EFFECT OF COMBINED APPLICATION OF VERMICOMPOST AND NPK FERTILIZERS ON THE YIELD OF MUNGBEAN

By

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CERTIFICATE

This is to certify that the thesis entitled, **"EFFECT OF COMBINED APPLICATION OF VERMICOMPOST AND NPK FERTILIZERS ON THE YIELD OF MUNGBEAN"** 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 **MOHAMMAD MAHMUDUL HASAN**, Registration No. 00849 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 30/11/07
Dhaka, Bangladesh

(Prof. Dr. Md. Nurul Islam)
Supervisor

Dedicated to

My

Beloved Mother

&

Late Father

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LIST OF SYMBOLS AND ABBRIVIATIONS

ABBREVIATION	FULL WORD
@	At the rate
Cm	Centimeter
i.e	That is
%	Per cent
AEZ	Agro-Ecological Zone
CEC	Cation Exchange Capacity
$CuSO_4.5H_2O$	Green vitriol
cv.	Cultivar(s)
CV%	Percentage of Coefficient of Variance
DMRT	Duncan's Multiple Range Test
e.g.	example
et al	and others
FYM	Farm Yard Manure
g	Gram
H_3BO_3	Boric acid
$HClO_4$	Perchloric acid
HNO_3	Nitric acid
H_2O_2	Hydrogen per oxide
H_2SO_4	Sulfuric acid
K	Potassium
kg	Kilogram
kg ha^{-1}	Kg per hectare
K_2SO_4	Potassium Sulfate
LSD	Least Significant Difference
TSP	Triple Super Phosphate
m	Meter
ml	Milliliter
mm	Millimeter
MP	Muriate of Potash
N	Nitrogen
NaOH	Sodium Hydroxide
NPK	Nitrogen, Phosphorus and Potassium
NS	Not Significant
OM	Organic matter
pH	Hydrogen ion concentration
^0C	Degree Celsius
No.	Number
SAU	Sher-E-Bangla Agricultural University
RCBD	Randomized Complete Block Design

EFFECT OF COMBINED APPLICATION OF VERMICOMPOST AND NPK FERTILIZERS ON THE YIELD OF MUNGBEAN

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ABSTRACT

A field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka 1207 during the *Kharif* season of 2007 to study the effect of vermicompost and NPK fertilizers on the yield of mungbean. The experimental soil was silty clay loam in texture having pH of 6.0. The treatments were 4 levels of vermicomposts viz. V_0 (0 t ha^{-1}), V_1 (1 t ha^{-1}), V_2 (2 t ha^{-1}), V_3 (4 t ha^{-1}), and 3 levels of chemical fertilizers viz. F_0 = (0-0-0 kg ha^{-1}), F_1 = medium (10-10-14 kg ha^{-1}), F_2 = high (20-20-28 kg ha^{-1}) of N-P-K with 12 treatment combinations and 3 replications. The results showed that with the increasing the doses of vermicompost and chemical fertilizers grain and straw yields of mungbean were increased significantly. The maximum significant grain and straw yields were obtained with the treatment combinations V_3F_1. The highest doses of vermicompost and chemical fertilizers increased N, P and K concentrations in mungbean plant significantly at maturity stage. Application of vermicompost and chemical fertilizers increased organic carbon, N, P and K status of postharvest soil significantly.

CHAPTER I

INTRODUCTION

CHAPTER 1

INTRODUCTION

Mungbean (*Vigna radiata* L.) is one of the most important pulses in Bangladesh. It belongs to the family Leguminosae. It is originated in South and Southeast Asia (India, Myanmar, Thailand etc.). Now it is widely grown in India, Pakistan, Bangladesh, Burma, Thailand, Philipines, China and Indonesia. It is also grown in parts of east and central Africa, the West Indies, USA and Australia (Gowda and Kaul, 1982). BARIMUNG-6 was released in Bangladesh in 2003 as a high yielding variety. It fits well in crop rotation between two cereal crops and breaks the build up of disease, insect and weed syndrome. It fixes nitrogen in symbiosis with Rhizobia and enriches the soil. Its root breaks the ploughpan of puddled rice fields and goes deep in search of water and nutrients. Mungbean plants provide useful fodder to animal. The production has not been improved in Bangladesh due to poor management and low yielding varieties. To meet up the demand it is necessary to boost up the production ha^{-1} through varietal development and proper management practices. Use of organic manure will produce better nodulation, nitrogen fixation, better growth and higher yield.

In a developing country like Bangladesh, pulse can improve the overall nutritional value of our diet. Unfortunately, there is an acute shortage of grain legumes production in the country. The daily consumption of pulses in Bangladesh is only 10 grams per head compared to 45 grams in India (FAO, 1984). Annual import of pulses in Bangladesh is approximately 55,000 tons (BBS, 1994). Increase of pulse production is urgently needed to reduce the import and meet up the demand of pulse consumption. It can also minimize the scarcity of fodder because the whole plant or its by-products can be used as good animal feed. Cultivation of pulses can improve the physical, chemical and biological properties of soil as well as increase soil fertility status through biological nitrogen fixation.

In Bangladesh, grain legumes are the main sources of plant protein of our teeming millions and mungbean is the most popular grain legume which is commonly cultivated as a pulse crop in this country. It has enormous potential to contribute to the amelioration of malnutrition. In general, pulses remained a major source of proteins while animal food products rich in protein are beyond the reach of poor people. There are 46.8% carbohydrates, 21.2% protein, some minerals and vitamins also present in Barimung-6 seed (BARI, 2003). At present only one-fourth of the total requirement of pulses are produced in the country. The productivity of mungbean is high compared to other pulses. Mungbean is an important crop that can be grown on flood-free soils nearly throughout the year.

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

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

Vermicompost is the end-product of the breakdown of organic matter by some species of earthworm. Vermicompost is a nutrient-rich, natural fertilizer and soil conditioner. The process of producing vermicompost is called vermicomposting. Vermiculture is a new development in biotechnology based product which helps to solve the pollution problems created by the use of inorganic fertilizers.

Mungbean cultivation covers an area of 60,000 acres producing about 18,000 metric tons (BBS, 2005). The average production of mungbean in the country is about 741 kg/ha, which is much lower than that of India and some other countries. Very recently, with the introduction of some high yielding varieties like BARIMUNG-6, increasing attention is being paid to the cultivation of this crop in order to mitigate the alarmingly protein shortage in the diet of our people. Vermicompost can play an important role for getting higher yield of this crop and to reduce dependence on the use of costly mineral fertilizer. Maximum dry matter production, N and P uptake of mungbean were obtained by the application of vermicompost (Bansal and Kapoor, 1999). Among the different sources of organic manure, vermicompost is important in maintaining and enhancing the quality of environment and conserving resources for sustainable agriculture (Simanaviciene *et al.*, 2001).

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

1. To observe the effect of vermicompost on the growth and yield of mungbean.
2. To observe the effect of combined application of vermicompost and chemical fertilizers on mungbean.
3. To know the impact of vermicompost as an alternative of chemical fertilizers.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

It is now realized that agriculture does not only refer to crop production but also to various other factors that are responsible for crop production. Vermicompost is one of the excellent components in the organic farming which is more nutritious and helpful for maintaining good soil health. Some of the published reports relevant to research topic are reviewed under the following headings:

2.1 Effect of vermicompost and NPK fertilizer on mungbean and legume crops

Abraham and Lal (2002) conducted an experiment on yield attributes, oil and protein content of mustard seed (*var. Pusa Bold*) in a cropping system of soybean (*kharif*)/mustard (*rabi*)/fodder cowpea. 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 and reported that seed yield and biological yield were 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.

Balachandran and Sasidhar (1991) conducted an experiment on green gram (*Vigna radiata*) cv. *Pusa Baisaki*, *S-8*, Co-2 and *Madira* and were given 0, 15, 30 or 45 kg P_2O_5/ha. Dry matter yield, P uptake, pod number/plant, seed number/pod and seed yield (0.63 t/ha) were highest in cv. *Co-2*. Mean seed yield was 0.36, 0.42, 0.51 and 0.54 t/ha with the 4 P rates, respectively. Increasing P rate increased pod number/plant but not seed number/pod or 100-seed weight.

Singh and Mukand (1991) conducted a field experiment on mung bean cv. *PS 16, PDM 62, PDM 54 and Pusa 105* and stated that yields were 1.21, 1.46, 1.79 and 1.52 t/ha with 0, 30, 60 and 90 kg P_2O_5/ha, respectively.

Bali *et al*. (1991) studied a field experiment on moongbean cv. *P.S. 16* and revealed that seed yield, 1000-seed weight increased with up to 40 kg N and 60 kg P_2O_5/ha.

Luo and Chen (1995) conducted a field experiment on green gram and stated that the proportions of nutrients returned from straw were 43.6-55.7% of N, 41.8-50.3% of P_2O_5 and 55.7-61.0% of K_2O and concluded that it was a K-enriched plant.

Thakur *et al*. (1996) carried out an experiment on green gram (*Vigna radiata*) and showed that seed and straw yields were not significantly affected by P source and seed yield averaged 0.91, 1.00, 1.24 and 1.13 t/ha at 0, 25, 50 or 75 kg P_2O_5/ha, respectively. P uptake was also highest with 50 kg P_2O_5.

