EFFECT OF COMBINED APPLICATION OF INORGANIC FERTILIZERS AND VERMICOMPOST ON GROWTH, YIELD, CHEMICAL COMPOSITION AND OIL CONTENT OF RAPESEED

(*Brassica campestris* var. SAU sharisha-1)

BY

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CERTIFICATE

This is to certify that the thesis entitled, **"EFFECT OF COMBINED APPLICATION OF INORGANIC FERTILIZERS AND VERMICOMPOST ON GROWTH, YIELD, CHEMICAL COMPOSITION AND OIL CONTENT OF RAPESEED"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment 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 **MD. ASADULLAH ARMAN ALI, REGISTRATION No. 00921** 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 such help or source of information, as has been availed of during the course of this investigation has been duly acknowledged by him.

Dated

Dhaka, Bangladesh

(Dr. Md. Nurul Islam)
Supervisor

Dedicated to
My
Beloved Parents

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ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka 1207 during the Rabi season of 2007-2008 to study the effect of combined application of inorganic fertilizers and vermicompost on growth, yield, chemical composition and oil content of rapeseed *(Brassica campestris* var. SAU Sharisha-1). The experimental soil was clay loam in texture having pH of 6.2. 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, K, S, Zn, B) viz. F_0= (0 – 0 – 0 – 0 – 0 – 0 kg ha^{-1}), F_1 = low fertilizer (45 – 15 – 20 – 12 – 1.5 – 1.0 kg ha^{-1}), F_2 = medium fertilizer (90 – 30 – 40 – 25 – 3 – 2 kg ha^{-1}), F_3 = high fertilizer (135 – 45 – 60 – 40 – 4.5 – 3.0 kg ha^{-1}) in 16 treatment combinations with 3 replications. The results demonstrated that the increasing doses of vermicompost and chemical fertilizers increased grain and straw yields of rapeseed 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 rapeseed 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 rapeseed grain were obtained with the treatment combination, V_2F_2 and S uptake was obtained with the treatment combination, V_3F_3. 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, B status significantly and that of N and K appreciably in the soil under study. The oil content was not significantly influenced by the different treatments.

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LIST OF ABBRIVIATIONS

ABBREVIATION	FULL WORD
AEZ	Agro-Ecological Zone
@	At the rate
CEC	Cation Exchange Capacity
cm	Centimeter
$CuSO_45H_2O$	Green vitriol
cv.	Cultivar(s)
CV%	Percentage of Coefficient of Variance
DMRT	Duncan's Multiple Range Test
e.g.	example
et al	and others
FYM	Farm Yard Manure
g	Gram
H_3BO_3	Boric acid
$HClO_4$	Perchloric acid
HNO_3	Nitric acid
H_2O_2	Hydrogen per oxide
H_2SO_4	Sulfuric acid
i.e	that is
K	Potassium
kg	Kilogram
kg ha^{-1}	kg per hectare
K_2SO_4	Potassium Sulfate
LSD	Least Significant Difference
S	Sulphur
TSP	Triple Super Phosphate
m	Meter
ml	Milliliter
mm	Millimeter
MP	Muriate of Potash
N	Nitrogen
NaOH	Sodium Hydroxide
NPKSZnB	Nitrogen, Phosphorus,Potassium, Sulphur, Zinc and Boron
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

Rapeseed and mustard belong to the family cruciferae, are important oil crops and currently ranked as the world's third important oil crop in terms of production and cultivated area. Among the species, *Brassica napus* and *Brassica campestris* are regarded as 'rapeseed' while *Brassica juncea* is regarded as 'Mustard'. The total annual production of *Brassica* worldwide is 44.41 million tons of seed from an area of 27.24 million hectares (FAO, 2004).

In Bangladesh, rapeseed-mustard is the principal oilseed crop. It covers an area of 0.28 million hectares with a production of 0.21 million tons (BBS, 2005). The average yield of mustard/Rapeseed in Bangladesh is very low (0.77 t/ha) that is less than 50% of the world average (FAO, 2004). Domestic production of edible oil almost entirely comes from rapeseed and mustard occupying only about 2% of total cropped area in Bangladesh. The annual oil seed production was 0.21 million tons, which was about 52% of the total edible oilseed production (BBS, 2005). It is in the top of the list in respect of area and production compared to other oilseed crops grown in Bangladesh.

Bangladesh is running with acute shortage of about 70% edible oil. The country is now producing about 0.16 million tons of edible oil as against the requirement of 0.5 million tons, So to meet the demand, the country has to import oil and oilseeds at a cost of about US $ 160 million per annum (Wahhab *et al.* 2002).

Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) have released a number of new high yielding varieties (HYV) of these crops for farmer's cultivation. The yield of HYV cultivars ranges from 1.4 to 2.1 ton ha^{-1} (BARI, 2002a). However, the yields in farmer's fields are still low due to imbalanced fertilizer application and deterioration of soil quality day by day.

In developed countries, for example, over-application of inorganic and organic fertilizer has led to environmental contamination of water supplies and soils (Canway and Pretty 1991; Bumb and Baanante 1996; NRC 1989). In developing countries, harsh climatic conditions, population pressure, land constraints, and the decline of traditional soil management practices have often reduced soil fertility (Stoorvogel and Smaling 1990; Tandon 1998; Henao and Baanante 1999; Bumb and Baanante 1996). Plants extract nutrient from soil and the nutrients are lost from the soil in various ways. So effective measures will have to take to reduce the removal of nutrients in order to maintain and sustain soil fertility for increased crop productivity.

Over application of inorganic and organic fertilizers is estimated to have boosted nutrient capacity in the soil by about 2000 kilograms of nitrogen, 700 kg of Phosphorus, and 1000 kg of potassium per hectare of arable land in Europe and North America during the past 30 years (World Bank, 1996). Such oversupply of nutrients can lead to environmental pollution, which often has negative consequences for human and animals. Over application of nitrogen, for example, allows the nutrient to be carried away in ground water and to contaminate surface and underground water. Ingestion of nitrate can be toxic to human and animals when it is transformed within the body into nitrite which affects the oxygen carrying ability of red blood cells. Evidences also suggest that nitrite and the carcinogenic compounds can create goiter, birth defects, heart disease, and stomach, liver, and esophagus cancers (Conway and Pretty 1991).

The use of inorganic fertilizers by farmers in developing countries, in contrast with those of the industrialized world, still have only limited access (FAO, 1993). This skewed distribution, and the high cost of fertilizer in most parts of the world, emphasizes the need for increasing the efficiency of their use, and many researchers look forward to the combination of inorganic with organic sources of nutrient as the best route for this purpose. Vermicompost can be an important tool to the combination of inorganic and organic sources of nutrient.

Vermicompost is an organic manure produced by the activity of earthworms. It is a mixture of worm casts, which is rich in macro and micronutrients, vitamins, growth hormones and immobilized microflora. The average nutrient content of vermicompost is much higher than that of FYM. Vermicompost contains 1.60% N, 5.04% P_2O_5 and 0.80% K_2O with small quantities of micronutrients. The C:N ratio of vermicompost is much lower (16:1) than that of FYM(30:1). Application of vermicompost facilitates easy availability of essential plant nutrients to crops.

In Bangladesh some promising varieties of mustard have been released those are being cultivated under inorganic fertilization. Such a promising rapeseed (*Brassica campestries*) cv. SAU Sharisha-1 was used in this experiment with combined application of vermicompost and inorganic fertilizers.

Limited information are available in Bangladesh on the effect of combined application of vermicompost and inorganic fertilizers on the growth, yield, chemical composition and oil content of oil producing *Brassica* spp.

Taking the above mentioned points into account the present study has undertaken with the following objectives-

- To know the growth and yield performance of rapeseed by the combined application of vermicompost and inorganic fertilizers.
- To know the interaction effect of vermicompost and inorganic fertilizers on chemical composition and nutrient uptake by both plant and seeds of rapeseed.
- To know the individual residual effect of vermicompost and fertilizers and the combined residual effect of vermicompost and inorganic fertilizers on soil chemical properties.

Chapter 2
Review Of Literature

REVIEW OF LITERATURE

A number of research works on the response of crops, especially rapeseed-mustard to different fertilizers and manures have carried out in Bangladesh and other oil seeds crops growing countries of the world. The farmers are also advised to use manures and fertilizers irrespective of crops, seasons and soils for boosting up yields, but information on the effect of combined application of vermicompost and inoganic fertilizers on growth, yield, chemical composition and oil content of rapeseed-mustard and on soil properties are very limited in our country. However, some of the works done in our country and elsewhere of the world are briefly reviewed here.

2.1 Effect of inoganic fertilizers on rapeseed-mustard :

Sharma and Jain (2002) conducted a field experiment to study the effects of cropping sequence and N rate on the yield and yield components of Indian mustard cv. RL 1359. The cropping systems consisted of fallow-Indian mustard, mung bean cv. K 851 (*Phaseolus radiatus* [*Vigna radiata*])-Indian mustard, fodder cowpea cv. C 152, *Sesbania cannabina*-Indian mustard, and pearl millet cv. MH 179-Indian mustard. N was applied to Indian mustard at 0, 40, 80, 120, and 160 kg/ha. Among the cropping systems, S. cannabina-Indian mustard gave the greatest plant height (202.4 cm), number of siliquae per plant (251.9) and seeds per siliqua (15.9) as well as seed yield (1596, 2311, and 1445 kg/ha in 1994-95, 1995-96, and 1996-97) respectively. The highest 1000-seed weight, however, was recorded under fallow-Indian mustard cropping system. The application of 80 kg N/ha resulted in the highest number of branches (24.4) and siliquae (260.9) per plant, number of seeds per siliqua (15.3), 1000-seed weight (5.85 g), and seed yields (1649, 2217, and 1261 kg/ha). The highest values of seed yield and yield attributes were recorded for S. cannabina-Indian mustard receiving 80 kg N/ha.

Singh (2002) conducted a field experiment to investigate the effect of different levels of N (0, 30, 60, 90 and 120 kg/ha) and P (1, 15, 30, 45 and 60 kg/ha) on yield, yield components and oil content of Indian mustard cv. Varuna. Application of N and P increased the length of siliqua, number of siliquae per plant, seeds per siliqua, seed yield and 1000-seed weight. However, the significant increase in yield and yield components was recorded in 60, 90 and 120 kg N/ha and 30, 45 and 60 kg P/ha treatments. The maximum seed yield was recorded from application of 45 kg P/ha (11.43 and 13.85 q/ha in 1999 and 2000, respectively) and 120 kg N/ha (12.98 and 13.83 q/ha in 1999 and 2000, respectively). The oil content also increased with the application of N and P, but was insignificant.

Giri (2001) conducted a field experiment to study the response of Indian mustard (cv. Pusa Jaikisan) and sunflower (cv. MSFH 8) to sowing date (19 October or 17 November 1995 and 16 October or 18 November in 1996), irrigation (irrigation at full bloom stage of Indian mustard and bud formation stage of sunflower or at flower initiation and pod development stages of Indian mustard and at the vegetative and flowering stages of sunflower), and N rate (40 and 80 kg/ha). Indian mustard outyielded sunflower by 91.7% in 1995 and 81.1% in 1996. Sowing in October gave higher dry matter content, number of pods per plant, seed weight, and seed yield than sowing in November. The irrigation did not significantly affect the yield attributes of both crops, except the dry matter accumulation of sunflower which was higher with the second irrigation treatment (1996-97). The variation in seed yield due to N rate was not significant..

Budzynski (2001) reported that the effects of pre-sowing application of NPK (161 kg/ha) + S (30 kg/ha) or Mg (5 kg/ha) and top dressing of N (0, 30, 25 + 5 and 60 kg/ha) on the yield, yield components and morphological features of white mustard [*Sinapis alba*] and Indian mustard seeds were evaluated in an experiment conducted in Poland. Supplementing NPK with S or Mg had no effect on the stand architecture and morphological features of both crops. N top dressing (30, 25 + 5 and 60 kg/ha) increased the height, diameter of stem base and branching of Indian mustard and white mustard stems. Both crops, however, exhibited lodging. The effects of NPKS and NPKMg on the yield potential of white mustard were not dependent on weather conditions. S was more effective than Mg when high rainfall occur during the flowering period. N applied at 30 kg/ha at the start of the flowering period gave the best results among the methods of white mustard on top dressing. Splitting this rate to 25 kg N/ha as a solid fertilizer and 5 kg N/ha in a solution gave results similar to that of the whole rate of 30 kg N/ha as a solid fertilizer. N at 60 kg/ha appeared to be less productive. The methods of pre-sowing application of NPKS and NPKMg showed no significant differences in Indian mustard yield. N applied as a solid fertilizer at a rate of upto 60 kg/ha increased the seed yield. Splitting the N rate to 25 kg/ha (solid fertilizer) and 5 kg/ha (solution) gave yield enhancing effects similar to that of the whole 30 kg N/ha rate.

Poonia *et al.* (2002) conducted a field experiment consisting of three sources (gypsum, single super phosphate and diammonium phosphate) and three levels of phosphorus (20, 40 and 60 kg P_2O_5 ha^{-1}). Results showed that the application of phosphorus through diammonium phosphate at 40 kg P_2O_5 ha^{-1} significantly increased the seed yield (16.92 q ha^{-1}) and oil yield (6.54 q ha^{-1}) of Indian mustard over 20 kg P_2O_5 ha^{-1} but was at par with application of 60 kg P_2O_5 ha^{-1}.

Vlasenko *et al.* (2001) stated that Various rates of N fertilizers (0, 60, 90, 120, 180 kg/ha) applied, with or without insecticide and herbicide, for Chinese mustard on leached chernozems in the forest-steppe zone of W. Siberia. Without the use of pesticides, the oilseed yield was about 1100 kg/ha, but with N 120 and pesticides the maximum oilseed yield was 2130 kg/ha. A regression equation was derived for calculating the optimum use of N fertilizer and pesticides.

Khurana and Chatterjee (2002) observed that mustard (*Brassica campestris* L. var. Sarson) was grown in refined sand at three levels, deficient (0.3), normal (30), and excess (300) micro M boron, each at low (0.02) and normal (2) mM sulfur. In mustard, dry matter and reproductive yields were highest at combined supply of adequate boron and sulfur. Foliar symptoms of boron deficiency were accentuated by low sulfur. Boron (B) deficiency at normal sulfur (S) reduced flowering, dry matter, pod yield, tissue boron, chlorophyll content, Hill reaction activity, protein and organic labile, and lipid phosphorus fractions, and increased the concentration of inorganic phosphorus, reducing and non-reducing sugars, phenol content, and the activities of peroxidase, acid phosphatase, and ribonuclease. A synergism between boron and sulfur was reflected when boron deficiency effects were accentuated further by combined deficiency of both nutrients. No seeds were formed in boron deficiency regardless of sulfur levels. The foliar symptoms of boron excess were initiated earlier than its deficiency and were more severe at low sulfur levels. At excess boron, the decreases in biomass, pod yield, chlorophyll, and lipid P concentrations were more pronounced at low sulfur level. Also an increase in leaf boron, reducing and non-reducing sugars, phenols, and activity of ribonuclease and peroxidase occurred, indicating a synergistic role of boron and sulfur in mustard..

Singh *et al.* (2002) conducted a field experiment comprising two improved Indian mustard cultivars (Varuna and Pusa Kranti) and 3 levels of P (20, 40 and 60 kg/ha). Varuna recorded higher number of siliquae per plant, seed yield per plant, test weight and seed (16.5 q/ha) and oil (6.40 q/ha) yields than Pusa Kranti, which gave 14.8 and 5.60 q/ha seed and oil yields, respectively. Application of 40 kg P_2O_5/ha was significantly superior to 20 kg P_2O_5/ha with respect to seed yield per plant and number of siliquae per plant; the percentage increase was 7.7 and 9.9, respectively. Significantly higher seed yield was obtained with application of 40 kg P_2O_5/ha (16.9 q/ha) compared to 20 kg P_2O_5/ha (14.4 q/ha), which was at par with 60 kg P_2O_5/ha (15.7 q/ha). Application of 40 kg P_2O_5/ha produced the highest oil yield of 6.5 q/ha, which was 18.2 and 10.2% more over 20 and 60 kg P_2O_5/ha, respectively.

Malewar *et al.* (2001) conducted a field experiment to investigate the effects of four levels of zinc sulfate (0, 10, 20 and 30 kg/ha) and three levels of borax (0, 5 and 10 kg/ha) on yield, nutrient uptake and seed quality of mustard (*Brassica juncea* cv. Pusa Bold). Stover and seed yield significantly increased with each levels of either zinc or boron which was attributed to the positive interaction of the two. Highest total mustard uptake of Zn and B was at 30 kg $ZnSO_4$ and 10 kg borax/ha, respectively. Zn and B interaction was also reflected in terms of improved seed quality of mustard. Oil and protein content was significantly increased with 30 kg $ZnSO_4 \times 10$ kg borax/ha treatment.

Abraham (2001) conducted a field experiment to study the effect of split application of sulfur on the growth and yield of Indian mustard cv. Pusa Jai Kisan. The treatments consisted of only one rate of sulfur (20 kg/ha) in the following combinations: (T1) 0 kg S + 30 kg N + 30 kg N/ha; (T2) 10 kg S + 30 kg N/ha; and (T3) 10 kg S + 5 kg S + 5 kg S + 30 kg N + 30 kg N + 30 Kg N/ha, applied in 2 and 3 split-doses. The seed and oil yields of Indian mustard were enhanced by split S application. The treatment T3 was the most effective in augmenting seed and oil yields. The highest number of pods per plant (425.7), seeds per pod (14.8), 1000-seed weight (8.75 g), biomass at harvest (23.14 kg/ha), seed yield (6.2 t/ha) and oil yield (2.51 t/ha) were recorded under T3 treatment.

Dwivedi *et al.* (2001) conducted three sets of field experiments to determine the effect of muriate of potash (MOP) particle sizes on the yield and K uptake of wheat, potato and Indian mustard. The MOP particle sizes evaluated in 1996-97 were 95, 90, 85, 80 or 75% of MOP materials retained on 0.25 mm sieve; while those evaluated in 1997-98 were 70 and 65% of MOP materials retained in 0.25 mm sieve. All MOP fertilizers were applied at 50 kg K/ha on wheat and Indian mustard, and at 100 kg K/ha on potato. A no-K application treatment served as control in both years. K application increased the yield of the crops compared to the control, but the magnitude of increase varied with particle size. The lowest yields was obtained in the treatment with MOP at 95% particle size. MOP particle sizes at 90, 85, 80, 75 and 70%; at 85, 80 and 75%; and at 85, 80, 75 and 70% produced high yields of wheat (during 1996-97), potato (during 1996-97) and Indian mustard (during 1997-98), respectively. K uptake increased with increasing fineness in the MOP material. The lowest K uptake was in the control treatment, followed by the treatment with MOP at 95% particle size. Laboratory studies on horizontal displacement showed that the drift of the different MOP material in the soil increased with increasing fineness of the MOP material..

Abdin *et al.* (2001) studied that the effect of S and N application on N-accumulation and N-harvest in rapeseed mustard (*Brassica juncea*, V_1; and *Brassica campestris*, V_2) under field conditions in New Delhi, India with a randomized block design. Three treatments viz. 0 kg S/ha + 100 kg N/ha (T_1), 40 kg S/ha + 100 kg N/ha (T_2) and 60 kg S/ha + 150 kg N/ha (T_3) were applied. The results showed that application of S along with N increased N-accumulation in both genotypes at all growth stages compared with N applied alone. This increase in N-accumulation was due to an increase in nitrate assimilation from reduced nitrogen forms as evidenced by the higher nitrate reductase (NR) activity in the leaves of plants grown with both S and N. This showed that application of S along with N considerably reduced the nitrate content in the leaves due to higher NR activity. The decline in nitrate assimilation was followed by an overall increase in N-accumulation in plants. Consequently, N content in the plant was increased from 22.1 to 146.2% and from 25.5 to 249.5% in V_1 and V_2, respectively, with the application of S along with N, compared with the application of N alone. N-harvest index was also higher in plants grown with both S and N compared with N alone. It is concluded that application of S along with N increases the accumulation of N. The treatment, T_2 resulted in maximum improvement in these parameters.

Ahmad *et al.* (2001) conducted a field experiment to study the interactive effect of N and S application on nitrogen accumulation, its distribution in various plant parts and nitrogen harvest of rapeseed-mustard (*Brassica juncea* cv. Pusa Jai Kisan V1; *Brassica campestris* cv. Pusa Gold V_2), field experiments were conducted in New Delhi, India using three combinations of S and N viz. 0 S + 100 N, 40 S + 100 N and 60 S + 150 N kg/ha. The results showed that combined application of S and N (40 S + 100 N and 60 S + 150 N kg/ha) increased the nitrogen accumulation in both the genotypes at all the growth stages over N alone (0 S + 100 N). This increase in N accumulation was due to the improvement in the reduction of nitrate into reduced N as evident from higher nitrate reductase (NR) activity in the leaves of plants grown with both S and N, compared with N alone. Nitrate-N content in the leaves of plants grown with only N was higher compared to those grown with both S and N, showing that application of S, along with N, appreciably reduced the nitrate content in the leaves due to the higher NR activity. This decline in NO_3 was followed by an overall increase in N-accumulation in the plants. Consequently, the N content in the plant increased by 11.7-57.6 and 11.0-58.9% in V_1 and V_2, respectively, with the application of S, along with N, compared to the application of N alone. N harvest index was also higher in plants grown with both S and N, compared to those grown with N alone. It is evident from these results that the application of S, along with N, not only increased N accumulation, but also its mobilization towards economic sinks. Among the different combinations of S and N, 40 S + 100 N proved to be the optimum for higher N accumulation and N harvest in rapeseed and mustard.

