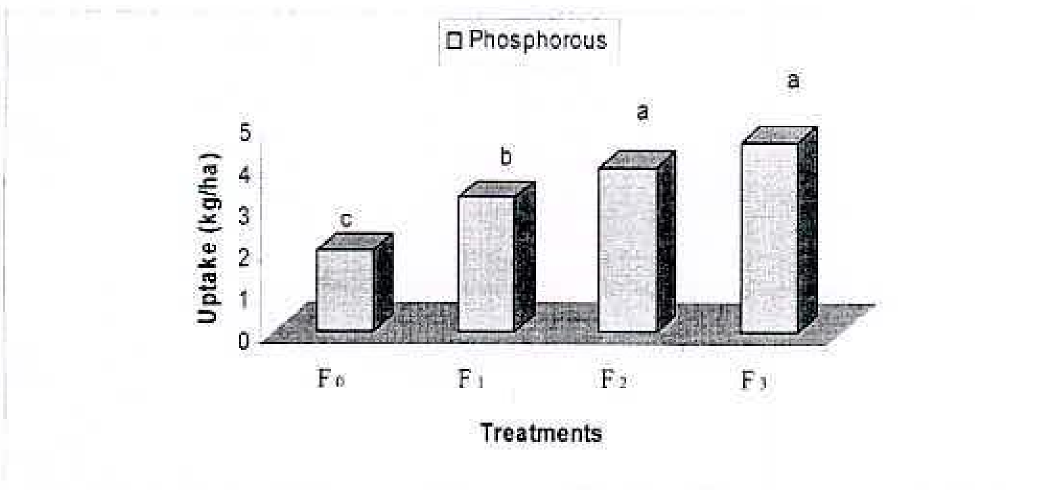
Appendix Figure 3. Effect of vermicompost on potassium uptake by soybean plant



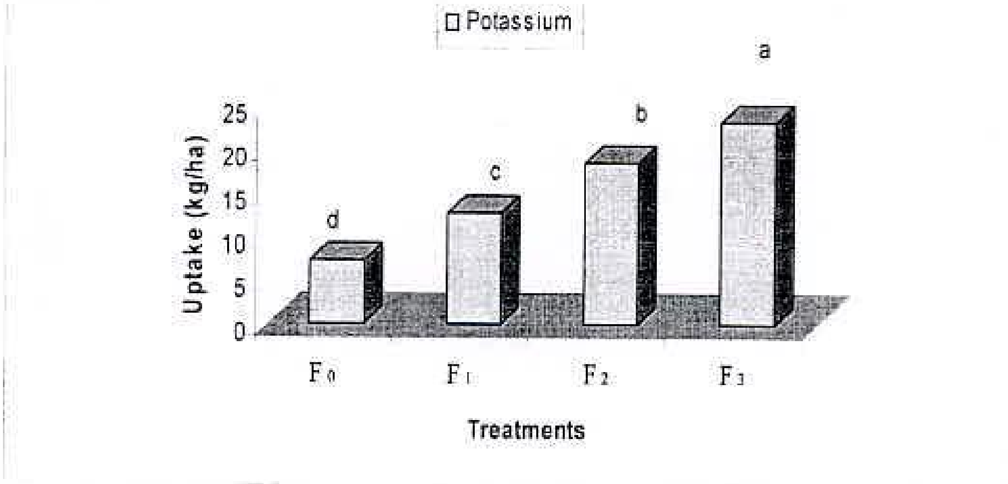
Appendix Figure 4. Effect of vermicompost on sulphur uptake by soybean plant