Singh *et al*. (1993) carried out an experiment on mung bean and revealed that P (30, 60 or 90 kg P_2O_5/ha) and Zn (5, 10 or 15 ppm) application increased the seed protein, N and P contents, but decreased the Mg and Ca contents.

Dhillon *et al.* (1994) carried out a field experiment on green gram and revealed that organic carbon influenced magnitude of response to added P and relatively higher yields were obtained in soils with >0.40% organic carbon.

Rajput *et al.* (1992) carried out a field experiment on mungbean cv. *BRM23 and BRM41* and revealed that average seed yield was 553 kg/ha without fertilizers and highest (803 kg) with 34 kg N + 67 kg P. *BRM23* had a higher seed yield (728 kg/ha) than cultivar *BRM41* (682 kg/ha).

Srinivas and Shaik (2002) revealed that plant height, number of branches and leaves per plant, number of pods per plant, pod length, number of seeds per pod, 1000-seed weight, and seed yield generally increased with increasing rates of P (0, 25, 50 and 75 kg/ha) and N up to 40 kg/ha followed by a decrease with further increase in N.

Asghar *et al.* (1996) conducted an experiment on mung beans cv. *NM.121-25* and showed that the number of pods/plant, number of seeds/pod, seed yield/ha and seed protein contents were influenced significantly by potassium application. The highest seed yield (1.67 t/ha) was obtained with application of 75 kg K_2O/ha.

Kumar, R. *et al.* (2003) conducted a field experiment on mungbean. Results showed that grain yield increased with increasing N rates up to 20 kg N/ha, but further increase in N rate did not affect yield. P at 40 and 60 kg/ha significantly increased grain and straw yields.

Kumar, R. *et al.* (2002) conducted a field experiment on mung bean during summer 1999 and 2000 and revealed that the N content in grain due to N and P levels did not differ significantly and was higher in straw with 20 kg N and 40 kg P_2O_5 ha^{-1} during both years. The N and P uptake increased significantly with 20 kg N and 40 kg P_2O_5 ha^{-1} over the control. The crop yield increased when supplied with 30 kg N ha^{-1} or 40 kg P_2O_5 ha^{-1}.

Ahmad, R. *et al.* (2003) conducted an experiment on mungbean and were supplied with NPK at 50:0:0 (F_1), 50:100:0 (F_2) and 50:100:50 kg/ha (F_3) and revealed that no significant differences in the number of pods per plant, number of grains per plant, grain yield and straw yield were observed in plants under F_2 and F_3. F_3 resulted in the highest grain yield value and costs, and lowest net field benefit.

Malik *et al.* (2003) conducted a study on the yield and quality of mung bean cv. NM-98 and revealed that a fertilizer combination of 25 kg N + 75 kg P ha^{-1} resulted in the maximum seed yield (1112.96 kg ha^{-1}).

Sharma, S. *et al.* (2003) conducted a field experiment on the growth and yield of mungbean cv. Pusa Baisakhi during the *kharif* season and showed that seed yield increased with increasing rates of N (0, 10 and 20 kg/ha) and P(0, 30 and 60 kg/ha).

Dost *et al.* (2004) conducted a field experiment on mung bean cv. *NM-92* and revealed that the maximum number of pods (17.0) were recorded at 80 kg P_2O_5/ha + *Rhizobium* inoculum and the number of grains per pod increased only with an increase of P levels. The maximum grains per pod (10.9) were recorded at 80 kg P_2O_5/ha followed by 10.83 at 65 kg P_2O_5/ha and the highest grain yield (1018 kg/ha) was with 65 kg P_2O_5/ha + *Rhizobium* inoculum.

Yakadri *et al*. (2004) conducted a study on greengram during 1999 and 2000. The treatment combination of N at 20 kg/ha + P at 60 kg/ha resulted in the highest dry matter production, N and P uptake, and seed yield.

Yadav (2004) carried out a field experiment on green gram cv. *RMG-62* during the *kharif* season and revealed that plant height, number of branches, number of pods per plant, number of seeds per pod, seed yield, increased with increasing rates of phosphorus and sulfur up to 40 kg/ha and decreased thereafter.

Singh *et al*. (2003) conducted a study on summer moong (*V. radiata*) during the *kharif* season and revealed that grain and stover yields of moong increased due to the application of P. The application of P up to 60 kg/ha significantly increased the grain yield and the effect was limited with the application of 60 kg P/ha in both grain and stover yields.

Subhendu *et al*. (2005) carried out a field experiment on summer greengram cv. *Pusa Baisakhi* and revealed that increase in the levels of P from 0 to 60 kg ha^{-1} increased the yield, nutrient uptake, gross and net return.

Khan *et al*. (2004) conducted a study on the yield components of mung bean cv. *NM-98* and revealed that the increase in phosphorus levels decreased the days to flowering and increased the branches per plant, number of pods per plant, 1000-grain weight and grain yield. The highest yield of 1022 kg/ha was obtained at the phosphorus level of 100 kg/ha compared to a 774 kg/ha yield in the control. However, the most economical phosphorus level was 40 kg/ha, because it produced a grain yield statistically comparable to 100 kg P/ha.

Ijaz *et al.* (2005) conducted an experiment on the yield and yield components (pods per plant, seeds per pod and 1000-seed weight) of mung bean cv. *NM-92* and showed that P at 90 kg/ha gave the highest seed yield, pods per plant, seeds per pod and seed weight.

Edwin *et al.* (2005) conducted a field experiment on green gram during pre-*kharif* season. Results showed that the highest number of branches per plant (3.23) was obtained with 30 kg Mussoorie rock phosphate (MRP) + 30 kg single superphosphate (SSP)/ha. SSP at 60 kg/ha gave the highest number of clusters per plant (4.36), pod length (7.34 cm), seeds per pod (10.46), 1000-seed weight (34.90 g) and seed yield (15.13 q/ha). Maximum plant height (31.20 cm), dry matter per plant (36.13 g/plant) and number of pods per plant (17.43) was obtained with 60 kg diammonium phosphate (DAP)/ha.

Manpreet *et al.* (2005) conducted a field experiment to assess the response of different mung bean genotypes in terms of nutrient uptake and quality to incremental levels of phosphorus application. Genotypes showed significant differences for straw and grain N content and grain P content while straw P content, N and P uptake differed non-significantly. Phosphorus application resulted in significant increase in N and P content and their uptake.

Mozumder *et al.* (2005) conducted an experiment on mungbean to evaluate the response of summer mungbean cultivars *Binamoog-2* and *Kanti* to *Bradyrhizobium* inoculation and N application. Results showed that the highest seed yield (1461 kg/ha) were obtained in the treatment with 40 kg N/ha along with *Bradyrhizobium* inoculation. The highest straw yield (4702 kg/ha) was obtained in the treatment with 60 kg N/ha with *Bradyrhizobium* inoculation.

Oad and Buriro (2005) laid out a field experiment to determine the effect of different NPK levels on the growth and yield of mung bean cv. *AEM 96* and showed that the 10-30-30 kg NPK/ha was the best treatment, recording plant height of 56.25 cm, pod length of 5.02 cm, seed weight per plant of 10.53 gm and the highest seed yield of 1205.2 kg/ha.

Dey and Basu (2004) conducted a study on green gram and showed that plant height and dry matter accumulation in aerial plant parts were highest with 40 kg K/ha along with 40 kg S/ha.

Oad *et al.* (2003) conducted a field experiment on the growth and yield performance of mungbean (*Vigna radiata*) and showed that mungbean varieties were significantly influenced by phosphorus and potassium fertilizers except pod number, seed weight per plant and seed index were non-significant. However, 100 kg P and 100 kg K ha^{-1} showed an increase in the yield of the crop.

Singh *et al.* (1993) conducted a pot experiment on mung bean (*Vigna radiata*). Results showed that compared with untreated controls, P and Zn application increased the seed protein, N and P contents, but decreased the Mg and Ca contents.

Patro and Sahoo (1994) conducted a field experiment during the winter season on mung bean cv. *Dhauli* and *PDM 54* with 0, 15, 30, 45 and 60 kg P_2O_5/ha and obtained seed yields of 706, 974, 1049, 1234 and 1254 kg/ha, respectively.

Duary *et al.* (2004) conducted a study on green gram and showed that *Rhizobium*, 10 kg N/ha, 30 kg P/ha, 30 kg K/ha, 20 kg S/ha produced the significantly highest seed yield.

Chanda, N. *et al.* (2002) carried out a field experiment on mungbean and showed that seed yield, protein content and net production value increased with increasing rates of K and S. Similarly, the status of N and P in soil decreased with increasing rates of K and S.

Chowdhury *et al.* (2000) conducted a pot experiment during *kharif* 1995 with mungbean and was given 0, 25, 50, 75 or 100 P/ha, with or without seed inoculation. Results showed that dry matter production increased with *Rhizobium* inoculation and increasing P rate.

Ram and Dixit (2000) conducted a field experiment on summer greengram cv. *K-851* and revealed that nodulation, N, P and K uptake and yield were increased with increasing P rate.