Upadhyay *et al.* (2000) conducted experiment on Indian mustard (*Brassica junce a*) with 1 - 3 irrigations and 0 - 40 kg $ZnSO_4$/ha. Maximum leaf area, crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate were given by 20 kg $ZnSO_4$/ha with three irrigations at 30, 55 and 75 days after sowing, while content of chlorophyll was highest with 3 irrigations and the highest Zn rate. The maximum seed yield was given by 20 kg $ZnSO_4$/ha and 3 irrigations.

Puri *et al.* (1999) observed significant influence of varying degrees of soil fertility status on nutrient concentration (N and P) and oil content in seeds (*Brassica juncea*) was observed. Relative mean concentrations of major nutrients (%) were in the following order: N(2.1) > K(0.76) > P(0.62) > Ca (0.566) > Mg (0.225) > S (0.218). The removal of major nutrients was significantly affected by fertilization. The N and P contents in seed, total removal of nutrients (N, P, K), seed yield and oil content were significantly affected by levels of fertilization (N, P, K). The highest seed yield (16.8 kg/ha) and oil content (39.72%) were noted in the treatments 100 : 40 : 20 kg N : P : K/ha. Significant negative correlation coefficients of oil content with protein content (r = 0.2663*), with yield (r = 0.4292), seed S content (r = 0.3242*) and seed Mg content (r = 0.2732*) were obtained.

Bandyopadhyay and Chattopadhyay (200 0) collected soil samples from 18 Alfisols at Kanska, West Bengal, India, to analyse B and S contents, and the yield of rape cv. B-9 plants on these soils and their B and S contents at pod formation. B and S were highly deficient in these soils. Their availability showed significant correlations with organic carbon and silt + clay contents. Available S exhibited a significant negative correlation with soil pH. Available B showed significant positive correlations with Fe_2O_3 and sesquioxide. Average total B and S content of plants were 15.6 mg/kg and 0.10%, respectively. Morgan's extractable S and hot water soluble B contents of the soils significantly positively correlated with their concentrations in plants.

Sinha *et al.* (2000) reported that mustard (*Brassica campestris*) cv. T9 grown in refined sand at three levels of boron (B): deficient (0.0033 ppm), normal (0.33 ppm), and excess (3.3 ppm), and three levels of zinc (Zn): low (0.00065 ppm), adequate (0.065 ppm), and high (6.5 ppm). The B deficiency effects were accentuated by low zinc, viz. the decreased biomass, B and Zn concentrations in leaves and seeds and the activity of carbonic anhydrase [carbonate dehydratase] and accumulation of reducing sugars and stimulated activities of peroxidase, ribonuclease, and acid phosphatase in B deficient leaves were aggravated further. Synergism was also observed between the two nutrients when both B and Zn were in excess together, as excess B accelerated the effects of high Zn by lowering further the reduced biomass, economic yield, and carbonic anhydrase activity and raised further the increased concentration of B and Zn in leaves and seeds, reducing sugars and activity of peroxidase obtained in excess Zn. High Zn levels lowered the high content of non-reducing sugars given by B deficiency.

RenShih *et al.* (1999) reported the effect of split applications of nitrogen (N) fertilizer on the growth and N composition of Chinese mustard [*Brassica chinensis*] assessed in an experiment in a 0.02 ha plastic shelter in Taiwan. There were six treatments in which various rates of N fertilizer were applied as a basal dressing and two top dressings. The plants were harvested 40 days after seeding and the N composition of the plants were determined. The soil was also sampled and the pH, electrical conductivity of 1:1 soil: water ratio extract, organic matter, nitrate-N (NO_3-N), Bray P_1-extractable phosphorus (P) as well as 1N neutral ammonium acetate-extractable potassium (K), calcium (Ca), and magnesium (Mg) concentrations after harvesting of the plants determined. The results showed that there was no significant difference in yield from the various treatments. Total N concentration in shoots receiving fertilizer as 25% basal dressing, 50% in the first top dressing and 25% in the second top dressing, was higher than that of the other treatments. However, NO_3-N, soluble reduced N, and insoluble N concentrations in shoots as well as NO_3-N, soluble reduced N, insoluble N, and total N concentrations of roots were not significantly different due to the treatments..

Mahapatra *et al.* (1999) conducted a field experiment during winter 1996/97 on sandy loam soils at Kalyani, West Bengal, India, rape cv. B-9, toria [*Brassica campestris* var. toria] cv. C-3 and T-9 and mustard [*Brassica juncea*] cv. RW-351 with 0, 20, 40 or 60 kg S/ha. Seed yield and yield component values were highest in mustard, and were increased in all genotypes by S application.

Deekshitulu *et al.* (1998) performed experiment with *Brassica juncea* cv. Seeta with 0, 50, 100 or 150 kg N/ha and 0, 25 or 50 kg S/ha. Seed and oil yields increased with increasing N and S rates. Oil content increased with increasing S rate, but peaked with 100 kg N, then decreased.

Nair (1998) conducted experiment with *Brassica carinata* cv. BACR – 66 – 1 with 0, 20, 40 or 60 kg N/ha. Mean seed yield increased with increasing N rate and decreased with later sowing.

Singhal and Rattan (1999) conducted that pot culture experiments with soyabeans cv. PK-327 and mustard (*Brassica juncea* cv. Pusa Bold) as test crops on a zinc deficient (0.44 mg kg^{-1} DTPA - Zn) Typic Ustifluvent to evaluate the effect of sources and rates of zinc application on dry matter yield and zinc concentration. Zinc sources ($ZnSO_4$, Zn-EDTA, ZnO and $ZnCO_3$) were used at 0 - 10 mg Zn kg^{-1} soil. Seed yield was increased most by $ZnSO_4$, followed in decreasing order by Zn - EDTA, ZnO and $ZnCO_3$. Zn content in seed and shoot tissues increased with increasing Zn application rate, and was generally highest from Zn - EDTA followed by $ZnSO_4$, ZnO and $ZnCO_3$. Application of Zn increased the amount of available Zn in soil after harvest, with the lowest increase given by $ZnSO_4$, while the Zn source giving the greatest increase depended on extractant used.

Khurana *et al.* (1998) conducted a field experiment to study the effect applying 0 - 40 kg S and 0 - 11 kg Zn/ha on *Brassica. juncea* cv. RLM - 619 and its residual effect on a subsequent maize crop. S and Zn applications increased *Brassica juncea* seed yield. The highest seed yield of 1.09 t/ha was obtained with 20 kg S + 11.0 kg Zn, which was 45.3% higher than the control yield. The oil content of *B. juncea* seed was increased by 2.0% due to the combined application of S and Zn. A portion of the applied nutrients remained in the soil, significantly increasing the grain yield and the uptake of S and Zn in the subsequent maize crop.

Rossetto *et al.* (1998) carried out a field experiment to study the effects of potassium fertilization and time of harvesting on rape seed yield. The soil was a red-yellow Latosol (Hapludox), and the experimental design was a subplot replicated four times in completely randomized blocks. Potassium levels (0 and 40 kg K/ha) were applied in the plots, and the subplots consisted of 7 weekly harvests, starting 112 days after planting. Yield and yield components were evaluated at each harvest. Although no positive effect of potassium fertilization on seed yield and growth parameters was evident, this fertilization caused higher retention of pods from the harvest at 147 and 154 days after planting. Time of harvesting did not affect seed yield. The maximum level of dry matter of the above-ground part of the plants was obtained from the harvest at 112 days, and, of seeds, at 126 days, at high potassium level.

Merbach *et al.* (1996) reported that the rape took up considerable amounts of N and protected it from displacement. After the rape was mulched in, the next maize crop (Bekenova) utilized ~30% of the N source (equivalent to ~11% of its N requirement).

Shukla and Kumar (1997) conducted experiment with six varieties of Indian mustard (Krishna, Varuna, Vardan, Kranti, Rohini and Pusa Bold) to assess the effect of nitrogen fertilization on yield attributes, seed yield and oil content during the winter seasons of 1987-89 at Pantnagar. Differences among the varieties were non-significant for seed weight/plant and harvest index. Oil content was significantly higher in Vardan and Krishna, as was nitrogen uptake. N application at rates up to 120 kg/ha significantly increased seed yield, maturity period, harvest index and nitrogen uptake, whereas a decreasing trend was observed in the case of oil content with increases in nitrogen fertilization.

Mondal *et al.* (1997) grew mustard [*Brassica juncea*] cv. RW-351, sesame cv. B-67 and groundnuts cv. JL-24 with 0-80 kg K_2O/ha. Sesame seed and oil yields increased with increasing K rate, while seed yield of mustard and pod yield of groundnuts, oil yields of these 2 crops and seed oil contents of all 3 crops were greatest with 60 kg K/ha. When grown in a rice-potatoe-groundnut sequence, pod yield of groundnuts increased significantly with the application of 75% of the recommended rate of NPK + 10 t FYM/ha to all the crops in the sequence compared with 100% NPK. When grown in a rice-potatoe-sesame sequence, highest seed yield and oil content of sesame was obtained with the application of 150% NPK to all the crops in the sequence, with no significant difference between this treatment and 75% NPK + 10 t FYM/ha.

Pramanik *et al.* (1995) conducted a field experiment on Ethiopian mustard (*Brassica carinata*) with 4 levels each of irrigation water : cumulative pan evaporation ratio (unirrigated control and irrigation at IW : CPE ratios of 0.4, 0.6 and 0.8) and nitrogen (0, 50, 100 and 150 kg/ha). The growth and yield attributes, seed and oil yields increased significantly only up to an IW : CPE ratio of 0.6 (2 irrigations). Nitrogen application improved the growth and yield attributes, and also the seed and oil yields significantly up to 100 kg N/ha, but harvested biomass up to 150 kg N/ha. Irrigation and N interacted significantly for plant height, total branches and siliquae/plant, harvested biological and seed yield. Significantly higher seed production (19.8 q/ha) and oil yield (7.7 q/ha) were obtained from the crop irrigated at an IW : CPE ratio of 0.6 fertilized with 100 kg N/ha, but biomass yield (83.3 q/ha) was highest with 150 kg N/ ha at an IW : CPE ratio of 0.8.

Jaggi and Sharma (1997) performed experiment on *Brassica juncea* cv. Varuna with 0, 30, 60 or 90 kg S/ha and 0, 13, 1 or 26.2 kg P/ha. Seed yield increased with increasing S and P rates. The application of 90 kg S + 26.2 kg P produced the highest seed yield of

2.15 t/ha and the highest uptakes of S and P. S and P had synergistic effect on yield parameters.

Gupta *et al.* (1996) grew mustard [*Brassica juncea*] cv. GSL-1, Pusa Bold and RS-1359 in the rabi [winter] seasons of 1992/93 and 1993/94 with recommended NPK fertilizers plus 10 or 20 kg Zn/ha, foliar application of 0.5% Zn, 25 or 50 kg S/ha, or 10 or 20 kg B/ha. Seed yield was highest in cv. GSL-1, and was increased more by S and B than by Zn.

Arthamwar *et al.* (1996) conducted a field experiment to investigate the effects of nitrogen (0, 50 or 100 kg N/ha) and phosphorus (0, 40 or 80 kg P_2O_5/ha) fertilizer application on *Brassica juncea* cv. Pusa Bold, PR 18, T 59 and Local. Yield components, seed and oil yields were assessed. The cultivar Pusa Bold consistently exhibited significantly higher seed and oil yields/ha than PR 18, T 59 and Local. All yield components increased with increasing N application in both seasons, a linear increase in seed yield/ha being observed from 0 to 100 kg N/ha application during the second year and on average. A linear increase in oil yield was observed with increasing N application from 0 to 100 kg N/ha during the second year, with 50 and 100 kg N/ha application resulting in identical oil yields in the first year. Increasing P application resulted in significant increases in all yield attributes, seed yield/ha, oil content and oil yield.

Vyas *et al.* (1996) studied that *Brassica juncea* cv. T 59 with 0 - 26.16 kg P and 0 - 75 kg S/ha. Seed yield was highest with 17.44 kg P (1.69 t/ha) compared with 1.21 t with no P. Increasing S application from 0 - 75 kg increased seed yield from 1.40 to 1.55 t/ha. Seed oil content increased with up to 50 kg S but was not affected by P application.

Pradhan and Sarkar (1993) conducted experiment on application of 20 kg S and 1 kg B/ha to rape-seed mustard [*Brassica juncea*] significantly increased plant height, leaf area index at flowering and crop growth rate, oil content and seed yield.

Ghosh *et al.* (1993) conducted experiment on *Brassica juncea* in soils of differing K status (< 50 to > 100 p.p.m. exchangeable K) with 30 - 90 kg K_2O/ha. Seed yield and K uptake increased with increasing K rate in all soils (with seed yields with 90 kg K fertilizer averaging 8.45% more than the control), and increased with increasing K status of the soil independently of K fertilizer.

Mandal *et al.* (1994) performed experiment on 4 rape and 10 *Brassica juncea* cultivars were given 0, 2 or 3 kg borax/ha. Mean yield was 1.64, 1.77 and 1.98 t/ha with 0, 2 or 3 kg borax, respectively. The highest yielding rape cultivar was B-9 (2.81 t/ha), while cv. TM 17 gave the highest *Brassica juncea* yield of 2.17 t.

Singh and Vinay (2005) conducted experiment on mustard (*Brassica juncea* cv. Rohini) to different levels of nitrogen (0, 40, 80 and 120 kg/ha), sulfur (0, 20, 40 and 60 kg/ha) and zinc (0 and 5 kg/ha). The seed yield of Indian mustard significantly increased with increasing levels of applied N, S and Zn. Nitrogen application increased the mean seed yield by 36.2%, but decreased the oil content by 0.5% from the control. Sulfur application increased the mean seed yield and oil content by 35.6 and 6.3% and zinc application increased 12.0 and 0.7%, respectively over the control. Nitrogen, S and Zn application increased significantly the protein content in seeds.

2.2 Effect of vermicompost / organic manures and inorganic fertilizers on rapeseed-mustard

Patel and Shelke (2000) reported that Indian mustard cv. Pusa Bold was supplied with farmyard manure (FYM; 0 and 5 t FYM/ha), P (0, 40, 80 and 120 kg P2O5/ha) and S (0, 30 and 60 kg S/ha) in a field experiment. FYM application increased the mean seed yield (by 7.83%), net returns (by 11.6%), oil (by 67 kg/ha), protein yield (by 53 kg/ha) and nutrient content. Total N, P and S uptake were also higher in FYM-treated vs. FYM-untreated plants, by 19.48, 3.99 and 3.55 kg/ha, respectively. An increase of 1.88 and 4.20 kg/ha available P and S, respectively, in the postharvest soil was also observed. The effects of 80 and 120 P_2O_5/ha applications were similar, and significantly increased seed and stover yields, net returns and oil and protein yields compared with the 0 and 40 P_2O_5/ha applications. Sulfur at 30 and 60 kg/ha resulted in higher seed and stover yields, and higher net returns. Increasing doses of S increased the oil and protein yield, N, P and S uptake, as well as the available P and S in the postharvest soil.

Yadav and Yaduvanshi (2001) reported that the yield of millable cane from the planted sugarcane was not affected by intercropped green manuring or plant arrangement but was increased by N fertilizer after both wheat and mustard. The residues from the green manuring and N fertilizer both increased the yield of the following crop of ratoon sugarcane by 9-10% with the residues increasing the numbers and length of millable canes and the N fertilizer increasing the number, girth and weight of the millable canes. None of the treatments affected the quality of cane juice in either the planted cane or the ratoon crop. Residues from the green manures and the N fertilizer treatments increased the organic carbon content and available N in the soils.

Jat *et al.* (2000) conducted a field experiment to study the response of Indian mustard cv. Pusa Jai Kisan with 5 levels of FYM + N and 4 levels of P. Seeds were sown on 22 October 1997. The treatments comprised: FYM + 0 N, 5 t FYM + 30 kg N, 5 t FYM + 60 kg N, 10 t FYM + 30 kg N, and 10 t FYM + 60 kg N/ha in main plots, and 0, 10, 20 and 30 kg P_2O_5/ha in subplots. Application of up to 10 t FYM + 30 kg N and 20 kg P_2O_5/ha significantly increased plant height, dry matter accumulation, number of primary and secondary branches, number of siliquae per plant, number of seeds per siliqua and seed yield over the control. Harvest index was not affected significantly by FYM + N and P.

Patel and Shelke (1999) revealed that the vegetative growth characters of mustard [*Brassica juncea*] were increased by farmyard manure (5 t/ha) during both years. These parameters were also increased significantly by increasing levels of phosphate and sulphur up to 120 kg P_2O_5 and 60 kg S per hectare, respectively. Application of farmyard manure gave greater absolute growth rate (AGR), leaf area index (LAI), specific leaf area (SLA), biomass duration (BMD) and crop growth rate (CGR) as compared to controls.

RenShih and FeiNeng (2000) conducted a pot experiment to assess the effect of different kinds of composts on the growth and nitrogen (N) composition of Chinese mustard (*Brassica chinensis*) in acid red soil. Pea residue compost, cattle manure compost, two pig manure composts (A and B), a lime-chemical fertilizer treatment and a control plot of conventional chemical fertilizer were used. The plants were harvested at 37 days after sowing and the growth and N composition of these plants were measured. The soil was also sampled, and selected chemical properties were determined after harvesting the plants. The results showed that different composts affected the growth and soil chemical properties significantly. The pH, NO_3-N, NH_4-N, electrical conductivity, and 1N ammonium acetate exchangeable K, Ca, Mg, Al, Mn, and Fe were all significantly affected by the compost treatment. The growth of plants in the control treatment was significantly lower than that of the compost-treated and lime-treated plants, suggesting that the acid Oxisol is unfavourable for the growth of Chinese mustard. Some composts could increase the growth of Chinese mustard. The lime-treated plants had higher concentrations of chlorophyll a and chlorophyll b than those of the compost-treated plants. There were no significant differences between treatments in the concentrations of chlorophyll a and chlorophyll b, however, there was a close correlation between the total chlorophyll concentrations and the shoot yield of the plants. The NO_3-N, soluble reduced N, and insoluble N concentrations in leaf blades and petioles of Chinese mustard varied significantly according to the compost applied. The pig manure compost B could adequately supply nutrients especially N for plant growth and caused little NO3-N accumulation in plant tissues.

Kumar *et al.* (2000) conducted a field experiment to study the direct and residual effects of different organic (farmyard manure, crop residues or green manures) and inorganic (urea, single superphosphate or potassium chloride) sources of fertilizers in a mustard (*Brassica juncea*)-rice (*Oryza sativa*) cropping sequence in acid lateritic sandy clay loam soil at Kharagpur, West Bengal, India. There was an increase in mustard yield by about 165% at the highest rates (60 kg N, 36 kg P and 24 kg K/ha) of fertilizer application. But there was no significant difference between inorganic or combined organic and inorganic fertilizer sources. Rice showed a 9-21% increase in grain yield when mustard crop residue or green manure (*Sesbania aculeata*) was applied compared with an untreated control. The organic materials applied alone or in combination with inorganic fertilizer gave greater residual soil fertility in terms of increase in organic carbon content from 0.36% to as high as 0.61% and the available N, P and K in the 2-year cropping cycle.

Patel *et al.* (1996) conducted experiment in India with mustard [*Brassica juncea*] cv. GM-1 and supplied 0, 10 or 20 t farmyard manure (FYM)/ha, 25, 50 or 75 kg N/ha as urea + DAP [diammonium phosphate] or AS [ammonium sulphate] + SSP [single superphosphate]. The P and S uptake and seed and stover yields were significantly higher in treatments where FYM was applied at either rate. N and S contents in seeds and stover, and N, P and S uptake and seed and stover yields increased with increasing N rate. The application of the S-containing source gave significantly higher N, P and S contents in seeds and stover, higher uptake of N, P and S, and higher seed and stover yields than the S-free fertilizer. The N and S contents in seeds and stover and the uptake of N, P and S were closely associated with seed yield.

Aulakh and Pasricha (1998) grew gobhi sarson [*Brassica campestris* var. sarson] cv. Ludhiana 1 in rotation with rice cv. PR 103, with or without a green manure crop of cowpeas grown before sarson and 0, 50, 100 or 150 kg N/ha and 0 or 20 kg S/ha. The seed yield of sarson increased significantly with N rate up to 100 kg/ha, then generally decreased with 150 kg. Green manure crops accumulated 62-86 kg N/ha. In the absence of fertilizer N, green manure significantly increased sarson yield. Green manure + 100 kg N (optimum rate) further improved the yield of sarson. Green manure application to sarson increased yield of the succeeding crop of rice. Protein concentration in sarson seed increased significantly with optimum N, optimum N + S and optimum N + S + green manure. Optimum N + S + green manure increased the oil yield to 992 kg/ha compared with 518 kg in the control.

Jakhar and Singh (2004) conducted a field experiment to study the residual influence of graded levels of FYM (0, 5 and 10 tonnes ha^{-1}) phosphorus (0, 20, 40 and 60 kg P_2O_5 ha^{-1}) and zinc (0, 5 and 10 kg Zn ha^{-1}) on growth, yield and quality of mustard [*Brassica juncea*]. The pooled mean plant height, number of siliquae per plant, test weight, seed and stover yield, protein and oil content and oil yield increased significantly due to the residual effect of 10 t FYM ha^{-1} Residual effect of 40 kg P_2O_5 ha^{-1} significantly increased the pooled mean plant height, number of siliquae per plant, test weight, seed yield, stover yield. 10 kg Zn ha-1 which was applied to preceding crop, recorded perceptible improvement in plant height, number of siliquae per plant, test weight, seed and stover yields, protein and oil content and oil yield..