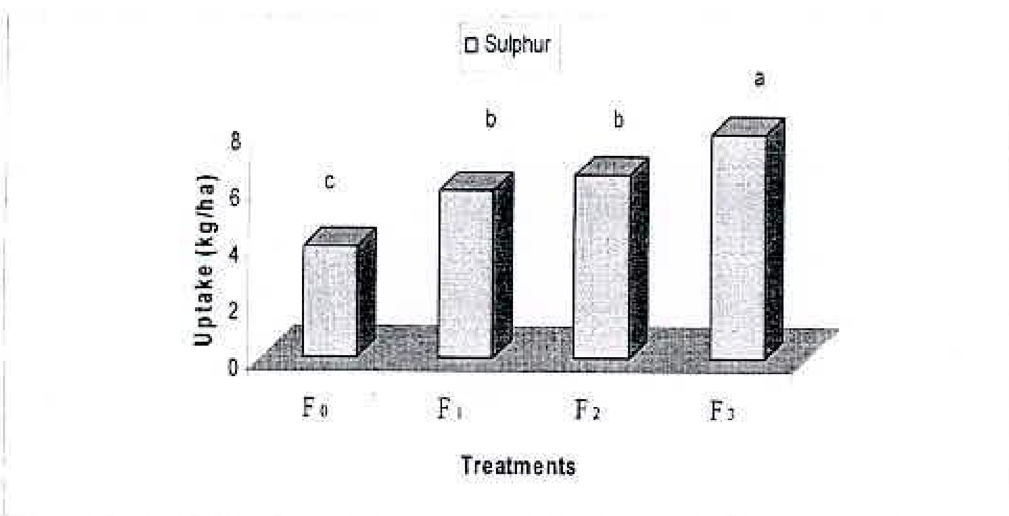
Appendix Figure 5. Effect of NPKS fertilizers on nitrogen uptake by soybean plant



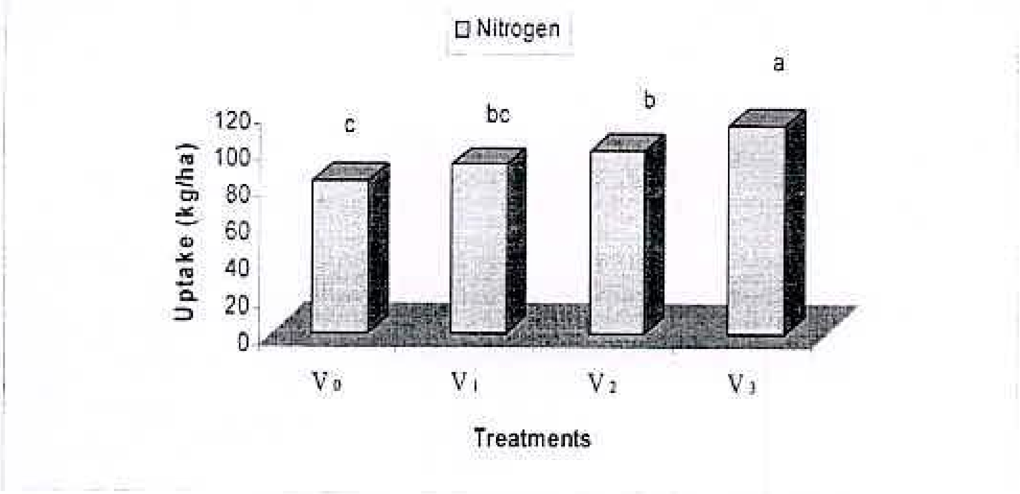
Appendix Figure 6. Effect of NPKS fertilizers on phosphorous uptake by soybean plant



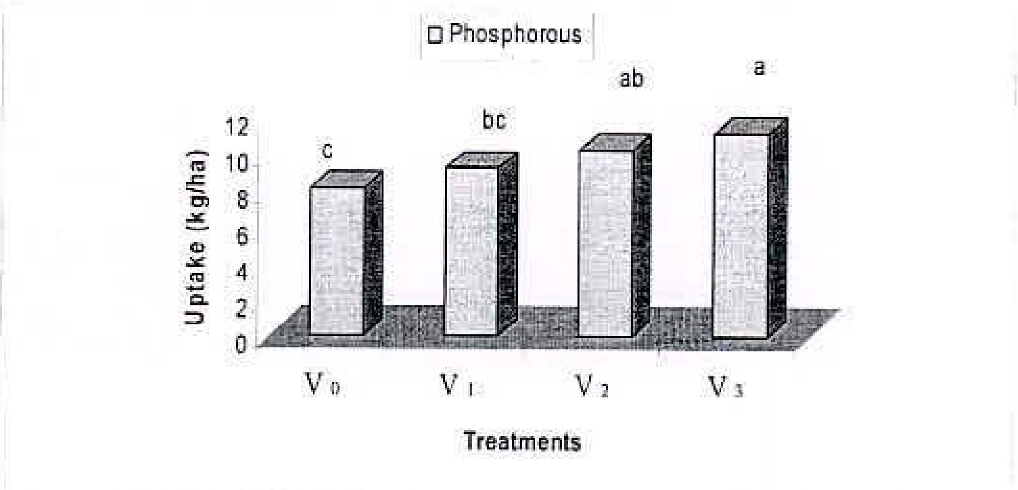
Appendix Figure 7. Effect of NPKS fertilizers on potassium uptake by soybean plant