Asghar *et al.* (1996) conducted a field experiment on the yield and quality of mungbean cv. *NM.121-25* and revealed that the number of pods/plant, number of seeds/pod, seed yield/ha and seed protein contents were influenced significantly by potassium application. The highest seed yield (1.67 t/ha) was obtained with application of 75 kg K_2O/ha.

Arvadiya *et al.* (1996) conducted a field study in summer on green gram and revealed that seed yield was 1082, 1231 and 1243 kg/ha with 0, 15 and 30 kg P/ha, respectively.

Tomar *et al.* (1996) conducted a field trial on summer mung (*Vigna radiata*) and showed that net returns of *V. radiata* were highest with application of 60 kg P_2O_5/ha. Leaf number, branch number and dry weight per plant were highest with 60 kg P_2O_5/ha.

Thakur *et al.* (1996) conducted a field experiment in *kharif* season on green gram (*Vigna radiata*) with 0, 25, 50 or 75 kg P_2O_5/ha. Results showed that seed and straw yields were not significantly affected by P source and seed yield averaged 0.91, 1.00, 1.24 and 1.13 t/ha at different P rates, respectively. P uptake was also highest with 50 kg P_2O_5/ha.

Prasad *et al.* (2000) conducted a pot experiment to study the effect of potassium on yield and K-uptake by summer mungbean (cv. *T-44*) and showed that the grain yield increased with potassium application but result was statistically non-significant. Increasing potassium levels significantly increased potassium uptake. Available K in soil after harvest of crop increased with increasing levels of K.

Mandal and Sikder (1999) conducted a pot experiment on mungbean cv. *BARI Mug-5* with 0, 50 or 100 kg N/ha and 0, 75 or 150 kg P/ha. Growth and yield increased significantly with N application, while P significantly increased the setting of pods and seeds. Interactions of the fertilizers stimulated the formation of pods and seeds together with seed yield.

Pathak *et al.* (2001) conducted an experiment on growth and yield of green gram under rainfed conditions during the summer of 1999. They showed that application of 20 kg N/ha yielded at par with that of 30 kg N/ha whereas it had higher yield than 10 kg N/ha and no N treatments. Similar trends were also observed for straw yield.

Chaubey and Kaushik (2000) conducted a field experiment with summer green gram cv. *T-44* and revealed that the highest yield was obtained with 100 kg P/ha, however, grain yield increased significantly up to 50 kg P/ha.The straw yield of green gram increased significantly with increasing level of P up to 75 kg/ha.

Singh and Humuman (2001) studied in an experiment on mungbean and revealed that maximum dry biomass/plant (24.8 g/plant) was recorded from 60 kg P_2O_5 /ha. Grain yield was maximum when plants were treated with 30 kg P_2O_5 /ha and 30 mg/kg Zn (4.3 g/plant). Maximum P content were recorded from 30 kg P_2O_5/ha and Zn 15 mg/kg (0.63%).

Sharma, S. *et al.* (2001) conducted a field experiment during the *kharif* seasons on Mung bean cv. *Pusa Baisakhi* and revealed that the highest levels of N and P_2O_5 applications resulted in the average maximum test weight, biological and grain yields, harvest index and seed protein content.

Teotia *et al.* (2001) conducted a greenhouse experiment to study the effect of P and S interaction on yield and nutrient composition of mung bean cv. *Pant Moong-2* and revealed that P and S applied individually or in combination increased the N and K content of the grain and straw yield of the plant.

Pandey and Sing (2001) conducted a field experiment on moong (*Vigna radiata cv. T-44*) and revealed that the highest grain and straw yields were obtained at 50 kg P_2O_5/ha and 40 kg S/ha, respectively.

Bhattacharyya and Pal (2001) conducted a field experiment on summer green gram and showed that *Rhizobium* inoculation and application of P significantly influenced the number of nodules per plant, dry matter accumulation in the shoot, crop growth rate and plant height. Maximum growth was obtained in *Rhizobium* treatments combined with P at 40 kg/ha.

Tiwari *et al.* (2001) conducted field experiments on wheat-mung bean cropping system to evaluate the performance of leguminous and non-leguminous natural green biomasses as amendment in association with varying levels of N and resulted that incorporation of green biomass when applied at 5.0 and 7.5 t ha^{-1} in combination with 50 or 100 kg N ha^{-1} as fertilizer significantly increased the grain yield.

Ram and Dixit (2001) conducted a field experiment to study the effects of P fertilizer rate (0, 20, 40 and 60 kg P_2O_5/ha) on green gram cv. *K 851*. The application of P significantly increased the yield and its components, except the number of plants per running meter and grains per pod, compared with the control. P at 40 and 60 kg/ha were at par in relation to producing the tallest plants and the highest number of branches per plant, dry matter accumulation and grain yield. The number of leaves per plant, however, was highest (13.04) with 60 kg P/ha.

Singh *et al*. (2001) conducted a field experiment on moongbean and stated that application of FYM at 5 t/ha increased yield of moongbean by 9.6% compared to without FYM and application of 20 and 40 kg P_2O_5/ha produced 9.9 and 18.6% more yield, respectively over the control.

Abraham and Lal (2003) conducted field experiments from 1997 to 1999 to investigate the effects of NPK fertilizer, organic manures (farm compost + vermicompost and farm compost + poultry manure) and biofertilizers on the productivity of black gram-wheat-greengram cropping system. Pod counts for black gram and green gram and grain yield for wheat were highest with farm compost + poultry manure, but the highest seed yield was recorded with farm compost + vermicompost in black gram in the first year. The treatment biofertilizers + cow's urine recorded higher values of pod count in the first year and weight and seed yield in the second year in green gram.

Bansal and Kapoor (1999) carried out an experiment on composting of farm wastes (cattle manure mixed with different crop residues) with and without earthworms. The effect of various composts on growth and N and P uptake of mungbean (*Vigna radiata*) was investigated in pot experiments. There was more total N in worm inoculated compost than in compost without worms. Maximum dry matter production, N and P uptake of mungbean were given by compost prepared from a 3:7 mixture of cattle manure and rice straw inoculated with earthworms.

Chandel *et al.* (2002) conducted a field experiment during winter seasons of 1994-95 and 1995-96 at Research Farm, BHU, Varanasi to study the effect of nitrogen levels and on yield, quality and nitrogen uptake of French bean var. HUR-137. Treatment comprised four nitrogen levels viz., control (N_0), low (N_{40}), medium (N_{80}) and high (N_{120}). The yield attributes, yield and protein yield significantly increased with increasing nitrogen levels and highest value was registered with 120 kg N ha^{-1} during both the years. The nitrogen content and uptake numerically increased with increasing nitrogen levels and maximum value was associated with 120 kg N ha^{-1}.

Das *et al.* (2002) studied the effects of vermicompost and chemical fertilizer application on the growth and yield of green gram (*V. radiata cv. Sujata*). The dry matter and pod yield of green gram were increased with the application of vermicompost applied in integrated form. The yield was highest with 100% enriched vermicompost compared to sole organic manure. Greater dry matter content, pod yield, nutrient uptake (N, P and K), plant height, leaf area, root volume, number of nodules and fresh weight of nodules were obtained with treatments containing vermicompost. Flowering was earlier by 7 days in vermicompost-treated plants compared with the control.

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

Jeyabal and Kuppuswamy (2001) investigated to recycle agricultural and agro-industrial wastes for the production of vermicompost using earthworms (*Eudrilus eugeniae*). Its response was studied in a rice-legume (black gram) cropping system during 1994-96 in Tamil Nadu, India. The study showed that biodigested slurry and weeds were found to be an ideal combination for vermicomposting considering the nutrient content and compost maturity period. The C:N ratio of vermicompost reduced to 12-17:1 from 21-69:1.The study showed that the integrated application of vermicompost, fertilizer N and biofertilizers viz., *Azospirillum* and phosphobacteria increased rice yield by 15.9% over fertilizer N application alone. The field experiment studied the direct and residual effect of different sources of organic N with fertilizer N and biofertilizers in rice-legume crop sequence. The integrated application of 50% N through vermicompost, 50% via fertilizer N and biofertilizers recorded a grain yield of 6.25 and 0.51 t ha^{-1} in the rice and legume, respectively. These yields were 12.2 and 19.9% higher than those obtained with 100% fertilizer N alone. The microbial population of the residual soil was increased by integrated application. The studies indicate that integrated nutrition comprising vermicompost, fertilizers N and biofertilizers could be applied to rice-legume cropping system to achieve higher yields and sustain soil health.

Karmegam *et al.* (1999) studied the effects of the vermicompost on germination efficiency, shoot length, root length, number of root nodules, fresh weight, dry weight, and yield performance of green gram (*Vigna radiata*). Chemical analysis showed a higher content of N, P and K in the vermicompost of green gram pods (GGP) + cattle manure mixture (1:1). Maximum growth and reproduction of earthworm (*Eudrilus eugeniae)* were also recorded in GGP + cattle manure mixture. The germination efficiency of green gram was 93.33% in the vermicompost-applied pots compared to 84.17% in the control. The growth and yield performance of green gram in vermicompost were also significantly higher than the control.