Premi *et al.* (2005) conducted a field experiment to study the effect of organic and inorganic nutrients on the growth, yield attributes, seed yield and oil content of Indian mustard. Application of vermicompost at 5.0 t/ha + 75% recommended dose of fertilizer (80 kg N and 40 kg P_2O_5/ha) recorded maximum plant height, number of primary and secondary branches per plant, number of siliquae per plant and number of seeds per siliqua, which in turn resulted in higher seed yield. It was at par with farmyard manure at 10.0 t/ha + 75% recommended fertilizer and recommended dose of fertilizer.

Kumar *et al.* (2004) conducted a field experiment to determine the effects of farmyard manure (5.0, 10.0 and 15.0 t/ha) and vermicompost (2.5, 5.0 and 7.5 t/ha) on the yield, yield components and oil content of Indian mustard cv. RH - 30. The maximum seed yield (1460 kg/ha) of Indian mustard was recorded with recommended NPK fertilizer rate (80 : 40 : 40 kg/ha), which was at par with 7.5 t vermicompost (1310 kg/ha) and 15.0 t farmyard manure/ha (1340 kg/ha). The yield components also followed a similar pattern. The maximum additional net return of Rs. 5999/ha was obtained with recommended fertilizer rate followed by 15.0 t farmyard manure/ha (Rs. 3910/ha). The oil content was not significantly influenced by the different treatments.

Abraham and Lal (2003) conducted a field experiment to investigate the combined effects of NPK fertilizer (100 and 33% of the recommended dose), organic manures (farm compost + vermicompost and farm compost + poultry manure) and biofertilizers (phosphate solubilizing bacteria (PSB) + *Rhizobium/Azospirillum* and PSB + 2 foliar applications of 33% cow's urine) on the productivity of the soyabean-mustard-fodder cowpea cropping system. Farm compost + poultry manure or vermicompost in combination with inorganic fertilizers showed synergistic effects on the growth and yield of the crops. The values obtained for most of the parameters with 100% recommended fertilizer dose were higher than those with lower dose of fertilizers, but the latter were statistically at par with the former. PSB + cow's urine recorded higher values of dry matter accumulation than dual inoculation of PSB and Rhizobium in fodder cowpea. The percentage of organic carbon and available nutrient status of P_2O_5 and K_2O in the soil also increased due to the integration of organic and inorganic sources of nutrients.

Abraham and Lal (2002) reported that yield attributes, and oil and protein contents of mustard seed (var. Pusa Bold) were compared after application of different fertilizers in a cropping system of soybean (kharif)/mustard (rabi)/fodder cowpea (zaid) on a sandy loam alluvium at the Allahabad Agricultural Institute, India. Treatments were 33% recommended dose of NPK, 100% recommended dose of NPK, and combinations of 33% NPK with farm compost + Vermicompost, farm compost + poultry manure, phosphate solubilizing bacteria (PSB) + *Rhizobium or Azospirillum* and PSB + foliar application of 33% cows urine. At the end of the experiment, seed yield and biological yield were found greatest in the 100% NPK treatment (3486.0 and 13270.0 kg/ha respectively). Seed oil and protein content reached the highest levels after 33% NPK/PSB + cows urine (33.06

%) and 33% NPK/PSB + *Rhizobium or Azospirillum* (5.147 %) respectively. Soil organic carbon was highest in the 33% NPK/farm compost + Vermicompost treatment (0.714 %) compared to 0.565 % in the unfertilized soil.

Singh (2007) carried out a field experiment to popularize the summer groundnut cultivation in multiple cropping of green gram-Indian mustard-summer groundnut on a nutrient-deficient soil. The treatments comprised a control, conventional system of recommended dose of fertilizer (RDF) alone and in combination with farmyard manure (FYM) at 2, 4, 6, 8, 10 and 12 t/ha for green manure; FYM was not applied to the succeeding crop of mustard and summer groundnut, which were grown on residues of different levels of FYM and RDF. Recommended doses of 20 : 50 kg NP/ha to green gram, 120 : 40 : 40 kg NPK/ha to mustard and 15 : 30 : 45 kg NPK/ha were given. The application of 20 kg N + 50 kg P_2O_5 in combination with FYM at 10 t/ha registered significantly higher growth, yield components and grain yield of green gram (5.29 q/ha) over the control and conventional system of RDF. The integration of residue of FYM at 10 t/ha with 120 kg N + 40 kg P_2O_5 + 40 kg K_2O ha^{-1} significantly increased the growth and yield traits of mustard, which culminated into a significant increase in seed yield of mustard (24.48 q/ha). The application of 15 kg N + 30 kg P_2O_5 + 45 kg K_2O/ha in conjunction with the remaining residue of 10 t FYM/ha recorded significantly higher pod yield of summer groundnut by 22.21 q/ha over the control and conventional system of RDF. The growth and yield-contributing characters noted in groundnut were concordant to the pod yield of groundnut. The uptake of N, P and K was increased under the different crops of the cropping system when supplied with the RDF in combination with FYM. Analysis of soil after harvesting of the different crops of the sequence showed a significant build up of N, P and K with the application of FYM. The population of earthworms was higher in the soil receiving plenty of FYM, inoculated with vermicompost.

Satyajeet *et al.* (2007) conducted a field experiment to study the residual effect of integrated nutrient management treatments on available NPK and organic carbon in pearl millet - mustard cropping system in loamy sand soils. Different treatments were tried during the *kharif* season, while only the residual effect on succeeding mustard (cv. RH - 30) crop was seen in the *rabi* season. Hybrid HHB 117 recorded the highest yield over rest of the cultivars. The grain yield was highest with 100% RD in conjunction with vermicompost and biofertilizer. Application of 100% RD and 75% RD + vermicompost + biofertilizer also gave comparable yields. The treatments where inorganic fertilizers were applied in conjunction with organic sources recorded significantly higher available nitrogen and phosphorus and organic carbon in soil. Higher organic carbon was recorded with hybrids over the composites.

2.3 Effect of vermicompost and inorganic fertilizers on soil properties :

Janardhan *et al.* (2006) conducted a field experiment consisted of three organic sources, viz., farmyard manure (FYM), vermicompost, and poultry manure; and one inorganic source, i.e., urea (in different combinations of 25, 50, 75 and 100% recommended nitrogen compared with no nitrogen), and recommended level of FYM (20 tonnes/ha per year) and fertilizers (250 kg N/ha, 100 kg P/ha and 100 kg K/ha). Data on the influence of integrated nitrogen management practices on the chemical properties of mulberry soil, i.e., pH, electrical conductivity, organic carbon, available nitrogen, available phosphorus and available potassium. The results indicated that irrigation without nitrogen fertilizer application puts a greater drain of native nitrogen in the soil by plant uptake. It is necessary to apply the recommended level of nitrogen per year for sustained productivity.

Teixeira *et al.* (2006) reported that the effect of different combinations of preparation and soil treatment (calcareous and organic and/or mineral fertilizer) on the physico-hydrological characteristics of an Argissolo Amarelo typic dystrophic soil in Capao do Leao, RS, Brazil, was determined. Treatments included: (T_1) no calcareous and no fertilizer; (T_2) calcareous humus; (T_3) NPK + calcareous; (T_4) calcareous; (T_5) humus; and (T_6) humus + P + calcareous. The humus used was obtained from vermicomposting of bovine manure. Deformed and not deformed soil samples were collected from experimental plots cultivated with rye grass (*Lolium multiflorum*) pasture under no-tillage system, and were analysed for soil density, macro- and microporosity, total porosity, organic matter, water retention, available and stored water. There was no statistical difference found between the soil density, microporosity, macroporosity, total porosity and available water. However, the treatments showed unacceptable rates of gaseous diffusion (< 0.10 m3) for macroporosity. T_2 and T_5 have higher organic matter content but not significantly different with T_3 and T_6. The greatest change for the retention curves was observed for T_1, which may be due to the effect of different fertilizers on the soil physical characteristics. Significant differences in stored water were found among the treatments.

Mohanty *et al.* (2005) conducted an investigation to study the direct and residual effects of organic manures on the crop performance in a groundnut-maize sequence. Treatments comprised : NK + 100% P through farmyard manure (FYM), NK + 100% P through poultry manure, NK + 100% P through vermicompost and NK + 100% P through sewage sludge and NK + 100% P though inorganic single superphosphate. Organic manures and inorganic single superphosphate were all applied at 34 kg/ha. In both crops, the organic source had a significant effect on the uptake of NPK compared to the inorganic and control treatments. The highest N uptake in groundnut stem was recorded from poultry manure (520.6 mg/pot), while that in kernel was recorded from FYM treatment (459.86 mg/pot). Similarly, poultry manure accounted for the highest P uptake in groundnut kernel (90.1 mg/pot). Poultry manure was at par with FYM and recorded the highest K uptake in groundnut kernel (87.63 and 85.69 mg/pot, respectively). The residual effect of organic manures on the subsequent crop maize was more pronounced than inorganic fertilizer. Among organic manures, FYM proved significantly better in N (254 mg/pot) and K uptake (122.58 mg/pot).

Arancon *et al.* (2006) studied that the effects of applications of food waste and paper waste vermicomposts on some soil chemical and biological properties in field plots planted with strawberries. Six-week old strawberries (*Fragaria ananasa*, var. Chandler) were transplanted into 4.5 m^2 raised beds under a plastic tunnel structure measuring 9.14

× 14.6 × 3.6 m. Vermicompost were applied at rates of 5 or 10 t ha^{-1} supplemented with inorganic fertilizers to balance fertilizer recommendations for strawberries of 85 – 155 – 125 kg NPK ha^{-1}. Total extractable N, NH_4-N, NO_3-N and orthophosphates did not differ significantly between treatments, except on the last sampling date (harvest date) in which significantly greater amounts of NH_4 - N, NO_3 - N and orthophosphates ($P \leq 0.05$) were recorded in vermicompost-treated soils than in the controls. Two major results of vermicompost applications to soils were increased in dehydrogenase activity and microbial biomass - N which were not dose-dependent. Increased dehydrogenase activity and microbial biomass - N was correlated positively with the increased amounts of NH_4 - N, NO_3 - N and orthophosphates in the vermicompost-treated plots than in the controls. Increases in microbial populations and activities are key factors influencing rates of nutrient cycling, production of plant growth-regulating materials, and the build-up of plant resistance or tolerance to crop pathogen and nematode attacks.

Ferreras *et al.* (2006) conducted a field experiment to assess the response of selected soil physical, chemical and biological properties, after two applications of different organic amendments to a soil with an extended horticultural use. Vermicompost from household solid waste (HSW) and from horse and rabbit manure (HRM), and chicken manure (CM) were applied at rates of 10 and 20 Mg ha-1. The proportion of water stable soil aggregates (Ws) was significantly higher ($p < 0.05$) in HSW, HRM and CM at 20 Mg ha^{-1}. The proportion of ethanol stable soil aggregates (Es) was significantly higher in HSW, HRM and CM at 20 Mg ha^{-1}, and CM at 10 Mg ha^{-1}. After the first amendment application, HSW and HRM at 20 Mg ha^{-1} resulted in higher soil organic carbon (SOC), while all the treatments showed a significant increase after the second amendment application. Linear relationships were found between Ws and Es with SOC. An increment in microbial respiration in all the amended plots was observed with the exception of HRM at the rate of 10 Mg ha^{-1}.

Joshi *et al.* (2005) conducted a study to determine the potential of vermicompost as a soil stabilizer, nutrifier and stimulator of microbial activities. Vermicompost was produced using *Eisenia fetida* with cow dung and leaf litter. Results showed that the physicochemical properties of the soil (e.g., temperature, pH, moisture content, alkalinity, available P, organic matter, N and C : N ratio) were improved with vermicompost compared with the soil alone. Observations showed multifold increase in the total colony counts of fungal populations wherein *Deuteromycotina* had the maximum number while *Ascomycotina* had the minimum number during decomposition. The species identified were *Mucor, Rhizopus, Penicillium, Syncephalastrum, Fusarium, Cunninghamella, Trichoderma and Aspergillus*..

Hernandez *et al.* (2005) reported that rates of 0, 20, 40 and 60 tonnes ha^{-1} of a vermicomposted mixture of pressmud cake vermicompost and bovine manure (1 : 1) were added to a clay soil to evaluate the effects on its physical properties. The vermicompost addition took place in January 2003 in Tabasco, Mexico. The soil was kept without tillage during 18 months. Sampling was made in June 2004. Bulk density, dry aggregate stability, wet aggregate stability and soil total carbon were measured. The structure and macroaggregates were visualized through thin section techniques and microscopy. Bulk density decreased with the increase of the vermicompost rate (r^2 = 0.09945, p = 0.06). In thin sections, a change in the structure of the soil surface was observed in both 40 and 60 tonnes ha^{-1} treatments; both in amount of macroaggregates and in porosity. The size distribution of wet aggregates indicate that there were more stable macroaggregates in soil treated with high amendment rates. The lowest carbon concentration was found in microaggregates (250 micro m), while the highest carbon concentration was present in small macroaggregates.

Barani and Anburani (2004) conducted an experiment with okra cv. *Arka Anamika* with 18 treatments, involving application of farmyard manure (FYM; at 12.5, 25 and 37.5 t/ha), inorganic fertilizer (at 50, 75 and 100% of the recommended dose of NPK of 40 : 50 : 30 ka/ha), vermicompost (at 3, 4 and 5 t/ha), and a control (application of the recommended dose of NPK). Application of FYM at 25 t/ha, along with 75% of the recommended dose of inorganic fertilizer and vermicompost at 5 t/ha, recorded the highest nutrient (N, P and K) uptake and postharvest available soil nutrients.

Arancon *et al.* (2005) reported that the vermicomposts were incorporated into the upper 10 cm of soil and supplemented, based on chemical analyses, with amounts of inorganic NPK fertilizers calculated to equalize initially with the rates of 95 - 95 NK kg/ha applied to the inorganic fertilizer control plots. Phosphorus was determined to be adequate in soils at the experiment site so was not added. All treatments were replicated four times in a randomized complete block design. The vermicompost applications increased the growth and yields of peppers significantly; including increased leaf areas, plant shoot biomass, marketable fruit weights and decreased yields of non-marketable fruit. Application of vermicomposts to soils increased their microbial biomass and dehydrogenase activity. Humic materials and other plant growth-influencing substances, such as plant growth hormones, produced by microorganisms during vermicomposting, and produced after increased microbial biomass and activity in soils, may have been responsible for the increased pepper growth and yields, independent of nutrient availability.

Bhalerao *et al.* (2005) conducted a field experiment to assess the possibility of replacing chemical fertilizers with organic material in suru sugarcane and its effects on soil properties, nutrient uptake, yield and quality of the crop. The treatments comprised a recommended dose as per soil test (RST; 400 : 140 : 105) (T_1), 125 t/ha yield target with 10 t farmyard manure (FYM) + urea blended with neem cake (UBNC) (T_2), 80% RST + 4.5 t pressmud cake (PMC) + 1 t spent wash ash (SWA) + biofertilizers (T_3), 80% RST + 10 t FYM + biofertilizers (T_4), 80% RST + 5 t vermicompost + UBNC + biofertilizers (T_5), 80% RST + 10 t trash compost + biofertilizers (T_6), 60% RST + 9 t PMC + 2 t SWA + UBNC + biofertilizers (T_7), 60% RST + 20 t FYM + UBNC + biofertilizers (T_8), 60% RST + 10 t vermicompost + UBNC + biofertilizers (T_9), and 60% RST + 20 trash compost + UBNC + biofertilizers. The biofertilizers used were *Azotobacter, Acetobacter, Azospirillum* and P solubilizers, each at 1.25 kg/ha. Approximately 40% chemical fertilizers can be substituted using either 9 t PMC + 2 t SWA + UBNC + biofertilizers or 20 t FYM + UBNC + biofertilizers. There were no changes in soil pH and electrical conductivity. However, organic C content and N, P and K uptake were increased in all the treatments where the organic matter was used.

Substitution of chemical fertilizers either with vermicompost or trash compost was not economical but were beneficial for soil properties.

Singh *et al.* (2005): conducted an experiment to study the efficacy of urea in integration with *Azolla* and vermicompost in rainfed lowland rice (*Oryza sativa*). The results indicated that the integration of chemical fertilizer with *Azolla* improved the yield attributes and yield of rice. Effective substitution of the recommended N dose of rice could be done up to 33% by vermicompost. Combined application of inorganic and organic source had better build up of soil organic C and available N, P and K after crop harvest.

Gholve *et al.* (2005) conducted a field experiment with pigeon pea-pearl millet (2 : 2) intercropping system involving 10 treatments, i.e. an absolute control, 50 and 100% recommended dose of fertilizer (RDF), farmyard manure (FYM) at 5 t/ha, vermicompost at 3 t/ha, 50% RDF + FYM, 50% RDF + vermicompost, 50% RDF + biofertilizer (*Azospirillum* for pearl millet and *Rhizobium* for pigeon pea), 50% RDF + FYM + biofertilizer, and 50% RDF + vermicompost + biofertilizer. The RDF for pigeon pea and pearl millet was 25 : 50 : 0 and 60 : 30 : 30 kg N : P_2O_5 : K_2O/ha, respectively. The maximum productivity and net returns in addition to improvement in soil fertility status and chemical properties could be possible from pigeon pea + pearl millet intercropping system under dryland condition with the application of 50% RDF of the respective crops on the basis of area proportion + vermicompost at 3 t/ha or FYM at 5 t/ha + biofertilizer.

Sharma *et al.* (2003) conducted a field experiment to evaluate the effects of organic manures and chemical fertilizers, alone or in combination, on the yield of turmeric. Uniform mother rhizomes of turmeric cv. Surma were planted in the last week of June. Farmyard manure (FYM) and vermicompost were incorporated in the soil before sowing, and 175 kg N, 60 kg P_2O_5 and 125 kg K_2O/ha were given as recommended dose of fertilizers (RDF). Recommended practices for turmeric cultivation were adopted, and the crop was harvested in the following April. The following treatments were established: control; 10 t FYM/ha; 10 t vermicompost/ha; 100% RDF; 50% RDF; 50% RDF + 5 t FYM/ha; 50% RDF + 5 t vermicompost/ha; 50% RDF + 10 t FYM/ha; 50% RDF + 10 t vermicompost/ha; and 50% RDF + 5 t FYM/ha + 5 t vermicompost/ha. Continuous application of chemical fertilizers reduced turmeric yield in the subsequent year, whereas addition of FYM or vermicompost enhanced the yield of turmeric by 7 - 10% over the preceding year. Application of 50% RDF + 10 t vermicompost/ha improved soil porosity, reduced soil bulk density and increased organic carbon content (from 0.44 to 0.72%). This treatment recorded the highest yield (250.4 q/ha), net return (Rs 192 785/ha) and benefit : cost ratio (3.35).

Hangarge *et al.* (2004) conducted a field experiment to study the influence of vermicompost and other organics on the fertility and productivity of soil (Vertisol) under chilli - spinach cropping system in Parbhani, Maharashtra, India. The application of vermicompost at 5 t ha^{-1} + organic booster at 1 litre m^{-2}, and soil conditioner (Tera care) at 2.5 t ha^{-1} + organic booster at 1 litre m^{-2} enhanced the availability of N, P, K and organic C content in soil. The recommended rates of NPK and organic sources each alone did not have any significant effect. The combined effect of inorganic + organic sources proved to be better than either organic alone or combination of organic + inorganic fertilizer.

Rajkhowa *et al.* (2003) studied that the effect of vermicompost (VC) alone or in combination with fertilizers on the performance of green gram cv. Pratap in the summer season on 1998 on the sandly loam soil of Jorhat, Assam, India. The treatments included: a control; 100% fertilizer (N at 15 kg/ha + P at 35 kg/ha); 100% fertilizer + VC at 2.5 t/ha; 75% fertilizer + VC; 50% fertilizer + VC; VC alone; and FYM at 2.5 t/ha. VC alone or in combination with fertilizers improved the N, P and K status, and organic carbon content of the soil. N and P uptake was higher with the VC treatment combined with 100 or 75% fertilizer than the other treatments. The highest number of nodules per plant (24.33 nodules/plant) was obtained in the treatment 75% fertilizer + VC.

Kademani *et al.* (2003) conducted a field experiment to study the integrated effect of organic and inorganic sources of nutrients on uptake of nutrients by sunflower and their availability after harvest. The organic sources included were maize residue, cotton stock, FYM each @ 5 t ha^{-1} and vermicompost @ 2 t ha^{-1}. The inorganic fertilizer levels were 0, 50, 75 and 100% recommended dose of fertilizer. The highest uptake of NPK was recorded in vermicompost treatment followed by FYM, cotton stock and maize residue. Among inorganic fertilizer 100 per cent RDF has given highest uptake of NPK followed by 75 and 50 per cent RDF. Available N, P, K and S in soil at harvest of crop was highest with application of vermicompost @ 2 t ha^{-1} followed by FYM. Among the fertilizer levels, 100 per cent RDF has given higher available N, P, K and S than at lower levels of fertilizer.

Bhadoria *et al.* (2003) carried out field experiments to evaluate the relative efficacy of organic manures in improving the productivity and pest tolerance of rice growing in a lateritic soil. The effects of three commercial manures: processed city waste (PCW), vermicompost (VC) and oil cake pellets (OCP), were assessed in comparison to farmyard manure (FYM) and inorganic fertilizer all at the same total N applied. Of the organic manures tested, FYM produced the maximum straw and grain yields. Differences in yield among the organic manure treatments were mainly attributed to variation in the amounts of available N, P, K and micronutrients. Effect of manures on soil physical condition was not studied. The uptake of N, P and K by rice plants with FYM was significantly greater than all other commercial manures and inorganic fertilizer. The tolerance of rice plants to attack by pathogens and pests, measured in terms of grain yield was highest in the treatment with FYM. Among the commercial manures PCW showed the greatest promise and emerged as a potential alternative to FYM.