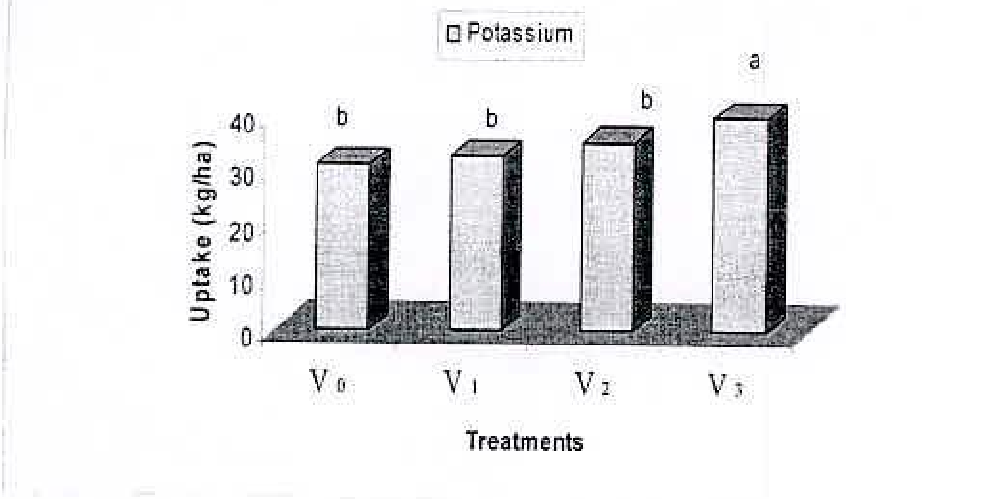
Appendix Figure 8. Effect of NPKS fertilizer on sulphur uptake by soybean plant



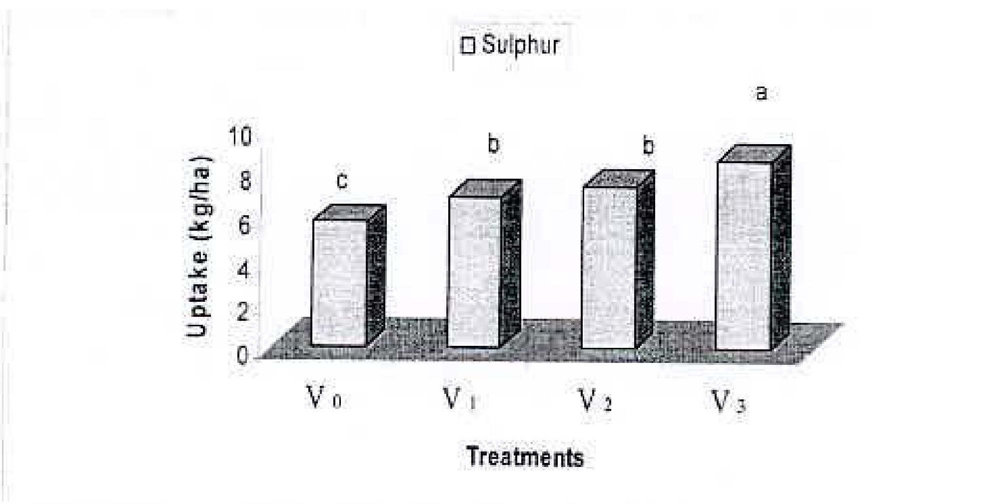
Appendix Figure 9. Effect of vermicompost on nitrogen uptake by soybean seed