Kumar *et al.* (2002) conducted a field study on the effect of N and P levels on nutrient content and their uptake during summer seasons of 1999 and 2000 with mungbean. The N content in grain due to N and P levels did not differ significantly but it was increased in straw with 20 kg N and 40 kg P_2O_5 ha^{-1} during both the years. The N and P uptake was also increased significantly with 20 kg N and 40 kg P_2O_5 ha^{-1} over control. The biological yield was also significantly affected due to the application of N and P and increased with 30 kg N ha^{-1} was 48.0, 18.5 and 0.23% over 0, 10 and 20 kg N ha^{-1}, respectively, whereas figures with 40 kg P_2O_5 were 61.2, 17.8 and 0.9% over 0, 20 and 60 kg P_2O_5 ha^{-1}.

Kumar *et al.* (2003) conducted a field experiment in 2001-02 on the sandy loam soil of Haryana, India to investigate the effect of *Rhizobium sp.* seed inoculation, FYM (farmyard manure) at 5 t/ha, vermicompost at 2.5 and 5 t/ha, and 4 levels of fertilizers (control, no chemical fertilizer; 75% recommended dose of fertilizer, RDF; 100% RDF. N:P at 20:40 kg/ha; and 125% RDF) on the performance of mungbean *cv. Asha.*

Rhizobium sp. inoculation significantly increased the grain yield. Increasing RDF levels up to 100% also increased grain yield. Vermicompost at 5 t/ha produced 16.5 and 9.5% higher grain yield compared to FYM at 5 t/ha and vermicompost at 2.5 t/ha, respectively. Vermicompost application at both levels resulted in higher yield compared to FYM. Yield increased with increasing fertilizer rate up to 125% RDF, when applied with FYM, but yield was higher under the treatment 100% RDF + vermicompost (both rates).

Rajkhowa *et al.* (2002) conducted a field experiment to investigate the effect of vermicompost (at 2.5 t/ha) in combination with fertilizers (recommended rate, N : P at 15:35 kg/ha; and 50 and 25% of the recommended), and farmyard manure at 2.5 t/ha on green gram. Results showed that the application of vermicompost at 2.5 t/ha + the recommended fertilizer rate resulted in the highest yield.

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

Reddy *et al.* (1998) carried out in a field trial during *kharif* of 1995 at Attibele, Karnataka, India, on peas *cv. Selection FC-1* with 0, 50 or 100% of the recommended rate of NPK (37.5:60:50 kg/ha), and 0, 5 or 10 t farmyard manure and/or vermicompost/ha. Plant height at harvest, days to initial flowering, number of branches per plant, number of pods per plant, number of seeds per pod and yield were highest with 10 t vermicompost + 100% recommended NPK.

Vishwakarma *et al.* (2002) conducted a field experiment during the winter seasons of 1996-97 and 1997-98 at Agricultural Research Farm, Banaras Hindu University, Varanasi, India to study the response of French bean (*Phaseolus vulgaris L.*) varieties to nitrogen application on sandy loam soil. Varieties showed differential performance for growth and yield attributes. Holland 84 was the tallest, whereas PDR 14 recorded the maximum dry matter production per plant as well as pods per plant, grains per pod, grains per plant, pod length and 100-grain weight. The growth and yield attributes and yield (grain and stover) increased with increasing rates of nitrogen upto 90 kg/ha.

Yadav and Malik (2005) conducted a field experiment during the 1999 *kharif* season in Hisar, Haryana, India to study the effect of *Rhizobium* inoculation and various N sources on the growth, nodulation and yield of cowpea *cv. V-240*. Vermicompost-treated and *Rhizobium*-inoculated cowpea gave the maximum plant height and dry matter per plant at 15, 30, 45 and 60 days after sowing and at harvest. The highest number of nodules per plant, dry weight of nodules and number of pods per plant at harvest was obtained with *Rhizobium* inoculation and all N sources.

2.2 Effect of vermicompost on other crops

Arancon *et al.* (2004) carried out an experiment on vermicomposts to evaluate the effects on the growth and yields of strawberries (*Fragaria ananasa*) *var. 'Chandler'*. Vermicompost applications increased strawberry growth and yields significantly; including increases of up to 37% in leaf areas, 37% in plant shoot biomass, 40% in numbers of flowers, 36% in numbers of plant runners and 35% in marketable fruit weights.

Arancon *et al.* (2004) substituted vermicomposts at a range of different concentrations into a soil-less commercial bedding plant container medium, Metro-Mix 360 (MM360), to evaluate their effects on the growth and yields of peppers in the greenhouse. Peppers grown in potting mixtures containing 40% food waste vermicomposts and 60% MM360 yielded 45% more fruit weights and had 17% greater mean number of fruits than those grown in MM360 only.

Atiyeh *et al.* (2000) conducted an experiment on the effects of earthworm-processed pig manure (vermicompost) on germination, growth, and yields of tomato (*Lycopersicon esculentum Mill.*) plants under glasshouse conditions. The germination rates of tomato seeds increased significantly upon substitution of Metro-Mix 360 with 20%, 30%, and 40% vermicompost. Seedlings grown in 100% pig manure vermicompost were significantly shorter, had fewer leaves, and weighed less than those in Metro-Mix 360 controls. Incorporation of 10% or 50% vermicompost into Metro-Mix 360 increased the dry weights of tomato seedlings significantly compared to those grown in the Metro-Mix 360 controls. The largest marketable yield was in the substitution of Metro-Mix 360 with 20% vermicompost (5.1 kg/plant). The average weight of a tomato fruit in substitution of Metro-Mix 360 with 20% vermicompost was 12.4% greater than that in the Metro-Mix 360 control. Substitution of Metro-Mix 360 with 10%, 20%, and 40% vermicompost reduced the proportions of fruits that were non-marketable, and produced more large size (diameter > 6.4 cm) than small size (diameter < 5.8 cm) tomato fruits. There was no significant difference in overall tomato yields between Metro-Mix 360 and 100% pig manure vermicompost.

Atiyeh *et al.* (2001) designed an experiment with tomatoes (*Lycopersicon esculentum Mill.*) to characterize the physical, chemical and microbial properties of a standard commercial horticultural, greenhouse container, bedding plant medium (Metro-Mix 360), that had been substituted with a range of increasing concentrations (0%, 5%, 10%, 25%, 50% and 100% by volume) of pig manure vermicompost. The percentage total porosity, percentage air space, pH and ammonium concentrations of the container medium all decreased significantly, after substitution of Metro-Mix 360 with equivalent amounts of pig manure vermicompost; whereas bulk density, container capacity, electrical conductivity, overall microbial activity and nitrate concentrations, all increased with increasing substitutions of vermicompost. The growth of tomato seedlings in the potting mixtures containing 100% pig manure vermicompost was reduced, possibly as a result of high soluble salt concentrations in the vermicompost and poorer porosity and aeration. The growth of tomato seedlings was greatest after substitution of Metro-Mix 360 with between 25% and 50% pig manure vermicompost, with more growth occurring in combinations of pig manure vermicompost treated regularly with a liquid fertilizer solution than in those with no fertilizer applied.

Atiyeh *et al.* (2002) accomplished some effects of humic acids formed by earthworms (vermicomposting), on tomato and cucumber plant growth. Vermicompost increased the growth of tomato and cucumber plants significantly, in terms of plant heights, leaf areas, shoot and root dry weights. Plant growth increased with increasing concentrations of humic acids incorporated into the medium up to a certain proportion, but this differed according to the plant species, the source of the vermicompost, and the nature of the container medium.

Atiyeh *et al.* (2002) conducted an experiment on the effects of additions of earthworm-processed pig manure (vermicompost) on the growth and productivity of French marigold (*Tagetes patula*) plants. The greatest vegetative growth resulted from substitution of Metro-Mix 360 with 30 and 40% pig manure vermicompost, and the lowest growth was in the potting mixtures containing 90 and 100% vermicompost. Most flower buds occurred in the potting mixtures containing 40% pig manure vermicompost (19.4 buds), and fewest in the potting mixtures containing 100% vermicompost. Marigolds grown in Metro-Mix 360 substituted with 90 and 100% pig manure vermicompost had the fewest and smallest flowers.

Bhalerao *et al.* (2002) revealed that the protein content of grain, protein yield of sorghum, uptake of N, P and K by sorghum and N, P and K status of soil after harvest were significantly influenced due to fertilizer levels and vermicompost levels, individually maximum values of all these characters were recorded with 100% RDF and with 3.0 t vermicompost ha^{-1}.

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

Gajalakshmi and Abbasi (2002) studied the impact of the application of compost/vermicompost from water hyacinth (*Eichhornia crassipes, Mart. Solms*) on plants, assessed in terms of growth and flowering of the angiosperm crossandra (*Crossandra undulaefolia*). Application of vermicompost led to statistically significant improvement in the growth and flowering of *crossandra* compared to the untreated plants. The impact of compost was also beneficial but a little less distinct than the positive impact of vermicompost.

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

Lima *et al.* (2000) conducted a field experiment with potatoes *cv. Alpha* with 2, 4 or 6 t/ha of chicken manure, vermicompost or compost, adjusted to a rate (considered optimum) of 165:200:300 kg NPK/ha with mineral fertilizers and reported that the highest total and marketable yield, production of dry matter and tuber N accumulation were obtained with chicken manure and the lowest with vermicompost.