Hati *et al.* (2006) conducted a field experiment to study the effects of combined use of inorganic fertilizer (NPK) and organic manure (farmyard manure) on soil physical properties, water - use efficiency, root growth and yield of soyabean [*Glycine max* (L.) Merr.] in a soybean-mustard cropping system. Application of 10 Mg farmyard manure and recommended NPK (NPK + FYM) to soyabean 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. The surface (0-15 cm) soil of the plots receiving both farmyard manure and recommended NPK had larger mean weight diameter (0.50 mm) and a higher percentage of water stable aggregates (55%) than both the inorganically fertilized (NPK) (0.44 mm and 49%) and unfertilized control plots (0.41 mm and 45.4%). The saturated hydraulic conductivity (13.32 × 10 - 6 m s^{-1}) of the NPK + FYM treatment of the 0 - 7.5 cm depth was also significantly greater than that of the NPK (10.53 × 10-6 m s^{-1}) and control (8.61 × 10-6 m s^{-1}) treatments. The lowest bulk density (1.18 Mg m^{-3}) in the 0 - 7.5 cm layer was recorded in NPK + FYM whereas it was highest in the control plots (1.30 Mg m^{-3}). However, at sub - surface (22.5 - 30 cm) layer, fertilizer and manure application had little effect on bulk density and saturated hydraulic conductivity. 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. The RLD showed a significant and negative correlation (r = -0.88**) with the penetration resistance.

Patra *et al.* (2006) conducted a field experiment for 7 years continuously to evaluate the influence of combined application of organic and inorganic fertilizer on soil fertility buildup and nutrient uptake in mint (*Mentha arvensis*) and mustard (*Brassica juncea*) cropping sequence. Maximum organic carbon was observed under full supply of organic manure (T_2; FYM at 20 t ha^{-1}) averaged across all the Stages of cropping sequence. It was increased by 38, 50, and 51% in T_2 in stages I (after mint harvest / presowing of dhaincha), II (after incorporation of dhaincha (*Sesbania aculeata*) / presowing of mustard), and III (after harvest of mustard / preplanting of mint), respectively, over their respective controls. In general, magnitude of organic carbon was recorded higher in Stage II after green manuring of Sesbania compared with Stages I and III. Nitrogen availability in treated plots was increased by 26.0 - 89.9, 15.2 - 64.5, and 4.9 - 52.0% in Stages I (after mint harvest / presowing of Sesbania), II (after incorporation of dhaincha / presowing of mustard), and III (after harvest of mustard / preplanting of mint), respectively, over their respective control. Average across all the three Stages showed a positive balance of nitrogen (N), phosphorus (P), and potassium (K) in soil under different treatments. Mean of the three Stages indicated that maximum available N, P, and K were increased by 36.1, 129.0, and 65.20% in T_4 (N : P : K : 133 : 40 : 40 and FYM at 6.7 t ha-1), T4 (N : P : K :: 133 : 40 : 40 and FYM at 6.7 t ha^{-1}), and T3 (N : P : K :: 100 : 30 : 30 and FYM at 10 t ha^{-1}), respectively, over their initial status. Supply of organic and inorganic fertilizer (T_4; N : P : K :: 133 : 40 : 40 and FYM at 6.7 t ha^{-1}) was found most suitable combination with respect to N, P availability in soil, and productivity of mint and mustard crop.

DeZhong *et al.* (1996) ivestigated the effects of partial replacement of inorganic fertilizers with groundnut cake, rapeseed cake or cattle manure on growth and quality of tobacco. Alkali-soluble N in the soil was increased by organic fertilizers in the order groundnut cake > rapeseed cake > cattle manure. N concentration in tobacco leaves was decreased when inorganic fertilizers were partially replaced with organic manures, although groundnut cake and rapeseed cake increased N content in roots. Uptake of P and K was increased by combined use of organic and inorganic fertilizers. Replacement of 25% of inorganic fertilizer with organic fertilizers gave improved growth and disease resistance. The best results were given by rapeseed cake + inorganic fertilizers, followed by groundnut cake + inorganic fertilizers and then cattle manure + inorganic fertilizers.

Zhu *et al.* (1993) grew rape cv. Zhongyou 21 in pots filled with 17 kg local brown red soil (pH 5.57, OM 0.91%, 11.2 p.p.m. readily available P and 136 p.p.m. K) and supplied with 0, 215, 430, 645, 860, 1075, 1290 and 1505 g urban refuse compost / pot. All composting treatments improved plant growth and development and increased yields. The addition of 215 g compost / pot produced the highest yield of 35.7 g / pot compared with 25.5 g / pot in the control. Refuse compost increased seed oleic acid content and decreased erucic acid content, and had no significant effect on protein content. Refuse compost also markedly improved soil properties. Ca, Mg, Mn, Fe, Zn, Pb and Cd accumulated in the shoots and seeds of the plants and in the soil to different degrees. The concentrations of Pb and Cd remained below their environmental thresholds.

Sikora and Enkiri (2001) conducted a study to compare the effects of blends of sewage sludge compost (C) with 15^{N} urea (U) or $15^{NO}{}_3$ (N) fertilizers alone on tall fescue (*Festuca arundinacea*) growth and N uptake. Blends which provided 0, 20, 40 or 60 mg N kg^{-1} application rate as compost N and 120, 100, 80 or 60 mg N kg^{-1} as fertilizer N, respectively, were added to sassafras sandy loam soil (Typic Hapludults). Fescue was grown on the blends in a growth chamber for 98 days. Fescue yields recorded by clippings taken at 23.46 and 98 days and roots harvested after the 98 - day clipping increased with increasing fertilizer level for both NH_4NO_3 and urea and with or without compost. Nitrogen uptake by fescue responded similarly to yield with increases recorded with increasing fertilizer levels with or without compost. Paired comparisons based on cumulative 98 - day clippings data showed that yields from blends were equal to yields from fertilizer treatments containing the same percentage of fertilizer as the blends. These data indicated that compost did not provide sufficient plant available N to increase yields or N uptake. None of the blends equaled 120 mg N kg^{-1} fertilizer rate except for 100 mg NH_4NO_3 - or urea-N kg^{-1} - 20 mg compost - N kg^{-1} blends. The data suggest that sewage sludge compost blended with fertilizer at a rate of 2 - 6 t ha^{-1} do not supply sufficient additional available N to increase yield or N uptake over those of fertilizer alone.

Srikanth *et al.* (2000) carried out a field experiment to study the direct and residual effects of enriched composts on soil properties in comparison with FYM, vermicompost and inorganic fertilizers. The soil nutrient value was high in enriched-compost-amended soil after the harvest of first and second crops. There was a slight decrease in the bulk density of the soil after the harvest of second crop in soil amended with compost compared to inorganic fertilizer treatment.

Maheswarappa *et al.* (1999) conducted a field experiment to study the effect of organic manures on physicochemical and biological properties of soil and crop yield of arrowroot [*Maranta arundinacea*] when grown as an intercrop in a coconut garden. FYM and vermicompost (VC) application alone and FYM + NPK application decreased the bulk density, and improved soil porosity and maximum water holding capacity (MWHC), whereas composted coir pith (CCP) generally had less effect except on MWHC.

Organic carbon and pH of the soil was increased to a greater extent under FYM and VC treated plots than with CCP. There was no change in these physico - chemical properties under NPK alone or control treatments. The microbial population and dehydrogenase activity was also higher under FYM and VC treatments compared to CCP treatments, whereas under NPK alone and control there was a decrease in the microbial count and activity. Application of FYM + NPK gave significantly higher yield components and fresh rhizome yield (17.1 t/ha) than FYM, VC, CCP and NPK applied alone.

Chapter 3
Materials and Methods

MATERIALS AND METHODS

The experiment was conducted at the Research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during November 2007 to February 2008 to study the combined effect of vermicompost and inorganic fertizers on growth, yield, chemical composition and oil content of rapeseed cv. SAU Sharisha-1.

3.1 Experimental site and soil

The experimental site was located at $23^0 77'$ N latitude and $90^0 3'$ E longitude with an elevation of 1.0 meter from sea level. The soil of the experimental site belongs to Tejgaon soil series under the Agro-ecological zone Madhupur Tract (AEZ- 28), which falls into Deep Red Brown Terrace Soils. Soil samples were collected from the experimental plots to a depth of 0-15 cm from the surface before initiation of the experiment and analyzed in the laboratory. The morphological characteristics of the experimental field and physical and chemical properties of initial soil are shown in Table 1 and 2.

Table 1. Morphological characteristics of experimental field

Morphological Features	Characteristics
Location	Shere-e-Bangla Agril. University Farm, Dhaka
AEZ No. and name	AEZ-28, Modhupur Tract
General soil type	Deep Red Brown Terrace Soil
Soil Series	Tejgaon
Topography	Fairly leveled
Depth of Inundation	Above flood level
Drainage condition	Well drained
Land type	High land

Table 2. Physical and chemical properties of the experimental soil

Soil Properties			Value
	1.	Particle size analysis of soil	
		% Sand	30.56
		% Silt	37.26
		% Clay	32.15
	2.	Soil texture	Clay loam
B.		**Chemical properties**	
	1.	Soil pH	6.2
	3.	Organic matter (%)	0.75
	4.	Total N (%)	0.073
	5.	Available P %	0.0015
	6	Exchangeable K (me / 100g soil)	0.0013
	7.	Available S %	0.0011
	8.	Available Zn %	0.0000016
	9.	Available B %	0.0000013

3.2 Climate

The experimental area has sub tropical climate characterized by heavy rainfall during May to September and scantly rainfall during rest of the year. The annual precipitation of the site is 2152 mm and potential evapotranspirations is 1297 mm, the average maximum temperature is 30.34^{0}C and average minimum temperature is 21.21^{0}C. The average mean temperature is 25.17^{0}C and average minimum was recorded during rabi season, 2005-06. Temperature during the cropping period ranged from 10^{0}C to 29.2^{0}C. The humidity varies from 61.72% to 70.45%. The day length was reduced to 10.5-11.0 hours only and there was little rainfall from the beginning of the experiment to harvesting.

3.3 Seeds and variety

SAU Sharisha-1, a high yielding and short duration variety of rapeseed *(Brassica campestris)* developed by Shere-e-Bangla Agricultural University, Dhaka was sued. The seeds were collected from The Genetics and Plant Breeding Department of Shere-e-Bangla Agricultural University, Dhaka.

3.4 Land preparation

The land was prepared by repeated ploughing with a disc harrow following with a power tiller. Laddering was done properly, which helped breaking the clods and leveling the land followed by every ploughing. Weeds, stubbles and crop residues were removed from the land.

3.5 Lay out of the experiment

The experiment was laid out in a randomized complete block design (RCBD), where the experimental area was divided into 3 blocks representing the replications to reduce the heterogenetic effects of soil. Each block was divided into 16 unit plots as treatments. Thus the total number of unit plots was 48. The unit plot size was 2m × 2m and plots were separated from each other by (0.5 m). 1.0 m drains separated unit blocks from one another. Treatments were randomly distributed within the blocks. The lay out of the experiment has been shown in Fig - 1.

3.6 Treatments

The experiment consists of 2 Factors i.e. vermicompost and fertilizer each have four levels. Details of factor 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 ha^{-1} + 0 kg K ha^{-1} + 0 kg S ha^{-1} + 0 kg Zn ha^{-1} + 0 kg B ha^{-1} (No Fertilizer)

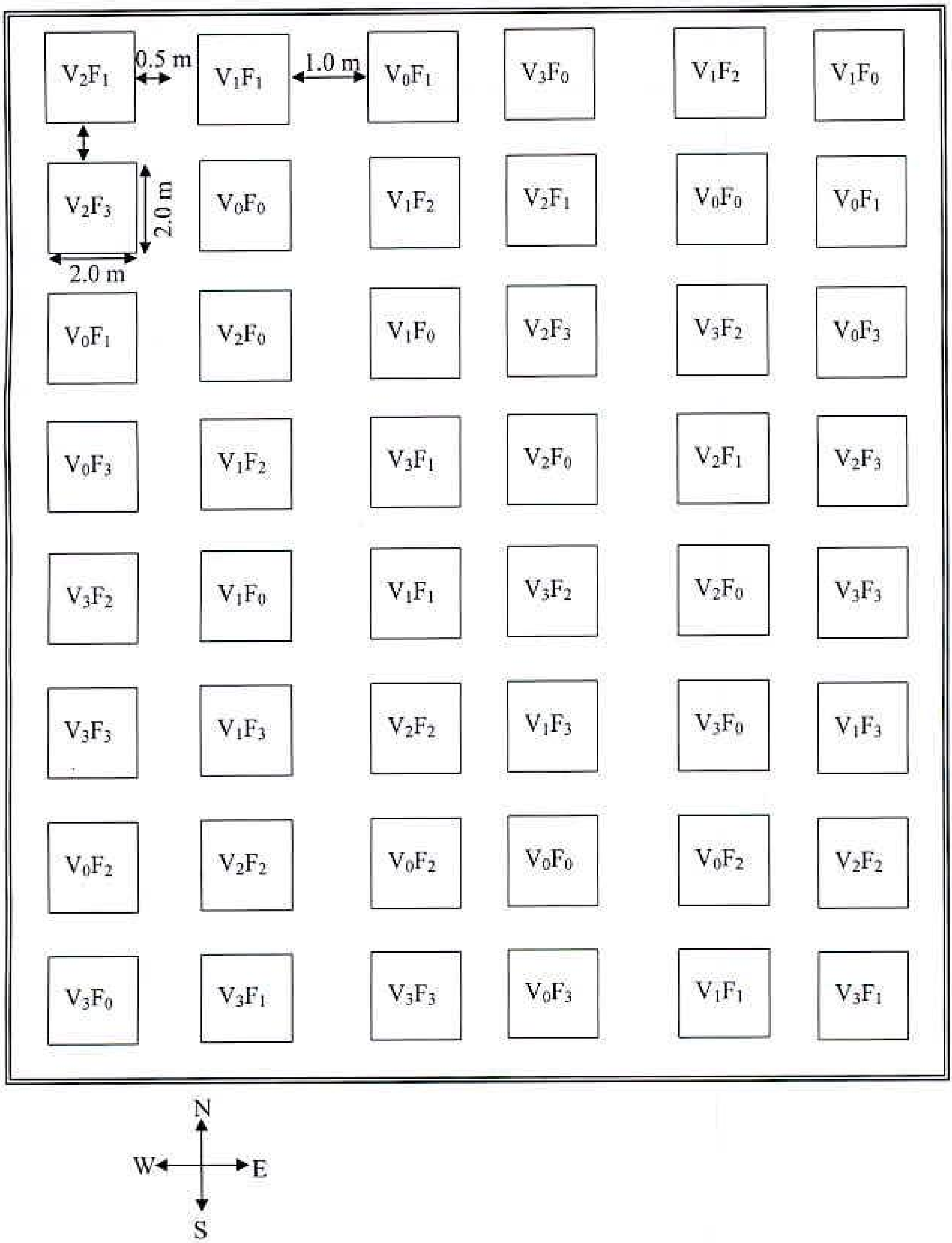
F_1 = 45 kg N ha^{-1} +15 kg P ha^{-1} + 20 kg K ha^{-1} + 12 kg S ha^{-1} + 1.5 kg Zn ha^{-1} + 1 kg B ha^{-1} (Low Fertilizer)

F_2 = 90 kg N ha^{-1} +30 kg P ha^{-1} + 40 kg K ha^{-1} + 25 kg S ha^{-1} + 3 kg Zn ha^{-1} + 2 kg B ha^{-1} (Medium Fertilizer)

F_3 = 135 kg N ha^{-1} + 45 kg P ha^{-1} + 60 kg K ha^{-1} + 40 kg S ha^{-1} + 4.5 kg Zn ha^{-1} + 3 kg B ha^{-1} (High Fertilizer)

Treatment Combinations

V_0F_0 = Control (No vermicompost + No Fertilizer)
V_0F_1 = (No vermicompost + Low Fertilizer)
V_0F_2 = (No vermicompost + Medium Fertilizer)
V_0F_3 = (No vermicompost + High Fertilizer)
V_1F_0 = (Low vermicompost + No Fertilizer)
V_1F_1 = (Low vermicompost + Low Fertilizer)
V_1F_2 = (Low vermicompost + Medium Fertilizer)
V_1F_3 = (Low vermicompost + High NPKSZnB)
V_2F_0 = (Medium vermicompost + No Fertilizer)
V_2F_1 = (Medium vermicompost + Low Fertilizer)
V_2F_2 = (Medium vermicompost + Medium Fertilizer)
V_2F_3 = (Medium vermicompost + High Fertilizer)
V_3F_0 = (High vermicompost + No Fertilizer)
V_3F_1 = (High vermicompost + Low Fertilizer)
V_3F_2 = (High vermicompost + Medium Fertilizer)
V_3F_3 = (High vermicompost + High Fertilizer)



Plot size : 2 m × 2 m (4 m^2)
Plot to plot distance : 0.5 m
Block to block distance : 1.0 m

Figure : 1 Layout of the experimental field.

3.7 Application of vermicompost and fertilizers :

Fertilizers were used as Urea for N; T.S.P. for P; M.P. for K; Gypsum for S; Zinc oxide for Z; and Boric Acid for B. The total required amounts of P,K,S Zn, B and 50% the N were applied plot wise as per treatments after final land preparation and layout of the experiment and were mixed with the soil through hand spading. The rest of the N (Urea) were be applied as top dressing after 22 days of germination and just before flowering. The required amounts of vermicompost as per treatment combinations were applied uniformly in the canals opened just before sowing the seeds of rapeseed in lines.

3.8 Seed Sowing

Rapeseed were sown on the 11th November 2007 in lines following the recommended line to line distance of 30 cm.

3.9 Intercultural Operations

Intercultural operations were done for ensuring and maintaining the normal growth of the crop. The following intercultural operations were done.

3.9.1 Irrigation

Necessary irrigations were provided to the plots as and when required during the growing period of rapeseed crop (20, 40 and 60 days after germination).

3.9.2 Weeding and thinning

Weeds of different types were controlled manually and removed from the field at 12 days after germination. At the same time fist thinning was done. The final weeding and thinning were done after 25 days of sowing. Care was taken to maintain constant plant population per plot.

3.9.3 Insect and pest control

The crop was infested with aphids (*Lipaphis ersimi*) at the time of siliqua filling. The insects were controlled successfully by spraying Syphanon 57 EC @ 2ml / L water. The insecticide was sprayed thrice, the first on 27 December 2007; the second on 06 January 2008 and the last on 13 January 2008. The crop was infested by cut worms at seedling stage and controlled by spraying of Dersban 20 EC. Alternaria blight of rapeseed disease was controlled by spraying Rovral 50 WP. The crop was kept under constant observations from sowing to harvesting.

3.10 Harvesting and threshing

The crop was harvested plot wise when 90% siliquae were matured. After collecting sample plants, harvesting was done on 16 February 2008. The harvested plants were tied into bundles and carried to the threshing floor. The plants were sun dried by spreading the bundles on the threshing floor. The seeds were separated from the stover by beating the bundles with bamboo sticks. Per plot yields of seed and straw were recorded after drying the plants in the sun followed by threshing and cleaning. At harvest, seed yield was recorded plot wise and expressed on hectare basis. Oven dried seeds were put in desiccators for chemical analysis.

3.11 Collection of experimental data

Ten (10) plants from each plot were selected at random and were tagged for the data collection. Data were collected at maturity stage and post harvest stage. The sample plants were uprooted prior to harvest and dried properly in the sun. The seed yield and stover yield per plot were recorded after cleaning and drying those properly in the sun. Data were collected on the following parameters

A. Maturity Stage :	B. Post Harvest Stage :
Plant height	No. of seeds / siliquae
No. of branches / plant	Wt of 1000 seeds
No. of siliquae / plant	Seed yield
	Stover yield

3.12 Collection and preparation of soil samples

Soil samples were collected at a depth of 0-15 cm from the surface. The samples were collected in two installments, initially before manure and fertilizer application to the experimental field and finally after harvest of the crop After removing weeds, plant roots, stubbles, stones, etc. the samples were air dried and ground to pass through a 2 mm (10 mesh) sieve. The samples were then stored in clean plastic bags for chemical and mechanical analyses.

3.13 Analyses of soil samples

Initial soil samples were analyzed for both physical and chemical properties such as texture, pH, organic carbon, total nitrogen, , available P, exchangeable K and available S available Zn available B. These results have been presented in Table 2. The post-harvest soil samples were also analyzed for chemical properties. The soil samples were analyzed following standard methods as follows :

3.13.1 Textural class

Particle size analysis of soil was done by hydrometer method (Bouyoucos, 1926) and the textural class was determined by plotting of values for % sand, % silt and % clay to the Marshall's Triangular Co - ordinate following the USDA system.

3.13.2 Soil pH

Soil pH was measured with the help of a glass electrode pH meter using soil: water ratio of 1: 2.5 as described by Page *et al.* (1989).

3.13.3 Organic matter content

Organic carbon was determined by wet oxidation method as outlined by Black (1965). To obtain the organic matter content, the value of organic carbon was multiplied by van Bammelen factor of 1.73 and the results were expressed in percentage (Page *et al.* 1989).

3.13.4 Total nitrogen

One gram of oven dry ground soil sample was taken into microkjeldahl flask to which 1.1 g catalyst mixture (K_2SO_4 : $CuSO_4$. $5H_2O$: Se = 100 : 10:1), 2ml 30% H_2O_2 and 5 ml H_2SO_4 were added. The flasks were swirled and allowed to stand for about 10 minutes. Then heating (380^0C) was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digest was used for nitrogen determination.