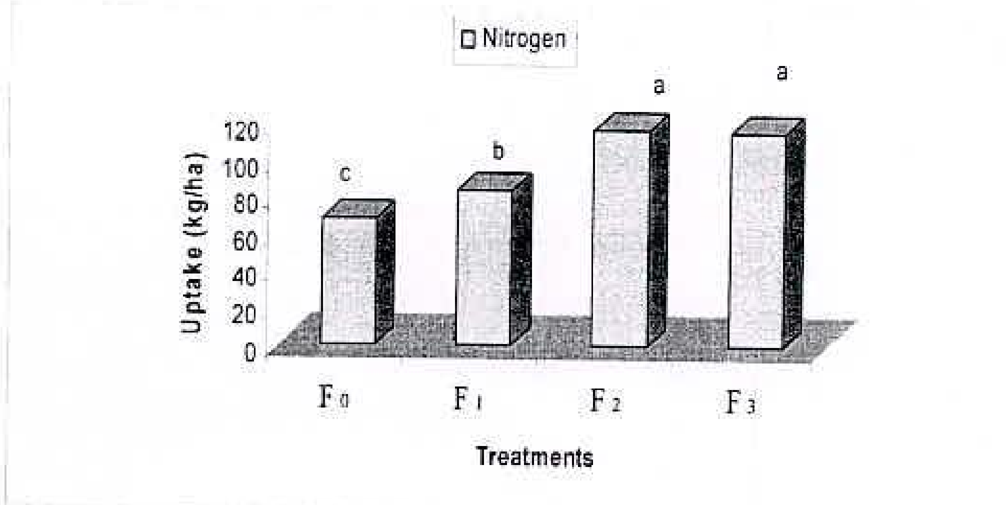
Appendix Figure 10. Effect of vermicompost on phosphorous uptake by soybean seed



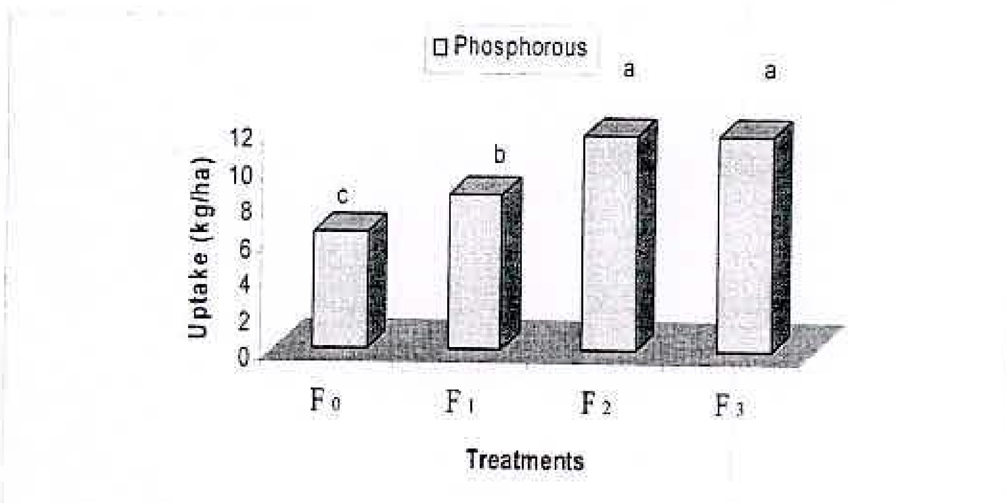
Appendix Figure 11. Effect of vermicompost on potassium uptake by soybean seed