Marimuthu *et al.* (2002) conducted a field experiment in red lateritic soil in Tamil Nadu, India during *kharif* seasons of 1998 and 1999 to study the utility of different sources of vermicompost and its nutrient status on the growth and yield of groundnut. Among the various sources of vermicompost, ornamental garden waste vermicompost application performed superior over other sources viz., organic waste, common weed biomass, water hyacinth, chopped young *Prosopis juliflora*, coir pith and farmyard manure.

Marinari *et al.* (2000) studied in a field experiment the influence of different fertilizer applications on soil biological and physical properties. Vermicompost from biological sludge stabilized dairy manure or mineral nitrogen fertilizer (NH_4NO_3) were applied to a corn crop (*Zea mays L.*) at 200 kg N ha^{-1}. Soil enzyme activity and CO_2 production were measured and these metabolic activities were correlated to soil physical properties such as soil porosity. There were positive correlations between soil porosity, enzymatic activity and CO_2 production in organic and mineral treatments. The addition of organic fertilizers improved soil physical and biological properties. Mineral fertilizer enhanced soil porosity by increasing regular and irregular pores and caused a priming effect of native soil organic matter.

Meena *et al.* (2007) conducted a field experiment on medium calcareous soil to study the response of *rabi* maize (*Zea mays L.*) to vermicompost and nitrogen levels. An application of 120 kg N/ha resulted in significantly more grain and stover yield, nutrient content, uptake and protein content compared with 80, 40 and 0 kg N/ha. Significantly higher grain and stover yield, nutrient content, uptake and protein content of maize were obtained with application of 1.5 t vermicompost/ha than 1.0, 0.5 t/ha and control.

Patil and Sheelavantar (2004) laid out a field experiment during winter seasons of 1994-1995 and 1995-1996 on deep black clayey soils (Vertisols) in Karnataka State of south India to evaluate the effect of cultural practices on soil moisture conservation, soil properties, root growth and yield of sorghum (*Sorghum bicolar L. Moench*).Among organic sources, incorporation of *Leucaena loppings* improved soil physico-chemical properties, conserved higher amount of moisture and increased winter sorghum yield to a greater extent than farmyard manure and vermicompost. Average grain yield (1994-1995 and 1995-1996) of winter sorghum increased by 11.7% with *Leucaena* application as compared to vermicompost. Grain yield increased significantly by 20% with application of 25 kg N ha^{-1} and further increase in nitrogen dose up to 50 kg ha^{-1}, increased the grain yield by 30.5% in the pooled data.

Rani and Srivastava (1997) conducted an experiment where vermicompost was tested in pot experiments for its ability to replace a proportion of the urea fertilizer applied to rice. Compared with N fertilizer alone, supplying one-third or one-quarter of N as vermicompost increased plant height, grain yield and yield components of rice.

Singh *et al.* (2005) conducted a field experiment in Imphal (Manipur, India) to study the effect of integrated management of N fertilizer, vermicompost and Azolla on grain yield and nutrient uptake of rice [*Oryza sativa*] and on soil fertility in a clayey soil for 3 years (1999-2001). The highest grain and straw yields were recorded with the application of 60 kg N ha^{-1} plus Azolla. The combined application of fertilizer N, vermicompost and Azolla sustained the productivity even at lower rate of N fertilizer application. The highest N, P and K uptake was also recorded with the application of 60 kg N ha^{-1} plus Azolla treatment.

Vasanthi and Kumaraswamy (1999) conducted a field experiments during 1994-95 and 1995-96 on a red sandy clay loam soil at Madurai, India, to evaluate the efficacy of vermicomposts prepared from sugarcane trash, Ipomeae weed, Parthenium, neem [*Azadirachta indica*] leaves and banana peduncle, to increase the yield of rice and the soil fertility status. Results showed that the grain yields were significantly higher in the treatments that received vermicompost from any of the above organic materials plus N, P and K at recommended levels than in the treatment that received N, P and K alone. Organic carbon content and fertility status as reflected by the available status of N, P and

K, micronutrients and cation exchange capacity were higher and bulk density lower in the treatments that received vermicompost plus N, P and K than in the treatment with N, P and K alone.

Vennila and Jayanthi (2007) conducted a field experiment at Tamil Nadu Agricultural University, Coimbatore during *rabi* 2002-03 and revealed that application of 75% RDFN (Recommended dose of fertilizer nitrogen) or 50% RDFN along with 25% N as organic manures [poultry manure (PM)/goat manure (GM)/Farmyard manure (FYM)] and 100% RDFN to wet seeded rice increased the yield attributes, yield and nutrient uptake of rice. However, application of 75% RDFN along with 25% N as organic manures to preceding wet seeded rice had significant residual effect on yield and nutrient uptake of succeeding greengram. Application of 75% RDFN+organic manures resulted in higher soil available organic carbon, nitrogen and phosphorus. There was no remarkable change in available soil potassium after harvest of rice and greengram.

2.3 Nutrient status of vermicompost

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

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

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

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

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

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

2.4 Importance of vermicompost

Arancon *et al.* (2005) studied in the greenhouse on the effects of commercial vermicomposts, produced from food waste, on infestations and damage by aphids, mealy bugs and cabbage white caterpillars on pepper, tomato, cabbage. Vermicomposts were used at substitution rates into a soil-less plant growth medium. The substitution rates of 20% and 40% vermicomposts suppressed populations of both aphids (*Myzus persicae Sulz.*) and mealy bugs (*Pseudococcus spp.*) on peppers and mealy bugs (*Pseudococcus spp.*) on tomatoes, significantly. Substitutions with vermicomposts decreased losses of dry weights of peppers, in response to both aphid and mealy bug infestations, decreased losses in shoot dry weights of tomatoes after mealy bug infestations significantly.

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

Edwards and Bohlen (1996) reported that vermicomposting is the managed bioconversion of organic materials through earthworm consumption (Blickwedel and Mach, 1983). Vermiculture and vercomposting experiments have been set up in many countries like

England, France, Germany, Italy, Israel, USA, Japan, The Philippines, India and other parts of South-East Asia, Australia, Cuba, The Bahamas and many countries in Africa and South America.

Gajalakshmi and Abbasi (2004) accomplished vermicomposting of neem (*Azadirachta indica A. Juss*) in 'high-rate' reactors operated at the earthworm (*Eudrilus eugeniae*) densities of 62.5 and 75 animals per litre of reactor volume. Contrary to the fears that neem - a powerful nematicide - might not be palatable to the annelids, the earthworms fed voraciously on the neem compost, converting upto 7% of the feed into vermicompost per day. Indeed the worms grew faster and reproduced more rapidly in the neem-fed vermireactors than in the reactors fed with mango leaf litter. Another set of experiments on the growth, flowering, and fruition of brinjal (*Solanum melongena*) plants with and without fertilization with vermicompost, revealed that the vermicompost had a significantly beneficial impact.

Garg and Kaushik (2005) made an investigation to explore the potential of an epigeic earthworm *Eisenia fetida* to transform textile mill sludge spiked with poultry droppings in to value added product, i.e., vermicompost. The maximum growth of *E. foetida* was recorded in 100% cow dung (CD). Worms grew and reproduced favourably in 70% poultry droppings (PD) + 30% solid textile mill sludge (STMS) and 60% PD + 40% STMS feed mixtures. Greater percentage of STMS in the feed mixture significantly affected the biomass gain and cocoon production. Vermicomposting resulted in significant reduction in C : N ratio and increase in nitrogen and phosphorus contents. Total potassium, total calcium and heavy metals (Fe, Zn, Pb and Cd) contents were lower in the final product than initial feed mixtures. Their trials demonstrated vermicomposting as an alternative technology for the recycling and environmentally safe disposal/management of solid textile mill sludge using an epigeic earthworm *E. foetida* if mixed with poultry droppings.

Ghosh (2004) revealed that vermicomposts as a biofertilizer can be a great option for pond manuring as they never cause any long term harm to the soil like chemical fertilizer. In his study vegetable and horticulture waste was used as an important media for vermiculture. Three separate cemented tanks were used in the system as control tank, vermicompost fertilized tank and inorganic fertilizer manured tank. Water retention capacity of vermicompost pond soil was better in comparison to other ponds. Result showed that the low cost model by integrating two production system vermiculture and pisciculture could be a commercially and environmentally viable option.

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

Kumar and Singh (2001) revealed the effect of inoculation of vermicompost with nitrogen-fixing *Azotobacter chroococcum* strains, *Azospirillum lipoferum* and the phosphate solubilizing *Pseudomonas striata* on N and P contents of the vermicompost. Inoculation of N-fixing bacteria into vermicompost increased contents of N and P. Enriching vermicompost with rock phosphate improved significantly the available P when inoculated with *P. striata*. During the incubation period, the inoculated bacterial strains proliferated rapidly, fixed N, and solubilized added and native phosphate.

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

Srikanth *et al.* (2000) carried out a field experiment in Bangalore, India, in 1996 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.

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

CHAPTER III

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

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

3.1 Experimental site

The research work relating to the study of the effect of vermicompost on the yield of mungbean was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka-1207 during the *Kharif* season of 2007. The map (Figure 1) shows the specific location of experimental site.