After completion of digestion, 40% NaOH was added with the digest for distillation. The evolved ammonia was trapped into 4% H_3BO_3 solution and 5 drops of mixed indicator of bromocressol green and methly red solution. Finally the distillate was titrated with standard 0.01 N H_2SO_4 until the color changed from green to pink. The amount of N was calculated using the following formula :

$$\% N = \frac{(T\text{-}B) \times N \times 0.014 \times 100}{S}$$

Where,

T = Sample titration value (ml) of standard H_2SO_4

B = Blank titration value (ml) of standard H_2SO_4

N = Strength H_2SO_4

S = Sample weight in gram

3.13.5 Available phosphorus

Available phosphorus was extracted from the soil samples by shaking with 0.5 M $NaHCO_3$ solution at pH 8.5 following Olsen method (Olsen *et al.* 1954). The extracted phosphorus was determined by developing blue color by $SnCl_2$ reduction of phosphomolybdate complex and measuring the intensity of color calorimetrically at 660 mm wavelength and the readings were calibrated to the standard P curve.

3.13.6 Exchangeable potassium

Exchangeable potassium was extracted from the soil samples with 1.0 N NH_4OAc (pH 7) and K was determined from the extract by flame photometer (Black, 1965) and calibrated with a standard curve.

3.13.7 Available sulphur

Available sulphur was extracted from the soil samples with $CaCl_2$ solution (0.15%) as described by Page *et al.* (1989). The S content in the extract was estimated turbidimetrically with spectrophotometer at 420 mm.

3.13.8 Available zinc

Available zinc were extracted from soil by DTPA extraction method (Page *et al.*, 1982). The extractable content of those elements was determined by atomic absorption spectrophotometer.

3.13.9 Available boron

Available boron content in soil was determined by the method described by Hunter (1984). The extracting agent was monocalcium phosphate solution (500 ppm) and the colour was developed by azomethine - H solution. The absorbance was read on spectrophotometer at 555 nm wavelength.

3.14 Chemical analyses of plant samples

3.14.1 Preparation of plant samples

The representative grain and straw samples were dried in an oven at 650_C for about 24 hours before they were ground by a grinding machine. The prepared samples were then stored in paper bags and finally they were kept into a desiccator until analysis was done.

3.14.2 Digestion of plant samples for total nitrogen determination

For the determination of nitrogen 0.1 g of oven dry ground plant sample (both grain and straw separately) was taken in a micro-kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se = 100: 10:1), 2 ml 30% H_2O_2 and 5 ml H_2SO_4 were added into the flask. The flask was swirled and allowed to stand for about 10 minutes. Then heating was continued until the digest was clear and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. The digest were used for nitrogen determination.

3.14.3 Digestion of plant samples for P, K, S, Zn and B determination

Plant sample of 0.5 g (grain or straw) was transferred into dry, clean 100 ml kjeldahl flask. 10 ml of diacid mixture (HNO_3 : $HClO_4$ = 2:1) was added into the flask. After leaving for a while the flasks were heated at a temperature and slowly raised to 200°C. The contents of the flasks were boiled until they became sufficiently clear and colorless. After cooling the digests was transferred into 100 ml volumetric flask and the volume was made up to the mark with distilled water. The digest was used for the determination of P, K, S, Zn and B.

3.14.4 Determination of N, P, K, S, Zn and B from plant samples

3.14.4.1 Nitrogen

Nitrogen contents in the digests were determined by the similar method as described in soil analysis.

3.14.4.2 Phosphorus

Phosphorus was determined following the same procedure of soil analysis using 1ml digest for grain sample and 2 ml digest for straw sample from 100 ml extract.

3.14.4.3 Potassium

Five ml of digest for the grain and 10 ml for the straw was taken and diluted to 50 ml volume to make desired concentration. The absorbance was measured by atomic absorption flame photometer.

3.14.4.4 Sulphur

Sulphur was determined following the same procedure as done in soil analysis \ using 10 ml of digest (both for grain and straw) from 100 ml extract and readings were taken by spectrophotometer at 420 nm of wave length (Hunt 1984).

3.14.4.5 Zinc

Zinc contents in the digests were determined by the similar method as followed for soil analysis.

3.14.4.6 Boron

Boron contents in the digests were determined by the similar method as followed for soil analysis.

3.15 Nutrient uptake

After chemical analysis of grain and straw samples, the nutrient contents were calculated and from the value of nutrient contents, nutrient uptakes were also calculated by the following formula :

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content (\%)} \times \text{Yield (kg/ha)}}{100}$$

3.16 Oil content of seed

Oil content of seed was determined by Nuclear Magnetic Resonance (NMR) technique. For this purpose 25 g clean seed sample was used.

3.17 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.

3.18 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 Discussions

Results and Discussion

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

4.1 Effect of vermicompost and fertilizers on the growth parameters and yield of rapeseed.

4.1.1. Plant height :

The effects of vermicompost and fertilizers alone and in combination of the two sources on the height of rapeseed plant are presented in Table 3. Significant variation was observed in plant height of rapeseed 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 (88.67 cm) and the lowest 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 the reason increasing dose of vermicompost increased plant height. Similar result was reported *Jat et al.* (2000).

Table 3. Effect of vermicompost on the yield contributing characters and the yield of rapeseed

Vermicompost	Plant Height (cm)	1000 seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})
V_0	80.29 c	3.79 b	1.54 c	1.43 c
V_1	85.28 b	3.93 a	1.64 bc	1.62 b
V_2	85.72 b	3.95 a	1.75 b	1.69 b
V_3	88.67 a	3.89 a	1.95 a	2.01 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 4. Effect of fertilizers on the yield contributing characters and the yield of rapeseed

Fertilizer	Plant Height (cm)	1000 seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})
F_0	80.05 d	3.40 b	1.33 c	1.20 c
F_1	81.39 c	3.59 a	1.57 b	1.64 b
F_2	87.97 b	3.50 ab	2.00 a	1.92 a
F_3	90.55 a	3.50 ab	1.97 a	2.00 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.

Rapeseed plants showed significant variation in respect of plant height when fertilizers in different doses were applied (Table 4). Among the different fertilizer doses, F_3 (High fertilizer) showed the highest plant height (90.55 cm), which was not statistically identical with the fertilizer dose F_2 (Medium fertilizer). On the contrary, the lowest plant height (80.05 cm) was observed in F_0 treatment where no fertilizer was). The result agrees well with the findings of Singh (2002).

Combined application of different doses of vermicompost and fertilizer had significant effect on the plant height of rapeseed (Table 5). The lowest plant height (71.77 cm) was observed in the treatment combination of $V_0 F_0$ (No vermicompost and No fertilizer). On the other hand, the highest plant height (97.17 cm) was recorded with $V_2 F_3$ (Medium vermicompost + High fertilizer). Similar result was reported by Jakhar and Singh (2004).

It is evident form the data that vermicompost at the medium rate along with high dose of fertilizer resulted the highest plant height of rapeseed.

Table 5. Effect of Vermicompost and fertilizer on the yield contributing characters and the yield of rapeseed

Vermicompost × Fertilizer	Plant Height (cm)	1000 seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})
V_0F_0	71.77 g	3.38	1.35 h	0.96 f
V_0F_1	74.70 f	3.48	1.33 fgh	1.08 ef
V_0F_2	83.83 d	3.44	1.79 cde	1.83 bcd
V_0F_3	90.87 e	3.35	1.90 bcd	1.84 bcd
V_1F_0	83.20 d	3.43	1.24 gh	1.22 ef
V_1F_1	83.00 d	3.42	1.53 efg	1.62 cd
V_1F_2	91.40 b	3.52	1.78 cde	1.64 cd
V_1F_3	83.53 d	3.53	2.02 abc	2.00 abc
V_2F_0	81.17 e	3.49	1.35 fgh	1.17 ef
V_2F_1	79.87 e	3.50	1.55 efg	1.69 cd
V_2F_2	87.50 c	3.47	2.20 a	2.03 abc
V_2F_3	97.17 a	3.46	1.81 cde	1.88 abc
V_3F_0	84.07 d	3.45	1.59 def	1.44 de
V_3F_1	88.00 c	3.48	1.87 bcde	2.15 ab
V_3F_2	91.97 b	3.55	2.17 ab	2.18 ab
V_3F_3	90.63 b	3.51	2.15 ab	2.28 a
Level of significance	0.01	NS	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 Thousand seed weight

There was a significant positive effect of vermicompost on 1000-seed weight of rapeseed (Table 3). Comparing the effect of different doses of vermicompost, there was no significant difference between vermicompost treatments except control. Thousand seed weight reached a peak (3.95 g) at V_2 treatment, thereafter it declined at the higher dose (V_3). The effect of Fertilizer on 1000-seed weight was also significant (Table 4). The interaction effect of vermicompost and fertilizer on 1000-seed weight was not significant (Table 5).

4.1.3 Seed yield of rapeseed

The seed yield as improved by different doses of vermicompost showed a statistically significant variation (Table 3) Among the different doses of vermicompost the highest grain yield (1.95 t ha^{-1}) was observed in V_3 treatment (6 t ha^{-1}), which was not statistically identical (1 .75 t ha^{-1}) with V_2 treatment (4 t ha^{-1}). The lowest seed yield (1.54 t ha^{-1}) was recorded in the V_0 treatment where no vermicompost was applied and it was closely followed (1.64 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 rapeseed

Application of different doses of fertilizers at different treatments showed a significant variation on the seed yield of rapeseed (Table 4). Among the different combinations of fertilizer doses, F_2 (Medium fertilizer) showed the highest seed yield (2.00 t ha^{-1}), which was closely followed (1.97 t ha^{-1}) by the fertilizer dose F_3 (High fertilizer). On the other hand, the lowest seed yield (1.33 t ha^{-1}) was recorded with F_0 treatment, where no fertilizer was applied.

Combined effects of different doses of vermicompost and fertilizers on seed yield showed a statistically significant variation (Table 5). The highest seed yield (2.20 t ha^{-1}) was recorded in the treatment combination of V_2F_2 (Medium vermicompost + Medium fertilizer) which was statistically similar with the treatment combination of V_3F_2 (High vermicompost + Medium fertilizer) and V_3F_3 (High vermicompost + High fertilizer). On the other hand, the lowest seed yield (1.35 t ha^{-1}) was found in V_0F_0. It is observed that the application of fertilizer combined with organic matter (OM) not only make good use of resources, but also enhance rapeseed yield. The result agrees well with the findings of Jat *et al.* (2000).

4.1. 4 Straw yield

Significant variation in straw yield of rapeseed was observed with different doses of vermicompost (Table 3). Among the different doses of vermicompost V_3 (6 t ha^{-1}) showed the highest straw yield (2.01 t ha^{-1}). On the other hand, the lowest straw yield (1.43 t ha^{-1}) was observed in the V_0 treatment, where no vermicompost was applied.

Straw yield showed significant variation when different doses of fertilizers were applied (Table 4). Among the different combinations of fertilizer, F_3 (High fertilizer) showed the highest straw yield (2.00 t ha^{-1}), which was closely followed (1.92 t ha^{-1}) by the fertilizer dose F_2 (Medium fertilizer). The lowest straw yield (1.20 t ha^{-1}) was observed with F_0 treatment, where no fertilizer was applied.

Combined effect of different doses of vermicompost and fertilizer showed a statistically significant effect on the straw yield of rapeseed (Table 5) .The lowest straw yield (0.96 t ha^{-1}) was observed in the treatment combination of V_0F_0 (No vermicompost and No fertilizer). On the other hand, the highest straw yield (2.28 t ha^{-1}) was recorded with V_3F_3 (High vermicompost + High fertilizer), which was statistically identical with the treatment combinations of V_3F_2 (High vermicompost + Medium fertilizer) and V_3F_1 (high vermicompost + Low fertilizer). The present result agrees well with findings of Patel *et al.* (1996).

4.1.5 Number of pods / plant

Significant variation was observed in the number of pods/plant of rapeseed when different doses of vermicompost were applied (Table 6). The highest number of pods / plant (158.58) was recorded in V_3 (6 t ha^{-1}), and the lowest number of pods / plant

(146.33) 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 material that helped proper growth and development of the rapeseed pod.

Table 6. Effect of Vermicompost on the yield contributing characters of rapeseed

Vermicompost	No. of pods/plant	Pod length (cm)	No. of seeds/ pod	No. of primary branches / plant
V_0	146.33 b	5.98 b	16.60 b	4.27 b
V_1	147.42 b	6.40 a	19.19 a	5.85 a
V_2	156.92 a	6.60 a	18.85 a	5.77 a
V_3	158.58 a	6.40 a	19.52 a	5.44 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 7. Effect of Fertilizers on the yield contributing characters of rapeseed

Vermicompost	No. of pods/plant	Pod length (cm)	No. of seeds/ pod	No. of primary branches / plant
F_0	148.83 d	5.58 b	15.44 c	4.44 b
F_1	150.75 c	6.63 a	17.94 b	5.52 a
F_2	156.67 a	6.82 a	20.77 a	5.94 a
F_3	153.00 b	6.72 a	20.02 a	5.44 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 7). Among the different doses of fertilizers, F_2 (medium fertilizer) showed the highest number of pods/plant (156.67). On the contrary, the lowest number of pods /plant (148.83) was observed with F_0.

The combined effect of different doses of vermicompost and fertilizer on number of pods/plant of rapeseed was significant (Table 8). The highest number of pods/plant (163.33) was recorded with the treatment combination of V_2F_2 (Medium vermicompost + Medium fertilizer). On the other hand, the lowest number of pods/plant (138.67) was found in V_0F_0 treatment (No vermicompost and No fertilizer).

Table 8. Combined effect of vermicompost and fertilizers on the yield contributing characters of rapeseed

Vermicompost × Fertilizer	No. of pods/plant	Pod length (cm)	No. of seeds/ pod	No. of primary branches / plant
V_0F_0	138.67 g	5.40	11.02 e	2.35 d
V_0F_1	140.00 g	6.27	15.35 d	4.02 c
V_0F_2	158.00 bc	6.27	20.02 abc	5.69 ab
V_0F_3	148.67 e	5.53	18.02 c	5.02 abc
V_1F_0	148.33 e	6.60	18.35 bc	5.69 ab
V_1F_1	148.00 e	7.07	18.35 bc	5.69 ab
V_1F_2	144.33 f	5.73	20.02 abc	6.02 ab
V_1F_3	149.00 e	7.13	20.02 abc	6.02 ab
V_2F_0	155.67 cd	6.93	14.02 d	5.02 abc
V_2F_1	154.00 d	5.67	19.33 abc	6.35 a
V_2F_2	163.33 a	5.53	21.02 ab	6.35 a
V_2F_3	154.67 cd	7.00	22.02 a	5.35 abc
V_3F_0	152.67 d	7.13	18.35 bc	4.69 bc
V_3F_1	161.00 ab	6.69	18.69 bc	6.02 ab
V_3F_2	161.00 ab	7.15	20.02 abc	5.69 ab
V_3F_3	159.67 ab	7.13	21.02 ab	5.35 abc
Level of significance	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.

4.1.6 Pod length

Pod length was significantly influenced by vermicompost application however the result did not vary significantly between vermicompost doses (Table 6). The same was true for fertilizer application with a significant difference between F_0 and F_1 or F_2 or F_3, and there was no significant difference between F_1, F_2 and F_3 treatments (Table 7). The pod length varied from 5.40 - 7.15 cm, over the combined Vermicompost and Fertilizer treatments (Table 8) . The interaction effect was not significant indicating that the two factors functioned independently.

4.1.7 Number of seeds/pod

Significant variation was observed in the number of seeds/pod of rapeseed when different doses of vermicompost were applied (Table 6). The highest number of seeds / pod (19.52) was recorded in V_3 (6 t ha^{-1}), and the lowest number of seeds/pod (16.60) was recorded in the V_0 treatment where no vermicompost was applied.

Different doses of chemical fertilizers showed significant variations in respect of number of seeds / pod (Table 7). Among the different doses of fertilizers, F_2 (medium fertilizer) showed the highest number of pods/plant (20.77) On the contrary, the lowest number of seeds/pod (15.44) was observed with F_0.

The combined effect of different doses of vermicompost and fertilizer on the number of seeds / pod of rapeseed was significant (Table 8). The highest number of seeds/pod (22.02) was recorded with the treatment combination of V_2F_3 (Medium vermicompost + High fertilizer). On the other hand, the lowest number of seeds/pod (11.02) was found in V_0F_0 treatment (No vermicompost and no fertilizer).

4.1.8 Number of Primary Branches /plant

Significant variation was observed in the number of primary branches / plant of rapeseed when different doses of vermicompost were applied (Table 6). The highest number of primary branches / plant (5.85) was recorded in V_1 (2 t ha^{-1}), and the lowest number of primary branches / plant (4.27) was recorded in the V_0 treatment where no vermicompost was applied.

Different doses of chemical fertilizers showed significant variations in respect of number of primary branches /plant (Table 7). Among the different doses of fertilizers, F_2 (medium fertilizer) showed the highest number of primary branches / plant (5.94) On the contrary, the lowest number of primary branches /plant (4.44) was observed with F_0.

The combined effect of different doses of vermicompost and fertilizer on number of primary branches / plant of rapeseed was significant (Table 8). The highest number of primary branches / plant (6.35) was recorded with the treatment combination of V_2F_2 (Medium vermicompost + Medium fertilizer). On the other hand, the lowest number of seeds/pod (2.35) was found in V_0F_0 treatment (No vermicompost and no fertilizer).

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

4.2.1 Nitrogen content

A statistically significant variation was observed in nitrogen concentration in rapeseed plant after harvest when different doses of vermicompost were applied (Table 9). The effect of different doses of vermicompost revealed that the highest nitrogen concentration (1.08%) was recorded in V_3 (6 t ha^{-1}) and the lowest nitrogen concentration (0.90%) 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. The result agrees well with the findings of Patel *et al.* (1996)

Application of different doses of chemical fertilizers showed a statistically significant variation in respect of nitrogen concentration in rapeseed plant after harvest (Table 10). Among the different combinations of fertilizer doses, F_3 (High fertilizer) showed the highest nitrogen concentration (1.18%) and the lowest nitrogen concentration (0.84%) 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 fertilizer) treatment in rapeseed plant. This may be due to more fertilizer application which helped to enhance nitrogen content in rapeseed 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 rapeseed crop (Table 11). The highest nitrogen concentration (1.42%) was recorded in the treatment combination of V_3 F_3 (High vermicompost + High fertilizer). On the other hand, the lowest nitrogen concentration (0.78%) was found in V_0F_0 (No Vermicompost + No fertilizer) treatment combination. The application of highest rate of Vermicompost with fertilizer showed the highest nitrogen content in shoot.

Table 9. Effect of vermicompost on the NPKS concentrations in rapeseed plant

Vermicompost	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0	0.90 b	0.20 b	0.75 b	0.37
V_1	0.96 b	0.22 ab	0.92 a	0.39
V_2	0.98 ab	0.22 ab	0.93 a	0.41
V_3	1.08 a	0.24 a	0.99 a	0.42
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 letters) differ significantly as per DMRT

Table 10. Effect of fertilizers on the NPKS concentrations in rapeseed plant

Fertilizer	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
F_0	0.84 c	0.19 c	0.63 d	0.35 b
F_1	0.86 c	0.21 b	0.80 c	0.39 ab
F_2	1.05 b	0.23 ab	0.99 b	0.42 a
F_3	1.18 a	0.25 a	1.18 a	0.43 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 letters) differ significantly as per DMRT

4.2.2 Phosphorous content

Significant variation was recorded with phosphorous concentration in rapeseed shoot after harvest when vermicompost was applied at different doses (Table 9). Considering the effect of different doses of vermicompost, the highest phosphorous concentration (0.24%) was recorded in V_3 (6 t ha^{-1}) and the lowest phosphorous concentration (0.20%) 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 11. Combined effect of vermicompost and fertilizers on the NPKS concentrations in rapeseed plant

Vermicompost × Fertilizer	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
$V_0 F_0$	0.78 d	0.17 e	0.52 h	0.33
$V_0 F_1$	0.78 d	0.19 de	0.72 fgh	0.34
$V_0 F_2$	1.05 be	0.20 bcde	0.82 ef	0.40
$V_0 F_3$	1.00 bed	0.23 abed	0.95 cde	0.41
$V_1 F_0$	0.82 cd	O.18 de	0.55 gh	0.32
$V_1 F_1$	0.86cd	0.22 abcde	0.82 ef	0.41
$V_1 F_2$	1.01 bed	0.23 abed	1.12 abc	0.42
$V_1 F_3$	1.15 b	0.25 abc	1.19 ab	0.41
$V_2 F_0$	0.88 cd	0.19cde	0.69 fgh	0.36
$V_2 F_1$	0.89 cd	0.21 abcde	0.82 ef	0.41
$V_2 F_2$	1.00 bed	0.22 abcde	0.95 cde	0.43
$V_2 F_3$	1.15 b	0.26 a	1.25 ab	0.44
$V_3 F_0$	0.88 cd	0.20 abcde	0.75 efg	0.38
$V_3 F_1$	0.89 cd	0.23 abed	0.85 def	0.42
$V_3 F_2$	1.13 b	0.25 ab	1 .05 bed	0.44
$V_3 F_3$	1.42 a	0.26 a	1.32 a	0.45
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 letters) differ significantly as per DMRT

Different doses of chemical fertilizers resulted a significant variation in phosphorous concentration in rapeseed plant at the harvest (Table 10). Among the different combinations of fertilizer doses, F_3 (High fertilizer) showed the highest phosphorous concentration (0.25%) in plant, and the lowest phosphorous concentration (0.19%) was recorded in the plants of the F_0 treatment. It was observed that phosphorous content increased due to higher rate of application of fertilizer.