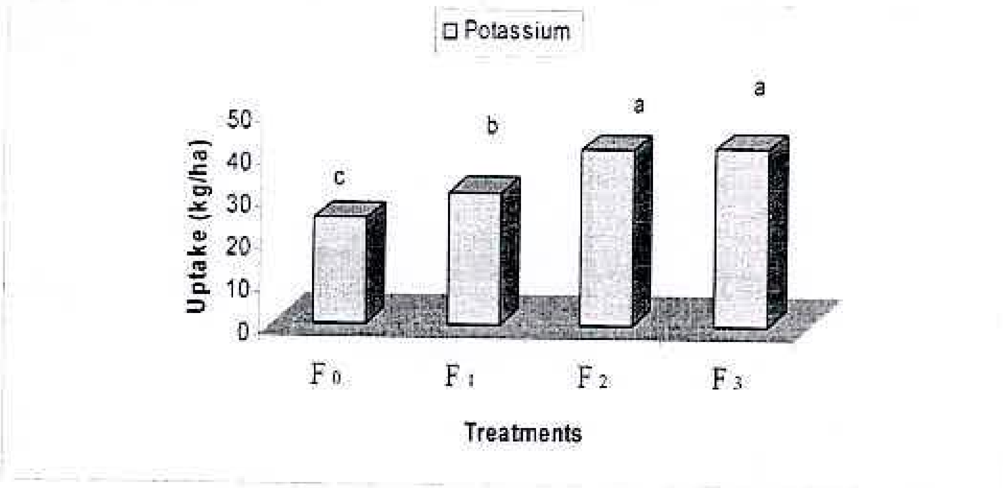
Appendix Figure 12. Effect of vermicompost on sulphur uptake by soybean seed



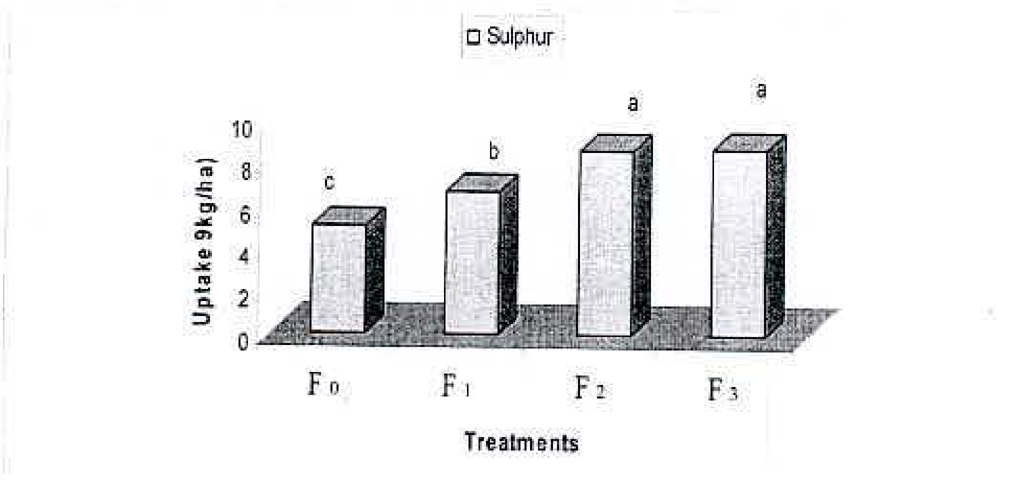
Appendix Figure 13. Effect of NPKS fertilizers on nitrogen uptake by soybean seed



Appendix Figure 14. Effect of NPKS fertilizers on phosphorous uptake by soybean seed



Appendix Figure 15. Effect of NPKS fertilizers on potassium uptake by soybean seed



Appendix Figure 16. Effect of NPKS fertilizers on sulphur uptake by soybean seed

Appendix Table1. Effect of vermicompost on nitrogen, phosphorous, potassium and sulphur uptake by soybean plant

Vermicompost	Kg ha^{-1}			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0	12.90 c	2.55 c	10.86 c	5.21 c
V_1	15.36 b	3.29 b	15.08 b	5.99 bc
V_2	16.25 b	3.47 b	15.57 b	7.60 ab
V_3	21.58 a	4.39 a	20.17 a	8.11 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

Appendix Table 2. Effect of NPKS fertilizers on nitrogen, phosphorous, potassium and sulphur uptake by soybean plant

Fertilizer	Kg ha^{-1}			
	Nitrogen	Phosphorous	Potassium	Sulphur
F_0	9.70 d	1.94 c	7.30 d	3.95 c
F_1	13.67 c	3.23 b	12.80 c	5.92 b
F_2	19.65 b	3.95 a	18.42 b	6.51 b
F_3	23.08 a	4.57 a	23.18 a	7.96 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

Appendix Table 3. Combined effect of vermicompost and NPKS fertilizers on nitrogen, potassium, phosphorous and sulphur uptake by soybean plant