3.2 Description of soil

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

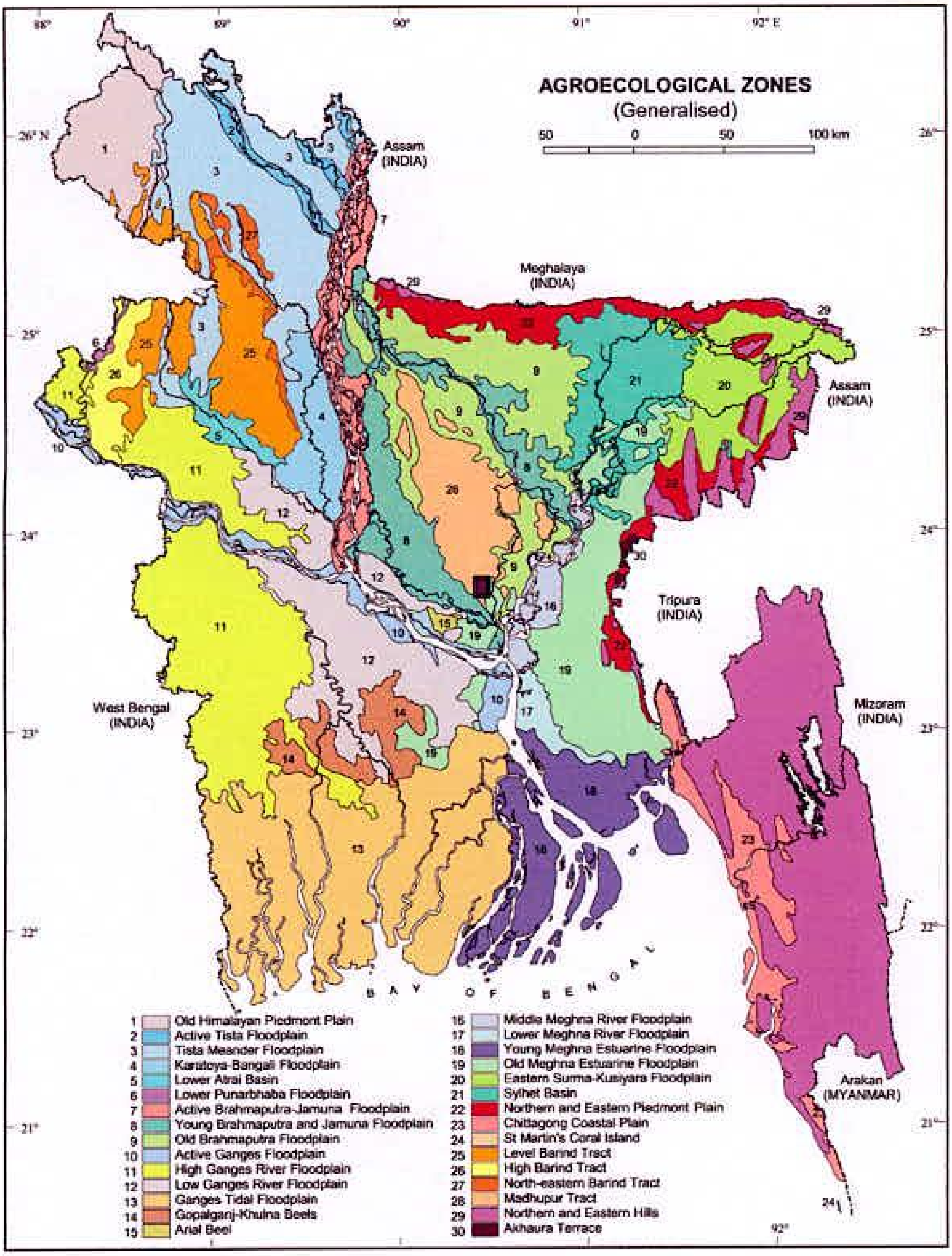


Figure 1. Map showing the experimental site under study

Table 1. Initial characteristics of the soil in experimental field

1. pH		6.0
2. Particle-size analysis of soil	Sand	29.04
	Silt	41.80
	Clay	29.16
3. Textural Class		Silty Clay Loam
4. Organic matter (%)		0.840
5. Total N (%)		0.0670
6. Phosphorous (ppm)		8.333
7. Potassium (ppm)		25.00

3.3 Description of the mungbean variety

BARIMUNG-6, a high yielding variety of mungbean was used as the test crop in this experiment. This variety was released by Bangladesh Agricultural Research Institute, Joydebpur, Gazipur in 2002. Life cycle of this variety ranges from 55 to 60 days. This variety is resistant to diseases, insects and pest attack.

3.4 Climate

The experimental area has sub-tropical climate characterized by heavy rainfall during May to September and scanty rainfall during rest of the year. The annual precipitation of the site is 2152 mm and potential evapotranspiration is 1297 mm, the average maximum temperature is 30.34^0C and average minimum temperature is 21.21^0C. The average mean temperature is 25.17^0C. The experiment was carried out during *kharif* season, 2007. The monthly average temperature, humidity and rainfall of the site during the experimental period are enclosed in appendix Table 1.

3.5 Preparation of the field

The plot selected for the experiment was opened by power tiller driven rotovator on the 7th April 2007; afterwards the land was ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed and the large clods were broken into smaller pieces to obtain a desirable tilth of soil for sowing of seeds. Finally, the land was leveled and the experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in the following section.

3.6 Layout of the experiment

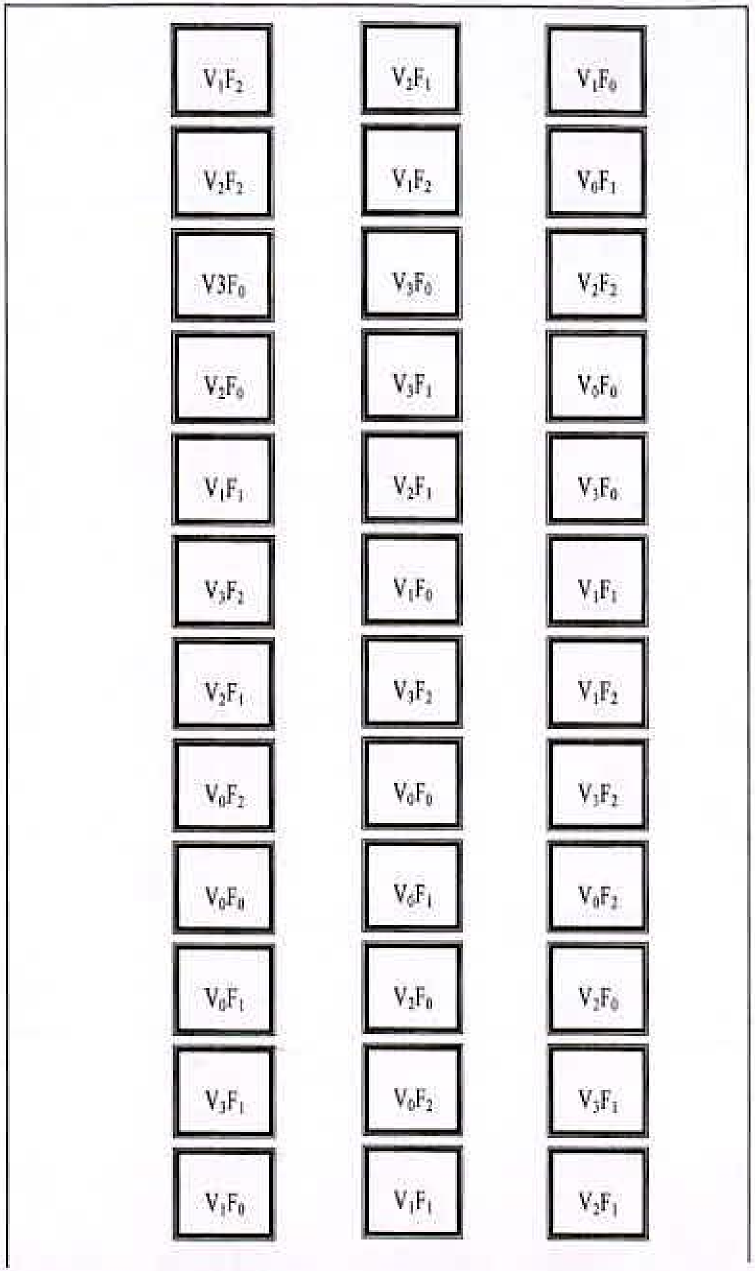
The experiment was laid out in a two factor Randomized Complete Block Design with three replications. The total number of plots was 36, each measuring 3 m × 3 m (9 m^2). The treatment combination of the experiment was assigned at random into 12 plots of each at 3 replications. The distance maintained between two plots was 50 cm and between blocks was 100 cm. The layout of the experiment is presented in Figure 2.