The effect of different doses of vermicompost and fertilizer at various combinations on the phosphorous concentration in rapeseed plant was statistically significant (Table 11). The highest phosphorous concentration (0.26%) was recorded in the treatment combination of V_2F_3 (Medium vermicompost + High fertilizer) which was statistically identical with V_3F_3 treatment combination. On the other hand, the lowest phosphorous concentration (0.17%) was found in V_0F_0 (No vermicompost + No fertilizer) 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 fertilizer in treatment.

4.2.3 Potassium content

Statistically significant variation was recorded in potassium concentration in rapeseed plant after harvest when different doses of vermicompost were added (Table 9). The highest potassium concentration (0.99%) 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 (0.75%) was recorded in the v_0 treatment where no vermicompost was applied.

Different doses of chemical fertilizers resulted a significant variation in potassium concentration in rapeseed plant at the harvest (Table 10). Among the different combinations of fertilizer doses, F_3 (Height fertilizer) showed the highest Potassium concentration (1.18%) in plant, and the lowest potassium concentration (0.63%) was recorded in the F_0 treatment.

Combined application of vermicompost and fertilizers at different levels showed significant effect on potassium concentration in rapeseed plant after harvest (Table 11). The highest potassium concentration (1.33%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High fertilizer). On the other hand, the lowest potassium concentration (0.52%) was found in V_0F_0 (No vermicompost + No fertilizer) treatment combination.

4.2.4 Sulphur content

Statistically significant variation was not recorded in sulphur concentration in rapeseed plant after harvest when the effects of different doses of vermicompost were compared (Table 9). Considering the effect of different doses of vermicompost, the highest sulphur concentration (0.42%) was recorded in V_3 (6 t ha^{-1}), and the lowest sulphur concentration (0.37%) 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 rapeseed plant after harvest (Table 10). Fertilizer dose, F_3 (high fertilizer) yielded highest sulphur concentration (0.43%) in plant which was statistically identical with F_2 treatment and the lowest sulphur concentration (0.35%) was recorded in F_0 treatment where no fertilizer was applied.

Combined effect of the different doses of vermicompost and fertilizer on the sulphur concentration in rapeseed plant did not show statistically significant difference (Table 11). The highest sulphur concentration (0.45%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High fertilizer). On the other hand, the lowest sulphur concentration (0.33%) was found in V_0F_0 (No vermicompost + No fertilizer) treatment combination. This might be due to the fact that, the combined effect of both vermicompost and fertilizer played positive effect on sulphur concentration in rapeseed plant up to certain limit.

4.3 Effect of vermrcompost and fertilizers on the nutrient concentrations in rapeseed seed

4.3. 1 Nitrogen content

Statistically significant variation was not observed in nitrogen concentration in rapeseed seed after harvest when different doses of vermicompost were applied (Table 12). The effect of different doses of vermicompost revealed that the highest nitrogen concentration (1.86%) was recorded in V_3 (6 t ha^{-1}) and the lowest nitrogen concentration (1.40%) was recorded in the V_0 treatment. It was observed that nitrogen content increased due to higher rate of application of vermicompost.

Table 12. Effect of vermicompost on the NPKS concentrations in rapeseed seed

Vermicompost	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0	1.40	0.53	2.02	0.40 b
V_1	1.63	0.58	2.01	0.44 ab
V_2	1.64	0.59	2.03	0.45 ab
V_3	1.86	0.60	2.08	0.46 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 13. Effect of fertilizers on the NPKS concentrations in rapeseed seed

Fertilizer	Concentration *(%)*			
	Nitrogen	Phosphorous	Potassium	Sulphur
F_0	1.19 c	0.51 b	1.90 c	0.40
F_1	1.43 be	0.57 ab	2.01 b	0.45
F_2	1.92 ab	0.61 a	2.10 ab	0.45
F_3	1.99 a	0.63 a	2.15 a	0.47
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 rapeseed seed after harvest (Table 13). Among the different combinations of fertilizer doses, F_3 (High fertilizer) showed the highest seed nitrogen concentration (1.99%) and the lowest nitrogen concentration (1.19%) was recorded in the fertilizer combination F_0 where none of the fertilizers was applied in rapeseed plant. Probably, higher rates of fertilizer application helped to enhance nitrogen content in rapeseed seed.

Table 14. Combined effect of vermicompost and fertilizers on the NPKS concentration in rapeseed seed

Vermicompost × Fertilizer	Concentration (%)			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0F_0	1.94	0.43 b	1.85 c	0.34 b
V_0F_1	1.38 ab	0.50 ab	2.02 abc	0.41 ab
V_0F_2	1.61 ab	0.58 a	2.09 abc	0.40 ab
V_0F_3	1.66 ab	0.63 a	2.15ab	0.43 ab
V_1F_0	1.17 ab	0.50 ab	1.86 c	0.42 ab
V_1F_1	1.42 ab	0.59 a	2.02 abc	0.46 ab
V_1F_2	2.00 ab	0.61 a	2.05 abc	0.43 ab
V_1F_3	1.96 ab	0.61 a	2.12 ab	0.46 ab
V_2F_0	1.15 ab	0.53 ab	1.92 be	0.44 ab
V_2F_1	1.18 ab	0.60 a	1.95 abc	0.46 ab
V_2F_2	2.10 ab	0.61 a	2.12 ab	0.48 ab
V_2F_3	2.11 ab	0.63 a	2.15 ab	0.43 ab
V_3F_0	1.50 ab	0.57 a	1.95 abc	0.39 ab
V_3F_1	1.74 ab	0.58 a	2.05 abc	0.47 ab
V_3F_2	1.95 ab	0.61 a	2.12 ab	0.51 a
V_3F_3	2.23 a	0.63 a	2.19 a	0.53 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 rapeseed crop (Table 14). The maximum nitrogen concentration (2.23%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High fertilizer). On the other hand, the minimum nitrogen concentration (1.94%) was found in V_0F_0 (No vermicompost + No fertilizer) treatment combination. Both the highest rate of application of vermicompost and fertilizer showed the highest nitrogen content in rapeseed seed.

4.3.2 Phosphorous content

Significant variation was not recorded with phosphorous concentration in rapeseed seed after harvest when vermicompost was applied at different doses (Table 12). Considering the effect of different doses of vermicompost, the highest phosphorous concentration (0.60%) was recorded in V_3 (6 t ha^{-1}) and the lowest phosphorous concentration (0.53%) 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 veimicempost.

Different doses of chemical fertilizers resulted a significant variation in phosphorous concentration in rapeseed seed at the harvest (Table 13). Among the different combinations of fertilizer doses, F_3 (High fertilizer) showed the highest phosphorous concentration (0.63%) in seed, which was statically identical with F_2 (Medium fertilizer) and the lowest phosphorous concentration (0.51%) was recorded in the F_0 treatment. It was observed that phosphorous content showed an increase due to higher rate of application of fertilizer.

The effect of different doses of vermicompost and fertilizer at various combinations on the phosphorous concentration in rapeseed seed was statistically significant (Table 14). The highest phosphorous concentration (0.63%) was recorded in the treatment combination of V_0F_3 (No vermicompost + High fertilizer) and V_3F_3 (High vermicompost + High fertilizer). On the other hand, the lowest phosphorous concentration (0.43%) was found in V_0F_0 (No vermicompost + No fertilizer) 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 rapeseed seed as well after harvest when different doses of vermicompost were added (Table 12). When different closes of vermicompost were considered, the highest potassium concentration (2.08%) was recorded in V_3 (6 t ha^{-1}) and the lowest potassium concentration (2.01%) was recorded in the V_1 treatment.

Application of different doses of chemical fertilizers resulted a significant variation in potassium concentration in rapeseed seed after harvest (Table 13). Among the different combinations of fertilizer, F_3 (High fertilizer) showed the highest potassium concentration (2.15%). On the other hand, the lowest potassium concentration (1.90%) was recorded with F_0 where no fertilizer was applied. Probably more fertilizer application helped to accumulate more potassium in rapeseed seed.

Combined application of vermicompost and fertilizes at different levels showed significant effect on potassium concentration in rapeseed seed after harvest (Table 14). The highest potassium concentration (2.19%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High fertilizer). On the other hand, the lowest potassium concentration (1.85%) was found In V_0F_0 (No vermicompost + No fertilizer) treatment combination.

4. 3.4 Sulphur content

Statistically significant variation was recorded in sulphur concentration in rapeseed seed after harvest when the effects of different doses of vermicompost were compared (Table 12). Considering the effect of different doses of vermicompost, the highest sulphur concentration (0.46%) was recorded in V_3 (6 t ha^{-1}), and the lowest sulphur concentration (0.40%) 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 rapeseed seed (Table 13). Fertilizer dose F_3 (High fertilizer) yielded maximum sulphur concentration (0.47%) in seed and the minimum sulphur concentration (0.40%) was recorded in F_0 treatment where no fertilizer was applied.

Combined effect of the different doses of vermicompost and fertilizer on the sulphur concentration in rapeseed seed showed statistically significant difference (Table 14). The highest sulphur concentration (0.53%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High fertilizer) which was statistically identical with V_3F_2 (High vermicompost + Medium fertilizer). On the other hand, the lowest sulphur concentration (0.34%) was found in V_0F_0 (No vermicompost + No fertilizer) treatment combination. This might be due to the fact that, the combined effect of both vermicompost and fertilizer played positive effect on sulphur concentration in rapeseed seed up to certain limit.

4.4 Effect of vermicompost and fertilizers on oil contents of rapeseed

4.4.1 Effect of vermicompost and fertilizers on oil contents of rapeseed

There was no significant effect of vermiscompost and fertilizer on oil content of mustard applied alone or in combination (Table 15, 16 & 17). The oil contents were the lowest in control treatments and it increased with increasing rates of vermicompost and fertilizer, whether applied alone or in combination. The result agrees well with the findings of Kumar *et al.* (2004).

Table 15. Effect of vermicompost on oil contents in rapeseed seed

Vermicompost	Oil Content (%)
V_0	42.9
V_1	43.0
V_2	43.3
V_3	43.6
Level of significance	NS

Table 16. Effect of fertilizers on oil contents in rapeseed seed

Fertilizer	Oil Content (%)
F_0	43.1
F_1	43.2
F_2	43.1
F_3	43.3
Level of significance	NS

Table 17. Effect of vermicompost and fertilizers on oil contents in rapeseed seed

Vermicompost × Fertilizer	Oil Content (%)
$V_0 F_0$	42.7
$V_0 F_1$	42.9
$V_0 F_2$	42.8
$V_0 F_3$	42.0
$V_1 F_0$	43.0
$V_1 F_1$	43.1
$V_1 F_2$	43.2
$V_1 F_3$	43.5
$V_2 F_0$	43.0
$V_2 F_1$	43.2
$V_2 F_2$	43.3
$V_2 F_3$	43.3
$V_3 F_0$	43.5
$V_3 F_1$	43.0
$V_3 F_2$	42.9
$V_3 F_3$	43.8
Level of significance	NS

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

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

4.5.1 Nitrogen uptake

The effect of vermicompost on nitrogen uptake by rapeseed plant showed significant variation (Figure 2 and Appendix I). Nitrogen uptake was maximum in the treatment V_3 (High vermicompost) having 23.58 kg ha^{-1}. The minimum nitrogen uptake by rapeseed (14.90 kg ha^{-1}) was recorded with control.

Application of fertilizer significantly influenced nitrogen uptake by rapeseed plants (Figure 3 and Appendix II). Nitrogen uptake ranged from 11.70 to 25.08 kg ha^{-1} with the highest in the treatment F_3 (High fertilizer) and the lowest in control (No fertilizer).

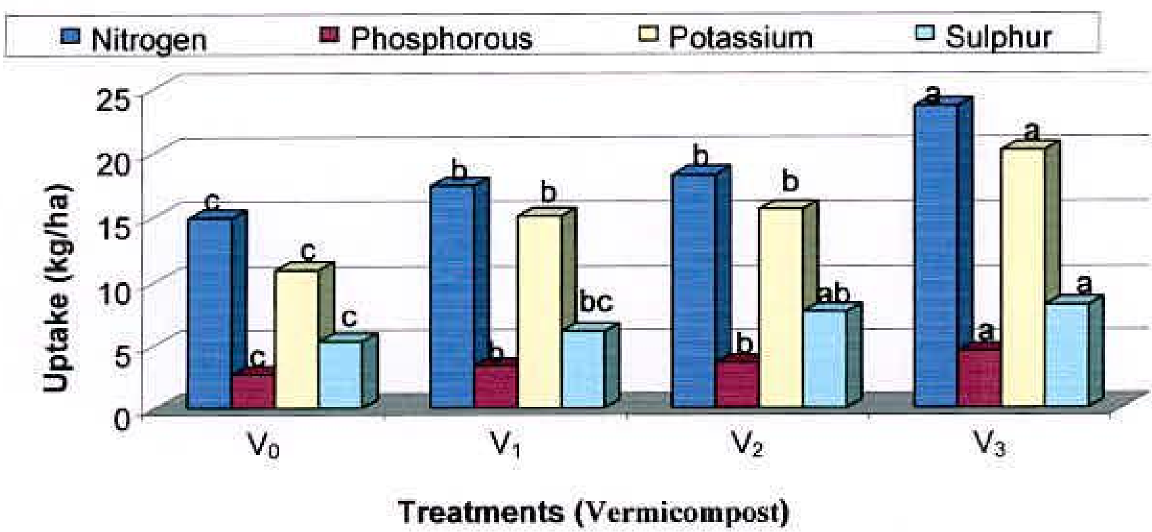


Figure 2. Effect of vermicompost on NPKS uptake by rapeseed plant

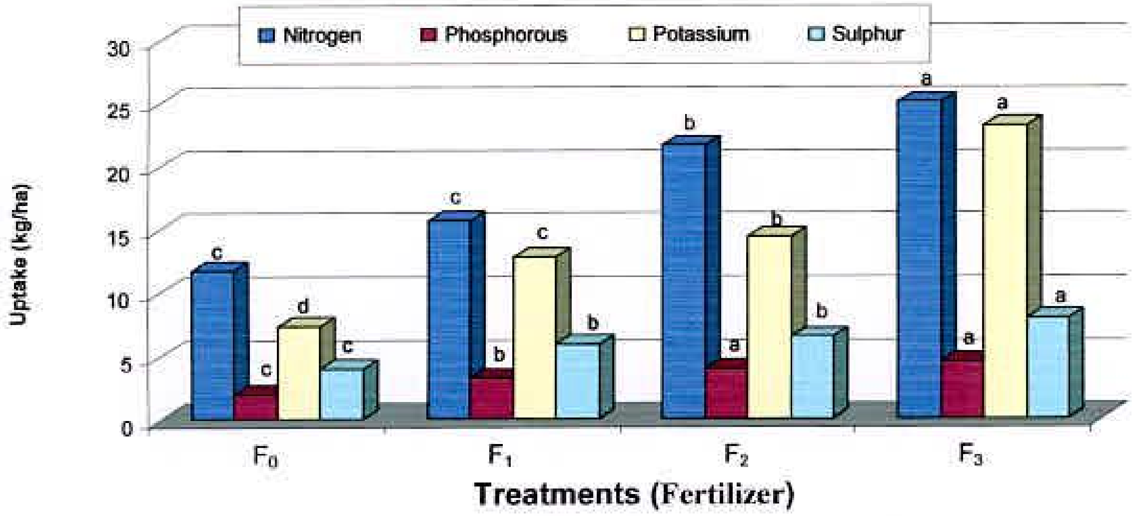


Figure 3. Effect of fertilizer on NPKS uptake by rapeseed plant

The combined effect of different doses of vermicompost and fertilizers on nitrogen uptake showed statistically significant variation (Figure 4 and Appendix III). The highest uptake (33.39 kg ha^{-1}) was recorded in the treatment combination of V_3F_3 (High vermicompost + High fertilizer). On the other hand , the lowest nitrogen uptake (8.14 kg ha^{-1}) was recorded in the control treatment (V_0F_0), where no vermicompost and no fertilizer was applied.

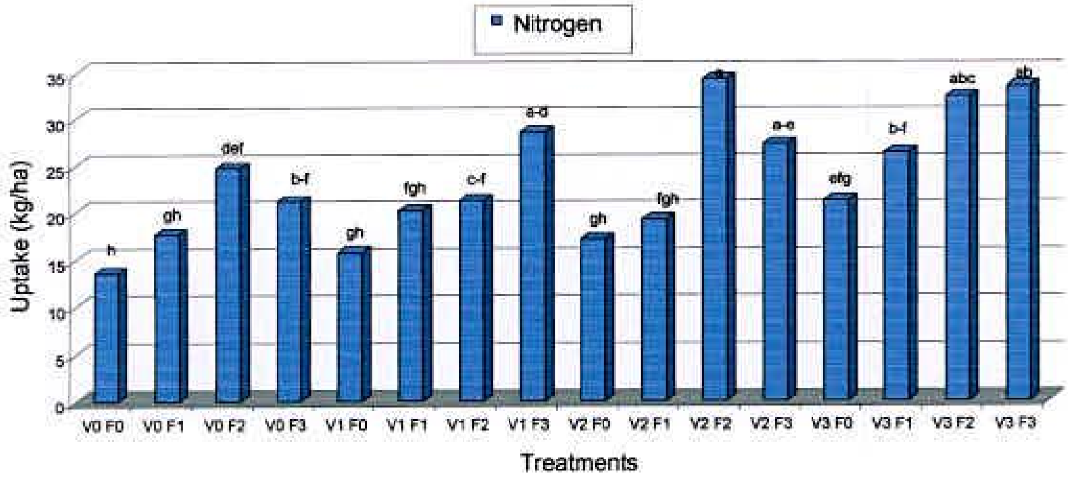


Figure 4. Combined effect of vermicompost and fertilizers on nitrogen uptake by rapeseed plant

4.5.2 Phosphorus uptake

Phosphorus uptake by rapeseed plant was significantly influenced due to the addition of vermicompost (Figure 2 and Appendix I). Phosphorus uptake ranged from 2.57 to 4.41 kg ha^{-1} with the maximum in the treatment, V_3 (High vermicompost) and the minimum in control (V_0).

Phosphorus uptake by rapeseed plant was significantly influenced due to the application of fertilizer (Figure 3 and Appendix II). Phosphorus uptake by plant ranged from 1.96 to 4.59 kg ha^{-1}. It was maximum with treatment, F_3 (High fertilizer) and minimum with F_0 treatment where no fertilizer was applied.

Combined effect of different doses of vermicompost and fertilizers on phosphorus uptake by rapeseed plant showed statistically significant variation (Figure 5 and Appendix III). The highest P uptake (5.42 kg ha^{-1}) was recorded in the treatment combination of V_3F_3 (High vermicompost + High fertilizer) and the lowest uptake (1.37 kg ha^{-1}) was recorded in the VoF_0 (No vermicompost + No fertilizer) treatment.

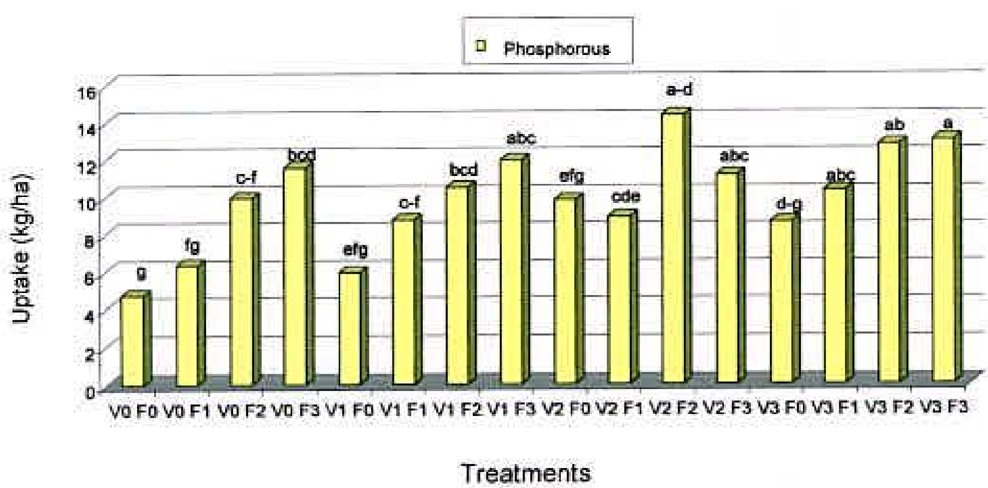


Figure 5. Combined effect of vermicompost and fertilizers on phosphorus uptake by rapeseed plant

4.5-3 Potassium uptake

The amount of potassium taken up by rapeseed plant with different doses of vermicompost resulted significanliy higher values over the control (Figure 2 and Appendix I). Potassium uptake by rapeseed plant was maximum (20.19 kg ha^{-1}) in the treatment V_3 (High vermicompost) and minimum (10.88 kg ha^{-1}) in the control. It is evident that vermicompost possibly supplied more potassium and as a consequence its uptake was higher with the higher doses.