Vermicompost x Fertilizer	Kg ha^{-1}			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0F_0	7.14 h	1.37 g	4.66 i	2.89 g
V_0F_1	8.08 h	1.77 fg	7.42 ghi	3.40 fg
V_0F_2	18.71 cde	3.2 cdef	14.36 def	7.37 bcd
V_0F_3	17.66 cde	3.84 bcd	17.01 cde	7.18 bcd
V_1F_0	9.61 gh	1.91 efg	6.37 hi	3.94 efg
V_1F_1	13.56 efg	3.21 cdef	12.73 efg	6.16 cdef
V_1F_2	16.12 def	3.50 bcd	18.09 bcde	6.75 bcde
V_1F_3	22.15 bc	4.54 abc	23.14 b	7.72 abcd
V_2F_0	9.80 gh	1.94 efg	7.53 ghi	3.90 efg
V_2F_1	14.41 efg	3.40 cde	12.93 defg	6.62 bcde
V_2F_2	19.70 bcd	4.09 abcd	18.79 bcd	8.24 ab
V_2F_3	21.11 bcd	4.45 abc	23.03 b	7.89 abc
V_3F_0	12.26 fgh	2.54 defg	10.63 fgh	5.08 defg
V_3F_1	18.62 cde	4.53 abc	18.11 bcde	8.52 abc
V_3F_2	24.05 b	5.03 ab	22.41 bc	9.07 a
V_3F_3	31.39 a	5.46 a	29.53 a	9.72 a
Level of Significance	0.05	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

Appendix Table 4. Effect of vermicompost on nitrogen, phosphorous, potassium and sulphur uptake by soybean seed

Vermicompost	Kg ha^{-1}			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0	83.08 c	8.10 c	30.85 b	5.77 c
V_1	91.45 bc	9.24 bc	32.63 b	6.91 b
V_2	98.93 b	10.28 ab	35.22 b	7.47 b
V_3	113.3 a	11.16 a	39.98 a	8.65 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

Appendix Table 5. Effect of NPKS fertilizers on nitrogen, phosphorous, potassium and sulphur uptake by soybean seed

Fertilizer	Kg ha^{-1}			
	Nitrogen	Phosphorous	Potassium	Sulphur
F_0	68.52 c	6.50 c	24.69 c	5.09 c
F_1	84.48 b	8.54 b	30.94 b	6.76 b
F_2	117.5 a	11.86 a	41.35 a	8.67 a
F_3	116.3 a	11.88 a	41.70 a	8.78 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

Appendix Table 6. Combined effect of vermicompost and NPKS fertilizers on nitrogen, potassium, phosphorous and sulphur uptake by soybean seed

Vermicompost x Fertilizer	Kg ha^{-1}			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0F_0	56.01 h	4.74 f	20.80 e	3.67 f
V_0F_1	70.94 gh	6.27 ef	26.23 e	5.16 def
V_0F_2	99.45 def	9.87 bcd	36.53 bcd	6.66 cde
V_0F_3	105.9 bcdef	11.54 abc	39.86 abc	7.60 bcd
V_1F_0	63.89 gh	5.88 ef	22.42 e	4.87 ef
V_1F_1	80.94 fgh	8.72 cde	30.16 cde	6.65 cde
V_1F_2	105.00 cdef	10.44 bc	36.20 bcd	7.21 bcde
V_1F_3	115.9 abcd	11.90 abc	41.75 ab	8.89 abc
V_2F_0	68.39 gh	9.79 def	25.15 e	5.53 def
V_2F_1	79.44 fgh	8.88 cde	29.55 de	6.82 cde
V_2F_2	137.2 a	14.34 a	47.46 a	10.40 a
V_2F_3	110.7 abcde	11.11 abc	38.71 abcd	7.13 bcde
V_3F_0	85.80 efg	8.59 cde	30.39 cde	6.27 cde
V_3F_1	106.6 bcdef	10.30 bc	37.82 abcd	8.42 abc
V_3F_2	128.2 abc	12.78 ab	45.20 ab	10.47 a
V_3F_3	132.8 ab	12.97 ab	46.50 a	10.86 a
Level of Significance	0.01	0.05	0.01	0.05

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