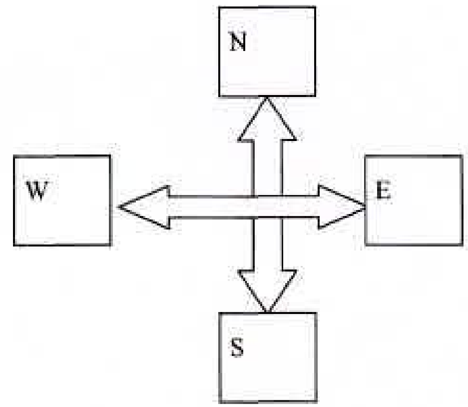
3.7 Treatments

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

Factor A: Vermicompost

V_0 = 0 t ha^{-1} (No vermicompost)
V_1 = 1 t ha^{-1} (Low vermicompost)
V_2 = 2 t ha^{-1} (Medium vermicompost)
V_3 = 4 t ha^{-1} (High vermicompost)





Plot size : 3 m x 3 m (9 m^2)
Plot to plot distance : **50** cm
Block to block distance : **100** cm

Figure 2. Layout of the experimental field

Factor B: Fertilizer

F_0 = 0 kg N ha^{-1} + 0 kg P ha^{-1} + 0 kg K ha^{-1} (No NPK)
F_1 = 10 kg N ha^{-1} + 10 kg P ha^{-1} + 14 kg K ha^{-1} (Half dose of the recommended NPK)
F_2 = 20 kg N ha^{-1} + 20 kg P ha^{-1} + 28 kg K ha^{-1} (Full dose of the recommended NPK)

Treatment combinations

V_0F_0 = Control (No vermicompost + No NPK)
V_0F_1 = (No vermicompost + Half dose of the recommended NPK)
V_0F_2 = (No vermicompost + Full dose of the recommended NPK)
V_1F_0 = (Low vermicompost + No NPK)
V_1F_1 = (Low vermicompost + Half dose of the recommended NPK)
V_1F_2 = (Low vermicompost + Full dose of the recommended NPK)
V_2F_0 = (Medium vermicompost + No NPK)
V_2F_1 = (Medium vermicompost + Half dose of the recommended NPK)
V_2F_2 = (Medium vermicompost + Full dose of the recommended NPK)
V_3F_0 = (High vermicompost + No NPK)
V_3F_1 = (High vermicompost + Half dose of the recommended NPK)
V_3F_2 = (High vermicompost + Full dose of the recommended NPK)

3.8 Application of vermicompost and fertilizers

The required amounts of N, P and K fertilizers (Urea, Triple Super Phosphate and Muriate of Potash, respectively) were applied at the time of final land preparation. The required amounts of vermicompost as per treatment combinations were applied uniformly in the canals opened for sowing the seeds of mungbean in lines.

3.9 Seed sowing

Mungbean seeds were sown on the 10th April 2007 in lines following the recommended line to line distance of 30 cm and plant to plant distance of 10 cm.

3.10 Cultural and management practices

Various intercultural operations such as thinning of plants, weeding and spraying of insecticides were accomplished whenever required to keep the plants healthy and the field weed free. At the very early growth stage (after 10 days of emergence of seedlings) the plants were attacked by Cutworm, which was removed by applying Malathion. Special care was taken to protect the crop from birds especially after sowing and germination stages. The field was irrigated twice- one at 15 days and the other at 30 days after sowing.

3.11 Harvesting

The crop was harvested at maturity on 10^{th} June 2007. The harvested crop of each individual plot was bundled separately. Grain and straw yields were recorded plot wise separately and the yields were expressed in t ha^{-1}.

3.12 Collection of samples

3.12.1 Soil Sample

The initial soil samples were collected randomly from different spots of the field selected for the experiment at 0-15 cm depth before the land preparation and mixed thoroughly to make a composite sample for analysis. Post harvest soil samples were collected from each plot at 0-15 cm depth on 15^{th} June 2007. The samples were air - dried, grounded and sieved through a 2 mm (10 meshes) sieve and preserved for analysis.

3.12.2 Plant sample

Plant samples were collected from every individual plot for laboratory analysis at maturity stage of the crop. Plants were collected from each plot by cutting above ground level. The plant samples were washed first with tap water and then with distilled water several times. The plant samples were dried in the electric oven at 70^0 C for 48 hours. After that the samples were grounded in an electric grinding machine and stored for chemical analysis. The plant samples were collected by avoiding the border area of the plots.

3.13 Collection of data

Data collection were done on the following parameters-

3.13.1 Plant height

The plant height was measured from the ground level to the top of the canopy of 10 plants randomly from each plot and averaged. It was done at the maturity stage of the crop.

3.13.2 Number of leaves /plant

No. of leaves from 10 plants randomly were counted at maturity stage from each plot and averaged.

3.13.3 Number of branches /plant

No. of branches were counted from 10 plants randomly at maturity stage from each plot and averaged.

3.13.4 Number of pods / plant

Pods of 10 plants were counted randomly at maturity stage from each plot and averaged.

3.13.5 Pod length (cm)

Pod length was measured at maturity stage for 10 pods randomly collected from each plot and averaged.

3.13.6 Number of seeds / pod

The number of seeds from 10 randomly selected pods from each plot were counted and averaged.

3.13.7 Thousand seed weight

Thousand seeds of mungbean were counted randomly and then weighed plot wise.

3.13.8 Grain yield

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

3.13.9 Straw yield

Straw obtained from 1 m^2 area from the center of each individual plot was dried, weighed carefully and expressed in t ha^{-1}.

3.14 Chemical analysis of the plant, soil and vermicompost samples

3.14.1 Plant sample analysis

The grounded plant samples were digested with conc. HNO_3 and $HClO_4$ mixture for the determination of P and K.

3.14.1. a Nitrogen

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

3.14.1. b Phosphorous

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

3.14.1.c Potassium

Potassium content in plant sample was determined by flame photometer.

3.14.2 Soil sample analysis

3.14.2. a Organic carbon

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

3.14.2. b Total nitrogen

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

3.14.2. c Available Phosphorous

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

3.14.2. d Exchangeable potassium

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

3.14.3 Vermicompost

Vermicompost was analyzed for organic matter, total N, available P and K contents following the methods used for plant and soil analysis. Vermicompost contained 11.06% organic matter, 0.6298% total N, 0.02249% available P and 0.07826% available K.

3.14.4 Statistical analysis

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

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

This chapter includes the experimental results along with discussions. Effects of vermicompost and NPK on growth, yield and yield attributes of mungbean presented in Tables 2-16 are discussed characterwise under the following heads.

4.1 Effect of vermicompost and NPK on the plant characters of mungbean

4.1.1 Plant height

The effects of vermicompost and NPK fertilizers alone and in combination of two sources on the plant height of mungbean are presented in Table 2 and appendix Fig. i. Significant variation was observed on the plant height of mungbean when the field was incorporated with different doses of vermicompost. Among the different doses of vermicompost, V_3 (4 t ha^{-1}) showed the highest plant height (57.60 cm). On the other hand, the lowest plant height (51.10 cm) was observed in the V_0 treatment where no vermicompost was applied. Vermicompost might have positive role on the soil moisture content, soil porosity and other plant growth enhancing characters and for that reason increasing dose of vermicompost increased plant height. These are in agreement with those of Yadav and Malik (2005), Reddy *et al.* (1998) and Das *et al.* (2002) who have reported that different levels of vermicompost significantly increased plant height.

Mungbean plants showed significant variation in respect of plant height when fertilizers in different doses were applied (Table 3 and appendix Fig. ii). Among the different fertilizer doses, F_2 (High NPK) showed the highest plant height (57.19 cm), which was statistically significant with other doses of fertilizers. On the contrary, the lowest plant height (50.90 cm) was observed in the treatment F_0 where no fertilizer was applied.

Combined application of different doses of vermicompost and fertilizers had also significant effect on the plant height of mungbean (Table 4 and appendix Fig. iii). The lowest plant height (51.90 cm) was observed in the control treatment where no vermicompost and fertilizer were added. On the other hand, the highest plant height (60.03 cm) was recorded with V_3F_2 (High vermicompost + High NPK) treatment. It is evident from the data that vermicompost at the high rate along with high dose of NPK resulted the highest plant height of mungbean plants.

Table 2. Effect of vermicompost on the plant characters of mungbean

Vermicompost	Plant height (cm)	Number of leaves/ plant	Number of branches/ plant
V_0	51.10 c	9.18	1.14
V_1	52.30 bc	9.22	1.34
V_2	54.70 b	8.58	1.37
V_3	57.60 a	9.68	1.38
Level of Significance	0.05	NS	NS

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

Table 3. Effect of NPK fertilizers on the plant characters of mungbean

NPK Fertilizers	Plant height (cm)	Number of leaves/ plant	Number of branches/ plant
F_0	50.90 c	8.83	1.17 c
F_1	54.04 b	9.05	1.30 b
F_2	57.19 a	9.62	1.45 a
Level of Significance	0.05	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

4.1.2 Number of leaves per plant

No significant variation was observed on the number of leaves per plant when the field was incorporated with different doses of vermicompost (Table 2). But among the different doses of vermicompost, V_3 (4 t ha^{-1}) showed the highest number of leaves per plant (9.68) and the lowest number of leaves per plant (9.18) was observed in the V_0 treatment where no vermicompost was applied. Further, it was observed that the number of leaves per plant increased with increasing level of vermicompost.