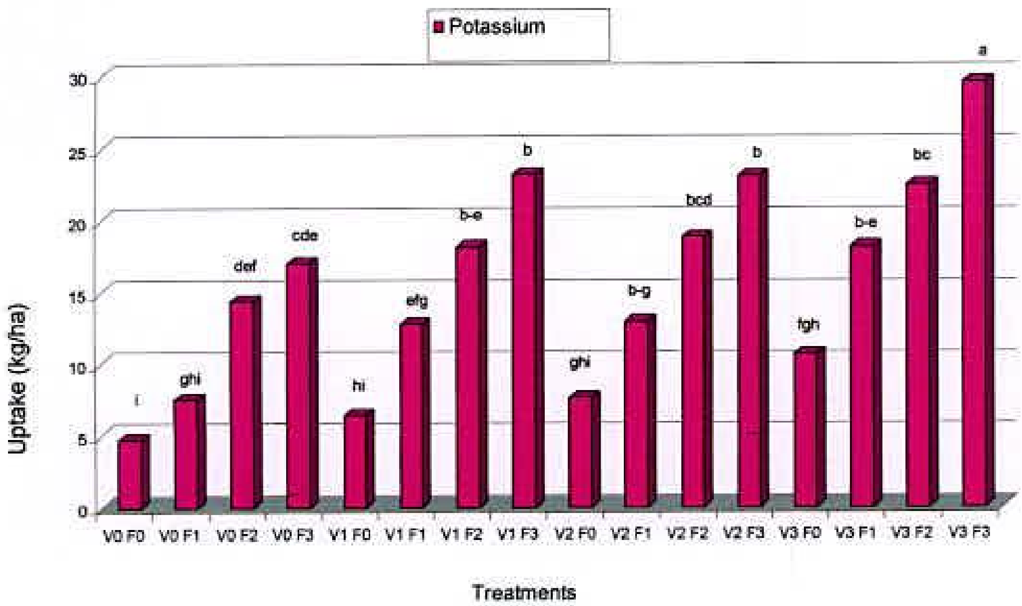


Figure 6. Combined effect of vermicompost and fertilizers on potassium uptake by rapeseed plant

Application of fertilizer significantly influenced potassium uptake by rapeseed. Potassium uptake ranged from 7.32 to 23.20 kg ha^{-1} (Figure 3 and Appendix II). The highest potassium uptake (23.20 kg ha^{-1}) was recorded with the treatment, F_3 (High fertilizer) and the lowest (7.32 kg ha^{-1}) in control (F_0) treatment.

The effect of combined application of different doses of vermicompost and fertilizers on potassium uptake by rapeseed plant showed statistically significant variation (Figure 6 and Appendix III), The highest uptake (29.55 Kg ha^{-1}) was recorded in the treatment combination of V_3F_3 (High vermicompost + High fertilizer). On the other hand, the lowest uptake (4.68 Kg ha^{-1}) was recorded in the treatment combination of V_0F_0 (No vermicompost + No fertilizer). It might be due to the fact that combined application of vermicompost and fertilizer showed positive effect on potassium uptake by rapeseed.

4.5.4 Sulphur uptake

Sulphur uptake by rapeseed plant was significantly inifuenced due to the application of vermicompost (Figure 2 and Appendix I). Sulphur uptake ranged from 5.23 to 8.13 kg h^{-1}. The maximum value was obtained with the treatment, V_3 (High vermicompost) and that of minimum in control (V_0).

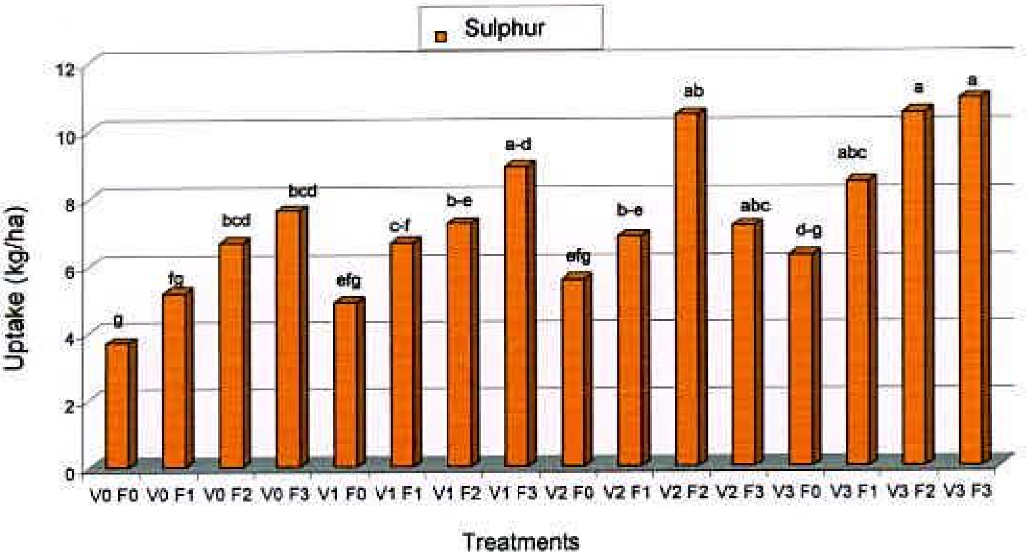


Figure 7. Combined effect of vermicompost and fertilizers on sulphur uptake by rapeseed plant

Sulphur uptake by rapeseed was significantly influenced due to the application of fertilizer (Figure 3 and Appendix II) and the maximum value (7.98 Kg ha^{-1}) was found in the treatment, F_3 (high fertilizer) the lowest value (3.97 kg ha^{-1}) was recorded in F_0 treatment where no fertilizer was applied.

Combined applications of different doses of vennicompost and fertilizers showed significant variation on sulphur uptake by rapeseed (Figure 7 and Appendix III). The highest uptake (9.74 kg ha^{-1}) was recorded in the treatment combination of V_3F_3 (High vennicompost + High fertilizer). On the other hand, the lowest uptake (2.91 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 fertilizers on the uptake of nutrients by rapeseed seed

4.6.1 Nitrogen uptake

The effect of vennicompost on nitrogen uptake by rapeseed seed showed significant variations (Figure 8 and Appendix IV). Nitrogen uptake was maximum in the treatment, V_3 (High vermicompost) having 28.33 kg ha^{-1}. The minimum nitrogen uptake by rapeseed (20.77 kg ha^{-1}) was recorded with control.

Application of fertilizer significantly influenced nitrogen uptake by rapeseed seed (Figure 9 and Appendix V). Nitrogen uptake ranged from 17.13 to 29.38 kg ha^{-1}

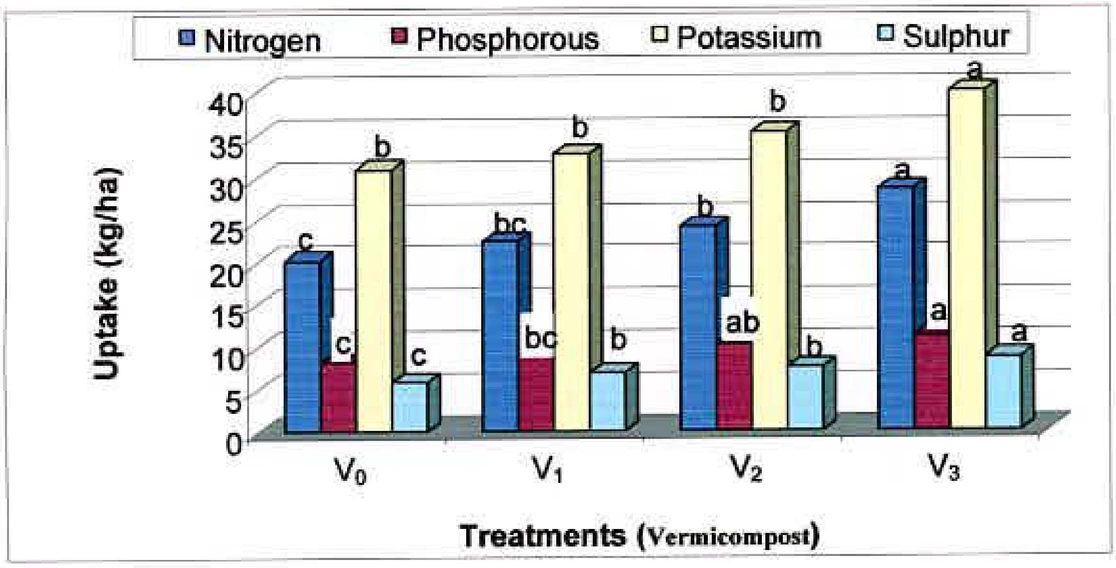


Figure 8. Effect of vermicompost on nitrogen phosphorous, potassium and sulphur uptake by rapeseed seed

with highest in the treatment F_2 (Medium fertilizer) which was statistically identical with F_2 (High fertilizer) and the lowest in control (No fertilizer)

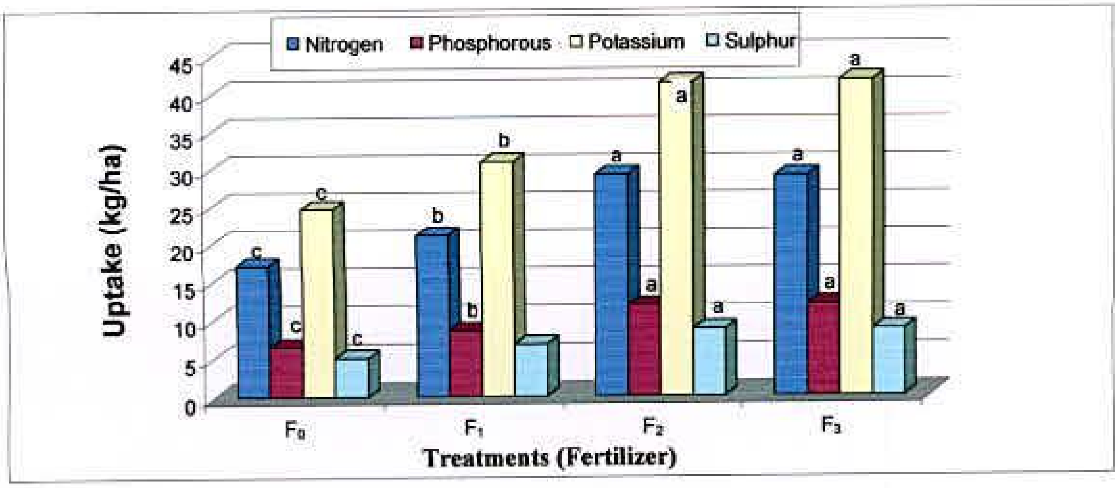


Figure 9. Effect of fertilizer on nitrogen, phosphorous, potassium and sulphur uptake by rapeseed seed

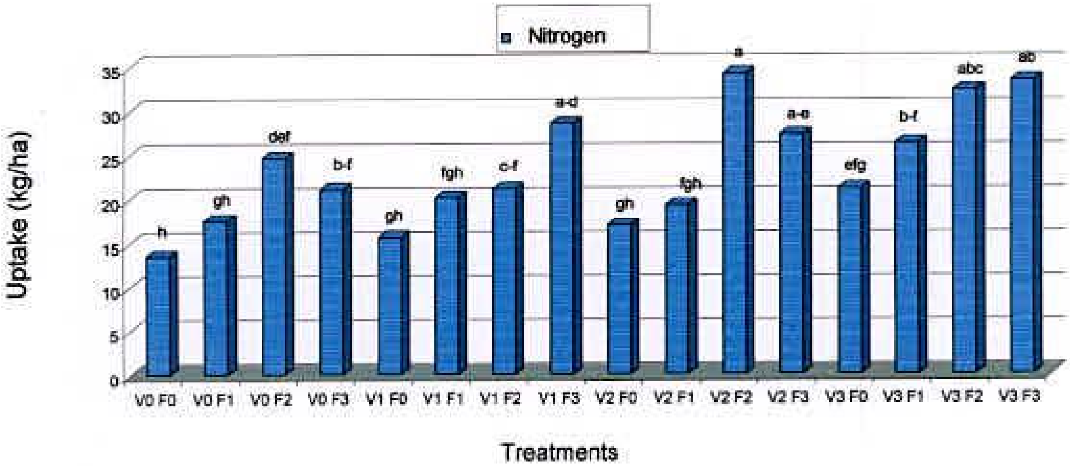


Figure 10. Combined effect of vermicompost and fertilizers on nitrogen uptake by rapeseed seed

The combined effect of different doses of vermicompost and fertilizers on nitrogen uptake showed statistically significant variation (Figure 10 and Appendix VI). The highest uptake (36.2 kg ha^{-1}) was recorded in the treatment combination of V_2 F_2 (Medium vermicompost + Medium fertilizer). On the other hand, the lowest nitrogen uptake (14.01 kg ha^{-1}) was recorded in the control treatment (V_0F_0), where no vermicompost and no fertilizer were applied.

4.6.2 Phosphorus uptake

Phosphorus uptake by rapeseed seed was significantly influenced due to the addition of vermicompost (Figure 8 and Appendix IV). Phosphorus uptake ranged from 8.12 to 11.18 kg ha^{-1} with maximum in the treatment, V_3 (High vermicompost) and minimum in control (V_0).

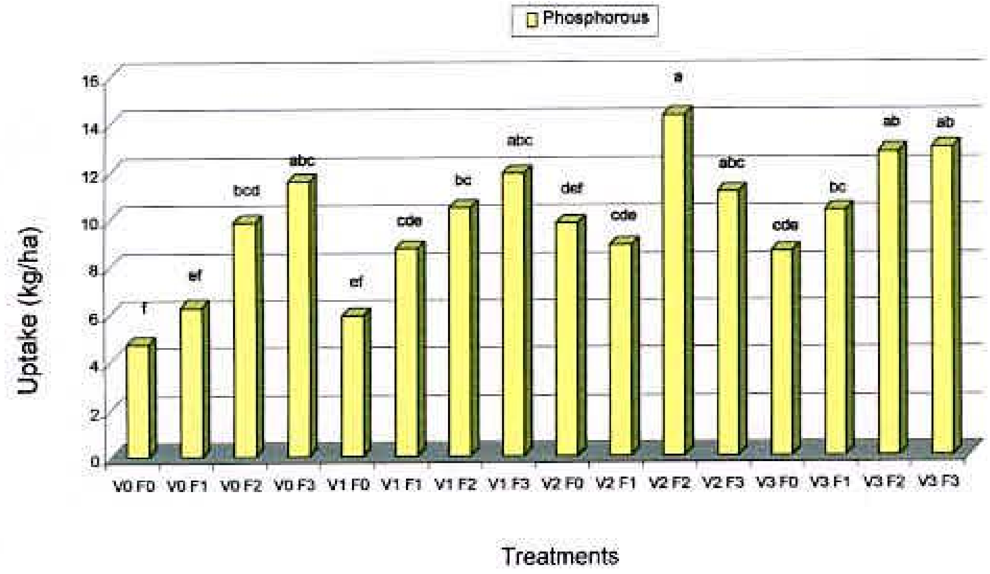


Figure 11. Combined effect of vermicompost and fertilizers on phosphorous uptake by rapeseed seed

Phosphorus uptake by rapeseed seed was significantly influenced due to the application of fertilizer (Figure 9 and Appendix V). Phosphorus uptake by seed ranged from 6.52 to 11.90 kg ha^{-1}. It was maximum with treatment, F_3 (High fertilizer) and minimum with F_0 treatment where no fertilizer was applied.

Combined effect of different doses of vermicompost and fertilizers on phosphorus uptake by rapeseed seed showed statistically significant variation (Figure 11 and Appendix VI). The highest uptake (14.36 kg ha^{-1}) was recorded in the treatment combination of V_2F_2 (Medium vermicompost + Medium fertilizer) and the lowest uptake (4.76 kg ha^{-1}) was recorded in the treatment combination, V_0F_0 (No vermicompost + No fertilizer).

4.6.3 Potassium uptake

The amount of potassium taken up by rapeseed seed with different doses of vermicompost resulted significantly higher value over the control (Figure 8 and Appendix IV). Potassium uptake by rapeseed seed was maximum (40.00 kg ha^{-1}) in the treatment, V_3 (High vermicompost) and minimum (30.87 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.

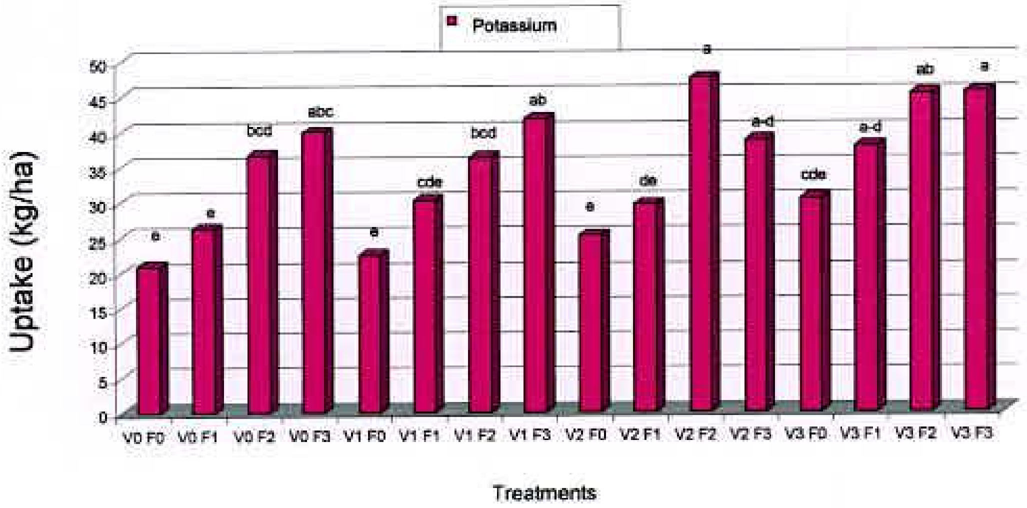


Figure 12. Combined effect of vermicompost and fertilizers on potassium uptake by rapeseed seed

Application of fertilizer significantly influenced potassium uptake by rapeseed seed. Potassium uptake ranged from 24.71 to 41.72 kg ha^{-1} (Figure 9 and Appendix V). The highest potassium uptake (41.72 kg ha^{-1}) was recorded with the treatment, F_3 (High fertilizer) which was statistically identical with F_2 (Medium fertilizer) and the lowest (24.71 kg ha^{-1}) in control (F_0) treatment.

The effect of combined application of different doses of vermicompost and fertilizers on potassium uptake by rapeseed seed showed statistically significant variation (Figure 12 and Appendix VI). The highesl uptake (47.48 Kg ha^{-1}) was recorded in the treatment combination of V_2F_2 (Medium vermicompost + Medium fertilizer) which was statistically identical with V_3F_3 (High vermicompost + High fertilizer). On the other hand, the lowest uptake (20.82 Kg h^{-1}) was recorded in the treatment combination of V_0F_0 (No vermicompost + No fertilizer). It might be due to the fact that vermicompost and fertilizer combined application showed positive effect on potassium uptake by rapeseed.

4.6.4 Sulphur uptake

Sulphur uptake by rapeseed seed was significantly influenced due to the application of vermicompost (Figure 8 and Appendix IV). Sulphur uptake ranged from 5.79 to 8.67 kg ha^{-1}. The maximum value (8.67 kg ha^{-1}) was obtained with the treatment, V_3 (High vermicompost) and minimum (5.79 kg $h.^{-1}$) in control (V_0).

Sulphur uptake by rapeseed was significantly influenced due to the application of fertilizer (Figure 9 and Appendix Table 5) and the maximum value (8.80 Kg hal^{-1}) was found in the treatment F_3 (High fertilizer), which was statistically identical with F_2 (Medium fertilizer) and the lowest value (5.11 kg ha^{-1}) was recorded in F_0 treatment where no fertilizer was applied.

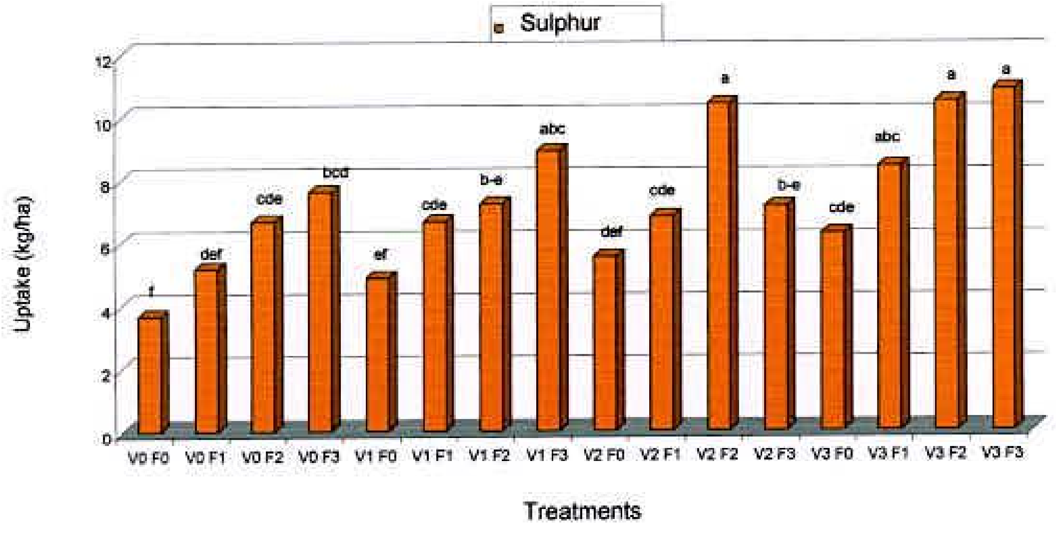


Figure 13. Combined effect of vermicompost and fertilizers on sulphur uptake by rapeseed seed

Combined applications of different doses of vermicompost and fertilizers showed significant variation on sulphur uptake by rapeseed seed (Figure 13 and Appendix Table 6). The highest uptake (10.88 kg ha^{-1}) was recorded in the treatment combination of V_3F_3 (High vermicompost + high fertilizer), which was statistically identical with V_3F_2 (high vermicompost + Medium fertilizer) and V_2F (Medium vermicompost + Medium fertilizer) treatments. On the other hand, the lowest uptake (3.69 kg ha^{-1}) was recorded in the treatment combination where no vermicompost and no fertilizer were added (V_0F_0).

4.7 Effect of vermicompnst 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 18). Among the different doses of vermicompost, V_3 (6 t ha^{-1}) treatment showed the highest OM content (1.06%) after the harvest of crop. On the other hand, the lowest OM content (0.85%) was observed in the Vo treatment where no vermicompost was applied and it was closely followed (0.90% & 0.94%) 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 18. Effect of vermicompost on the organic matter (OM), total N, available P, exchangeable K, available S, available Zn and available B contents in the soil after rapeseed harvest

Vermicompost	OM (%)	Total N (%)	Available P (%)	Available K (%)	Available S (%)	Available Zn (%)	Available B (%)
V_0	0.85b	0.080 d	0.0020 b	0.0015 d	0.0015 c	0.00021 c	0.0020 c
V_1	0.90 b	0.083 c	0.0020 b	0.0017 c	0.0016 bc	0.00024 bc	0.0023 bc
V_2	0.94 b	0.087 b	0.0022 b	0.0020 b	0.0017 ab	0.00026 b	0.0025 b
V_3	1.06 a	0.090 a	0.0024 a	0.0023 a	0.0019 a	0.00030 a	0.0029 a
Level of significance	0.01	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 19). The contents of OM were almost the same (0.91 to 0.96%) in all the fertilizer treated plots after harvest of the crop.

Combined application of different doses of vermicompost and fertilizer showed no significant effect on the OM content of soil after harvest (Table 20). The lower OM contents of the soil (0.83 to 0.86%) after harvest were recorded in the treatment combinations where vermicompost was not applied. On the other hand, the higher OM contents (1.06 to 1.07%) were recorded in the treatment combination of the highest vermicompost with fertilizer doses. These results are in agreement with Bhalerao *et al.* (2005) who found that organic C content and N, P and K uptake were increased in all the treatments where the organic matter was used.

Table 19. Effect of fertilizers on the Organic Matter (OM), total N, available P, exchangeable K, available S, available Zn and available B content in the soil after rapeseed harvest

Vermicompost	OM (%)	Total N (%)	Available P (%)	Available K (%)	Available S (%)	Available Zn (%)	Available B (%)
F_0	0.91	0.080 c	0.0020 c	0.0016 c	0.0015 c	0.00021 c	0.0022 c
F_1	0.93	0.083 c	0.0021 bc	0.0017 c	0.0015 c	0.00023 c	0.0025 bc
F_2	0.95	0.087 b	0.0022 ab	0.0020 b	0.0017 ab	0.00026 b	0.0027 b
F_3	0.96	0.090 a	0.0024 a	0.0023 a	0.0019 a	0.00030 a	0.0031 a
Level of significance	NS	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

4.7.2 Nitrogen content of soil

Significant variation was recorded on the nitrogen content of rapeseed field after harvest of the crop when the field was treated with different doses of vermicompost (Table 18). Among the different doses of vermicompost, V_3 (6 t ha^{-1}) treatment showed the highest N content (0.090%) and the lowest N content (0.080%) 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.

A significant variation was recorded in the N content of soil after harvest of the rapeseed crop when different fertilizers in different doses were applied (Table 19). In considering the different combinations of fertilizer doses, F_3 (High fertilizer) showed the highest N content (0.089%) and the lowest N content (0.081%) was observed in the F_0 treatment where no fertilizer was applied which was statistically identical with F_1 (Low fertilizer) treatment.

Combined application of different doses of vermicompost and fertilizer showed no significant effect on the N content of soil after harvest (Table 20). The highest N content of crop-harvested soil (0.095%) was recorded in the treatment combination of V_3F_3 (High vermicompost + High fertilizer). On the other hand, the lowest N content (0.076%) was recorded in V_0F_0 (No vermicompost + No fertilizer). These results are corroborated with the finding of Singh *et al.* (2005) who found that combined application of inorganic and organic source had better build up of soil organic C and available N, P and K after crop harvest.

Table 20. Combined effect of vermicompost and fertilizers on the organic matter (OM), total N, available P, exchangeable K, available S, available Zn and available B contents in the soil after rapeseed harvest

Vermicompost	OM (%)	Total N (%)	Available P (%)	Available K (%)	Available S (%)	Available Zn (%)	Available B (%)
V_0F_0	0.83	0.076	0.0019 c	0.0012	0.0013 d	0.00019 c	0.0016 c
V_0F_1	0.84	0.081	0.0020 bc	0.0014	0.0015 cd	0.00020 bc	0.0017 bc
V_0F_2	0.85	0.078	0.0021 bc	0.0016	0.0015 cd	0.00020 bc	0.0019 bc
V_0F_3	0.86	0.085	0.0022 abc	0.0019	0.0017 bcd	0.00022 bc	0.0020 bc
V_1F_0	0.89	0.079	0.0019 c	0.0016	0.0013 d	0.00020 bc	0.0020 bc
V_1F_1	0.89	0.080	0.0020 bc	0.0017	0.0015 cd	0.00022 bc	0.0021 bc
V_1F_2	0.90	0.084	0.0020 bc	0.0018	0.0017 bcd	0.00023 bc	0.0020 bc
V_1F_3	0.93	0.090	0.0022 abc	0.0018	0.0019 abc	0.00025 b	0.0025 b
V_2F_0	0.90	0.082	0.0019 c	0.0017	0.0017 bcd	0.00023 bc	0.0021 bc
V_2F_1	0.93	0.084	0.0020 bc	0.0020	0.0014 cd	0.00023 bc	0.0021 bc
V_2F_2	0.97	0.092	0.0023 abc	0.0021	0.0017 bcd	0.00021 bc	0.0022 bc
V_2F_3	0.98	0.088	0.0024 a	0.0024	0.0020 ab	0.00028 a	0.0026 a
V_3F_0	1.04	0.085	0.0022 abc	0.0018	0.0016 bcd	0.00023 bc	0.0020 bc
V_3F_1	1.06	0.087	0.0023 abc	0.0020	0.0017 bcd	0.00022 bc	0.0020 bc
V_3F_2	1.06	0.091	0.0025 a	0.0024	0.0019 ab	0.00028 a	0.0026 a
V_3F_3	1.07	0.095	0.0024 a	0.0027	0.0022 a	0.00028 a	0.0028 a
Level of significance	NS	NS	0.01	NS	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

4.7.3 Phosphorous content of soil

A significant variation was observed in the P content of soil in the rapeseed field after harvest where the field was manured with different doses of vermicompost (Table 18). Among the different doses of vermicompost, V_3 (6 t ha^{-1} vermicompost) treatment showed the highest P content (0.0024%) after the harvest of crop. On the other hand, the lowest P content (0.0020%) 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 18).

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 19). Among the different combinations of fertilizer doses, F_3 (High fertilizer) showed the highest P content (0.0024%) and the lowest P content (0.0020%) was observed in the F_0 treatment where no fertilizer was applied.

Combined effect of different doses of vermicompost and fertilizer produced significant variation in respect of P content of soil after the harvest of rapeseed crop. (Table 20). The lowest P content of crop harvested soil (0.0019%) was recorded in the treatment combination of V_0F_0 (No vermicompost + No fertilizer). On the other hand, the highest P content (0.0026%) was recorded in V_2F_3 (Medium vermicompost + High fertilizer) and V_3F_3 (High vermicompost + High fertilizer) treatments. These results are corroborated with the finding of Singh *et al.* (2005) who found that combined application of inorganic and organic source had better build up of soil organic C and available N, P and K after crop harvest.

4.7.4 Potassium confent of soil

Significant variation was recorded in the K content of soil in the rapseed field after harvest of the crop where different doses of vermicompost were applied (Table 18). Application of vermicompost at the rate of 6 t ha^{-1} (V_3) showed the highest K content

(0.0023%) and the lowest K content (0.0015%) 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 19). Fertilizer dose F_3 (High fertilizer) showed the highest K content (0.0023%) and the lowest K content (0.0016%) was recorded in the F_0 treatment (No fertilizer) and that was statistically identical with F_1 treatment (Low fertilizer).

The effect of combined application of vermicompost and fertilizer showed no significant differences in respect of K content of soil after harvest (Table 20). However, the lowest K content of crop-harvested soil (0.0012%) was recorded in the treatment combination of V_0F_0 (No vermicompost+ No fertilizer) and the highest K content (0.0027%) was recorded with V_3F_3 (High vermicompost + High fertilizer) treatment combination.

4.7.5 Sulphur content of soil

Significant variation was recorded in the S content of soil after rapseed harvest where the plots were incorporated with different doses of vermicompost (Table 18). The highest dose of vermicompost, V_3 (6 t ha^{-1}) resulted the highest S content (0.0019%) after the harvest of crop and the lowest S content (0.0015%) 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 19). Fertilizer dose, F_3 (High fertilizer) showed the highest S content (0.0019%) and the lowest S content (0.0015%) was observed in the F_0 treatment where no fertilizer was applied and that was closely followed by the treatment, F_1 (Low fertilizer). These results are corroborated with the finding of Patel and Shelke (2000) who found that increasing doses of S increased the available S in the postharvest soil.

The effect of combined application of different doses of vermicompost and fertilizer showed significant differences in respect of S content of soil after rapeseed harvest (Table 20). However, the lowest S content of crop-harvested soil (0.0013%) was recorded in the treatment combination of V_0F_0 (No vermicompost + No fertilizer) and the highest S content (0.0022%) was recorded in V_3F_3 (High vermicompost + High fertilizer) 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 rapeseed harvest where the soils were incorporated with different doses of vermicompost (Table 18). The highest dose of vermicompost, V_3 (6 t ha^{-1}) resulted the highest Zn content (0.00030%) in soil after the harvest of crop and the lowest Zn content (0.00021%) 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 19). Fertilizer dose F_3 (High fertilizer) showed the highest Zn content (0.00030%) and the lowest Zn content (0.00021%) was observed in the F_0 treatment where no fertilizer was applied and that was closely followed by the treatment F_1 (Low fertilizer).

The effect of combined application of different doses of vermicompost and fertilizer showed significant differences in respect of Zn content of soil after rapeseed harvest (Table 20). The lowest Zn content of crop-harvested soil (0.00019%) was recorded in the treatment combination of V_0F_0 (No vermicompost + No fertilizer) and the highest Zn content (0.00030%) was recorded in V_3F_3 (High vermicompost + High fertilizer) treatment combination which was statistically identical wilh V_3F_2 (High vermicompost + Medium fertilizer) and V_2F_3 (Medium vermicompost + High fertilizer) treatment combinations. This might be due to application of higher rate of vermicompost and fertilizer.

4.7.7 Boron content of soil

Significant variation was recorded in the B content of soil after rapeseed harvest where the soils were incorporated with different doses of vermicompost (Table 18). The highest dose of vermicompost, V_3 (6 t ha^{-1}) resulted the highest Zn content (0.0029%) in soil after the harvest of crop and the lowest B content (0.0020%) was observed in the V_0 treatment where no vermicompost was applied.

Significant variation in the B content of soil after harvest was obtained when different combinations of fertilizers at different doses were applied (Table 19). Fertilizer dose, F_3 (High fertilizer) showed the highest B content (0.0031%) and the lowest B content (0.0022%) was observed in the F_0 treatment where no fertilizer was applied and that was closely followed by the treatment F_1 (Low fertilizer).

The effect of combined application of different doses of vermicompost and fertilizer showed significant differences in respect of B content of soil after rapeseed harvest (Table 20). The lowest B content of crop-harvested soil (0.0016%) was recorded in the treatment combination of V_0F_0 (No vermicompost + No fertilizer) and the highest B content (0.0028%) was recorded in V_3F_3 (High vermicompost + High fertilizer) treatment combination which was statistically identical wilh V_3F_2 (High vermicompost + Medium fertilizer) and V_2F_3 (Medium vermicompost + High fertilizer) 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 2007-2008 to study the effect of combined application of inorganic fertilizers and vermicompost on growth, yield, chemical composition and oil content of rapeseed. The soil was clay loam in texture having pH 6.2, organic matter 0.78% Randomized complete block design was followed with sixteen treatments having unit plot size of 2m × 2 m ($4m^2$) replicated thrice. The treatments were V_0F_0 Control (No vermicompost + No NPKSZnB), V_0F_1 (No vermicompost + Low NPKSZnB), V_0F_2 (No vermicompost + Medium NPKSZnB), V_0F_3 (No vermicompost + High NPKSZnB), V_1F_0 (Low vermicompost + No NPKSZnB), V_1F_1 (Low vermicompost + Low NPKSZnB), V_1F_2 (Low vermicompost + Medium NPKSZnB), V_1F_3 (Low vermicompost + High NPKSZnB), V_2F_0 (Medium vermicompost + No NPKSZnB), V_2F_1 (Medium vermicompost + Low NPKSZnB), V_2F_2 (Medium vermicompost + Medium NPKSZnB), V_2F_3 (Medium vermicompost + High NPKSZnB), V_3F_0 (High vermicompost + No NPKSZnB), V_3F_1 (High vermicompost + Low NPKSZnB), V_3F_2 (High vermicompost + Medium NPKSZnB) and V_3F_3 (High vermicompost + High NPKSZnB). Nitrogen from urea, P from TSP and K from Muriate of potash (MP), sulphur from gypsum, zinc from ZnO, boron from boric acid were supplied. Half of the urea and the whole amount of other chemical fertilizers were used as a basal dose and the whole required amounts of vermicompost was applied in line during sowing and rest of the urea was top dressed after irrigation. Rapeseed seeds cv. SAU Shrisha-1 were sown on 11^{th} November, 2007 and the crop was harvested on 16^{th} February 2008. Intercultural operations were done when required. The data were collected plot wise for plant height, number of pods per plant, number of primary branches per plant, number of seeds per pods, weight of 1000 seeds, yield and straw yields. Soil samples were collected plotwise after the harvest of the crop. The post harvest soil samples were analyzed for organic matter, N, P, K., S, Zn and B 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 rapeseed responded significantly to the vermicompost and fertilizer treatments. The highest seed yield of 2.20 t ha^{-1} was obtained in V_2F_2 (Medium vermicompost + Medium fertilizer) treatment. The lowest seed yield (1.35 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 fertilizers, the effect showed better performance on yield rather than applying vermicompost or fertilizers alone. The highest straw yield (2.28 t ha^{-1}) was recorded in V_3F_3 (High vermicompost + High fertilizer) treatment and the lowest (0.96 t ha^{-1}) in V_0F_0 control (No vermicompost + No fertilizer).

The N, P, K and S contents and uptake of these nutrients by rapeseed plant and seed were influenced significantly by the application of vermicompost and chemical fertilizers. The highest N, P, K and S content in straw (1.42%, 0.26%, 1.32% and 0.45% at after harvest, respectively) were recorded in V_3F_3 (High vermicompost + High fertilizer) treatment. The lowest N, P, K and S content (0.78%, 0.17%, 0.52% and 0.33%, respectively) were obtained with V_0F_0 treatment.

The highest uptake of 31.41, 5.48, 29.55 and 9.74 kg ha^{-1} and the lowest uptake 7.16, 1.39, 4.68 and 2. 19 kg ha^{-1} of N, P, K and S, respectively by rapeseed plant at harvest stage were found in V_3F_3 (High vermicompost + High fertilizer) and in V_0F_0 control (No vermicompost + No fertilizer) treatments.

The N, P, K and S contents and uptake of these nutrients by rapeseed seed were influenced significantly by the application of vermicompost and chemical fertilizers. The highest N, K and S contents in seed (2.23%, 2.19% and 0.53%, respectively) were recorded in V_3F_3 (High vermicompost + High fertilizer) treatment and the highest P content in seed (0.63%) 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 (0.94%, 0.43%, 1.86% and 0.34%, respectively) were obtained with V_0F_0 treatment.

The highest uptake of 34.2, 14.36, 48.46 and 10.88 kg ha^{-1} and the lowest uptake 13.34, 4.76, 20.82 and 3.69 kg ha^{-1} of N, P, K and S, respectively by rapeseed seed were found in V_2F_2 (Medium vermicompost + Medium fertilizer) except S (V_3F_3 treatment). The lowest value was obtained with V_0F_0 control (No vermicompost + No fertilizer) treatments in every case.

Oil content in rapeseed seed was not influenced significantly by the application of vermicompost and chemical fertilizers. The highest oil content in seed (43.8%) was recorded in V_3F_3 (High vermicompost + high fertilizer) and the lowest oil content (42.7%) was obtained with V_0F_0 treatment (No vermicumpost + No fertilizer).

The soil properties such as organic matter, total nitrogen, phosphorus, potassium, sulphur, zinc and boron 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 I. Effect of vermicompost on nitrogen, phosphorous, potassium and sulphur uptake by rapeseed plant.

Vermicompost	Kg ha^{-1}			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0	14.90c	2.57 c	10.88 c	5.23 c
V_1	17.36 b	3.31 b	15.10 b	6.01 be
V_2	18.25 b	3.49 b	15.59 b	7.62 ab
V_3	23.58 a	4.41 a	20.19 a	8.13 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 II. Effect of fertilizers on nitrogen, phosphorous, potassium and sulphur uptake by rapeseed plant

Fertilizer	Kg ha^{-1}			
	Nitrogen	Phosphorous	Potassium	Sulphur
F_0	11.70 d	1.96 c	7.32 d	3.97c
F_1	15.67 c	3.25 b	12.82 c	5.94b
F_2	21.65 b	3.97 a	1 8.44 b	6.53 b
F_3	25.08 a	4.59 a	23.20 a	7.98 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

Appendix III. Combined effect of vermicompost and fertilizers on nitrogen, potassium, phosphorous and sulphur uptake by rapeseed plant

Vermicompost × Fertilizer	Kg ha^{-1}			
Fertilizer	**Nitrogen**	**Phosphorous**	**Potassium**	**Sulphur**
V_0F_0	9.14h	1.39g	4.68i	2.91 g
V_0F_1	10.08 h	1.79fg	7.44 ghi	3.42 fg
V_0F_2	20.71 cde	3.22cdef	14.38 def	7.39 bed
V_0F_3	19.66 cde	3.86 bed	17.03 cde	7.20 bed
V_1F_0	11.61 gh	1.93 efg	6.39 hi	3.96 efg
V_1F_1	15. 5 6 efg	3.23 cdef	12.75 efg	6.18 cdef
V_1F_2	18.12 def	3.52 bed	18.11 bcde	6.77 bcde
V_1F_3	24. 15 be	4.56abc	23.16 b	7.74 abed
V_2F_0	11.80 gh	1 .96 efg	7.55 ghi	3.92 efg
V_2F_1	16.41 efg	3.42 cde	12, 95 defg	6.64 bcde
V_2F_2	21. 70 bed	4.11 abed	18.81 bed	8.24 ab
V_2F_3	23.11 bed	4.47 abc	23.05 b	7.91 abc
V_3F_0	14.26 fgh	2.56 defg	10.65 fgh	5.10 defg
V_3F_1	20.62 cde	4.55 abc	18.13 bcde	8.54 abc
V_3F_2	26.05 b	5.05 ab	22.43 be	9.09 a
V_3F_3	33 .39 a	5. 48 a	29.55 a	9.74 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 IV. Effect of vermicompost on nitrogen, phosphorous, potassium and sulphur uptake by rapeseed seed

Vermicompost	Kg ha^{-1}			
	Nitrogen	Phosphorous	Potassium	Sulphur
V_0	27.69 c	8.12 c	30.87 b	5.79 c
V_1	30.49 bc	9.26 bc	32.65 b	6.93 b
V_2	32.97 b	10.30 ab	35.24 b	7.49 b
V_3	30.76 a	11.18 a	40.00 a	8.67 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 V. Effect of fertilizers on nitrogen, phosphorous, potassium and sulphur uptake by rapeseed seed

Fertilizer	**Kg ha^{-1}**			
	Nitrogen	Phosphorous	Potassium	Sulphur
F_0	22.84 c	6.52 c	24.71 c	5.11 c
F_1	28.16 b	8.54 b	30.96 b	6.78 b
F_2	39.16 a	11.88 a	41.37 a	8.69 a
F_3	38.76 a	11.90 a	41.72 a	8.80 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 VI. Combined effect of vermicompost and fertilizers on nitrogen, potassium, phosphorous and sulphur uptake by rapeseed seed

Vermicompost x Fertilizer	Kg ha^{-1}			
	Nitrogen	**Phosphorous**	**Potassium**	**Sulphur**
V_0F_0	18.67 h	4.76 f	20.82 e	3.69 f
V_0F_1	23.64 gh	6.29 ef	26.25 e	5.18 def
V_0F_2	33.15 def	9.89 bcd	36.55 bcd	6.68 cde
V_0F_3	35.3 bcdef	11.56 abc	39.88 abc	7.62 bcd
V_1F_0	21.29 gh	5.90 ef	22.44 e	4.89 ef
V_1F_1	26.98 fgh	8.74 cde	30.18 cde	6.67 cde
V_1F_2	35.00 cdef	10.46 bc	36.22 bcd	7.23 bcde
V_1F_3	38.63 abcd	11.92 abc	41.77 ab	8.91 abc
V_2F_0	22.79 gh	9.81def	25.17 e	5.55 def
V_2F_1	26.48 fgh	8.90 cde	29.57 de	6.84 cde
V_2F_2	45.73 a	14.36 a	47.48 a	10.42 a
V_2F_3	36.9 abcde	11.13 abc	38.73abcd	7.15 bcde
V_3F_0	28.6 efg	8.61 cde	30.41 cde	6.29 cde
V_3F_1	35.53 bcdef	10.32 bc	37.84 abcd	8.44 abc
V_3F_2	42.73 abc	12.80 ab	45.22 ab	10.49 a
V_3F_3	44.26 ab	12.99 ab	46.52 a	10.88 a
Level of Significance	0.0 1	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