Mungbean plants did not show significant variation in respect of the number of leaves per plant when fertilizers in different doses were applied (Table 3). Among the different fertilizer doses, F_2 (High NPK) showed the highest number of leaves per plant (9.62) and the lowest number of leaves per plant (8.83) was observed in the treatment F_0 where no fertilizer was applied. Tomar *et al.* (1996) found that the highest numbers of leaves were obtained from 60 kg P_2O_5/ha.

Combined application of different doses of vermicompost and fertilizers significantly influenced the number of leaves per plant of mungbean (Table 4). The highest number of leaves per plant (10.77) was recorded withV_3F_1 (High vermicompost + Medium NPK). On the other hand, the lowest number of leaves per plant (7.77) was observed in the treatment combination of V_0F_0 (no vermicompost and no NPK).

4.1.3 Number of branches per plant

No significant variation was observed on the number of branches per plant when the field was incorporated with different doses of vermicompost (Table 2). But among the different doses of vermicompost, V_3 (4 t ha^{-1}) showed the highest number of branches per plant (1.38) and the lowest number of branches per plant (1.14) was observed in the V_0 treatment where no vermicompost was applied. Further, it

the number of branches per plant increased with increasing level

These are in agreement with those of Yadav and Malik (2005), Rec

Table 4. Combined effect of vermicompost and NPK fertilizers on the plant characters of mungbean

Vermicompost × NPK Fertilizers	Plant height (cm)	Number of leaves/ plant	Number of branches/ plant
V_0F_0	51.90 c	7.77 c	0.96 c
V_0F_1	52.20 bc	8.36 bc	1.13 abc
V_0F_2	53.97 bc	9.63 abc	1.20 abc
V_1F_0	51.90 c	9.03 abc	1.03 bc
V_1F_1	53.00 bc	9.26 abc	1.26 abc
V_1F_2	55.13 abc	10.33 ab	1.56 abc
V_2F_0	52.53 bc	8.43 bc	1.30 abc
V_2F_1	54.33 abc	9.03 abc	1.43 abc
V_2F_2	54.83 abc	8.80 abc	1.36 abc
V_3F_0	53.43 bc	8.00 c	1.23 abc
V_3F_1	58.23 ab	10.77 a	1.70 a
V_3F_2	60.03 a	10.63 a	1.56 ab
Level of Significance	0.05	0.05	0.05

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

Mungbean plants showed significant variation in respect of the number of branches per plant when fertilizers in different doses were applied (Table 3). Among the different fertilizer doses, F_2 (High NPK) showed the highest number of branches per plant (1.45), which was statistically significant with other doses of fertilizers. On the contrary, the lowest number of branches per plant (1.17) was observed in the fertilizer combination F_0 where no fertilizer was applied.

Combined application of different doses of vermicompost and fertilizers significantly influenced the number of branches per plant of mungbean (Table 4). The lowest number of branches per plant (0.96) was observed in the treatment combination of V_0F_0 (No vermicompost and No NPK). On the other hand, the highest number of branches per plant (1.70) was recorded with V_3F_1 (High vermicompost + Medium NPK).

4.2 Effect of vermicompost and NPK on the yield and yield attributes of mungbean

4.2.1 Number of pods per plant

The effect of different levels of vermicompost on the number of pods per plant was statistically significant (Table 5 and appendix Fig. iv). The highest number of pods per plant (16.37) was recorded in V_3 (High vermicompost) and the lowest number of pods per plant (14.49) was recorded under V_0 (No vermicompost) treatment. These are in agreement with that of Reddy *et al.* (1998) who has reported that different levels of vermicompost significantly increased number of pods per plant of mungbean.

A significant variation was recorded in consideration of number of pod per plant with different doses of fertilizers (Table 6 and appendix Fig. v). The highest number of pods per plant (15.98) was recorded in medium dose of fertilizers (F_1), which was statistically similar with high dose of fertilizers (F_2). The lowest number of pod per plant (14.92) was recorded in the plot where no fertilizer was applied. Balachandran and Sasidhar (1991) and Ijaz *et al.* (2005) found that numbers of pods were increased with the increasing rate of P.

The combind effect of vermicompost and fertilizers on the number of pods per plant was statistically significant (Table 7 and appendix Fig. viii). The highest number of pods per plant (18.40) was recorded in V_3F_1 (High vermicompost + Medium fertilizer). The lowest number of pods per plant (13.17) was recorded in V_0F_0 treatment combination.

4.2.2 Pod length

There was no significant effect on the pod length of mungbean due to different doses of vermicompost (Table 5). The highest pod length (9.25 cm) was found in the treatment V_3 (High vermicompost) and the lowest pod length (8.98 cm) was recorded in F_0 treatment (no vermicompost). The result showed that pod length increased with increasing levels of vermicompost.

The pod length of mungbean was significantly influenced by different doses of fertilizers (Table 6). The maximum pod length (9.35 cm) was obtained from the treatment F_2 (High NPK), which was statistically similar with F_1 (Medium NPK). The minimum pod length was observed in the treatment F_0 (No NPK). Pod length increased with increasing level of NPK.

Significant variation was found in pod length of mungbean due to different doses vermicompost and fertilizers (Table 7). Pod length varied from 8.70 cm to 9.51 cm due to combination of vermicompost and NPK fertilizers. The highest pod length (9.51 cm) was obtained from the treatment V_3F_1 (High vermicompost + Medium NPK) and the lowest pod length (8.70 cm) was recorded with V_0F_0 (control) treatment combination.

4.2.3 Number of seeds per pod

There were significant differences on the number of seeds per pod produced under the different levels of vermicompost (Table 5 and appendix Fig. vi). The number of seeds per pod gradually increased with increasing levels of vermicompost. The highest number of seeds per pod (11.33) was obtained with the application of high vermicompost (F_3). The lowest number of seeds per pod (10.11) was produced in V_0 treatment.

The effect of NPK fertilizers on the number of seeds per pod was found positive and significant (Table 6 and appendix Fig. vii). Number of seeds per pod increased with increasing level of NPK up to medium dose. The highest number of seeds/pod (11.48) was obtained with the application of medium dose of NPK, which was not statistically different from high NPK. The lowest number of seeds per pod (10.20) was found in F_0 treatment.

The effect of treatment combinations of vermicompost and NPK fertilizers on the number of seeds per pod were significant (Table 7 and appendix fig. ix). The highest number of seeds/pod (11.83) was obtained in V_3F_1, which was not statistically different from most of other treatments and the lowest number of seeds per pod (10.22) was produced under the control treatment.

Table 5. Effect of vermicompost on the yield and yield attributes of mungbean

Vermicompost	No. of pods/ plant	Pod length (cm)	Number of seeds/ pod	1000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
V_0	14.49 c	8.98	10.11 b	45.67	0.87 b	1.57 c
V_1	15.62 bc	9.09	10.73 ab	45.78	0.91 ab	2.07 b
V_2	16.00 ab	9.22	10.75 ab	47.44	0.91 ab	2.42 ab
V_3	16.37 a	9.25	11.33 a	46.67	1.16 a	2.59 a
Level of Significance	0.05	NS	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

Table 6. Effect of NPK on the yield and yield attributes of mu

NPK Fertilizers	No. of pods/ plant	Pod length (cm)	Number of seeds/ pod	1000-grain weight (g)		
F_0	14.92 b	8.67 b	10.20 b	46.00	0.83 c	1.78 b
F_1	15.98 a	9.13 ab	11.48 a	46.33	0.96 b	2.25 ab
F_2	15.77 a	9.35 a	11.01 ab	46.83	1.11 a	2.45 a
Level of Significance	0.05	0.05	0.05	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

Table 7. Combined effect of vermicompost and NPK fertilizers on the yield and yield attributes of mungbean

Vermicompost × NPK Fertilizers	No. of pods/ plant	Pod length (cm)	Number of seeds/ pod	1000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
V_0F_0	13.17 d	8.70 b	10.22 b	43.33 d	0.787 c	1.62 b
V_0F_1	13.90 cd	9.01 ab	10.38 ab	44.00 cd	0.80 bc	1.71 b
V_0F_2	15.17 bcd	9.18 ab	10.43 ab	45.33 bcd	0.88 bc	2.03 ab
V_1F_0	15.63 a-d	9.13 ab	10.16 b	45.00 bcd	0.88 bc	2.02 ab
V_1F_1	16.40 abc	9.21 ab	10.79 ab	47.00 abc	0.95 bc	2.18 ab
V_1F_2	16.47 abc	9.18 ab	10.81 ab	47.00 abc	1.06 bc	2.60 a
V_2F_0	17.00 abc	9.08 ab	10.93 ab	46.33 a-d	0.85 bc	2.21 ab
V_2F_1	14.73 bcd	9.17 ab	11.09 ab	47.33 ab	0.91 bc	2.58 a
V_2F_2	14.87 bcd	8.98 ab	11.17 ab	47.67 ab	1.03 bc	2.59 a
V_3F_0	14.60 bcd	8.95 ab	10.74 ab	46.67 abc	0.79 bc	2.39 ab
V_3F_1	18.40 a	9.51 a	11.83 a	49.00 a	1.55 a	2.62 a
V_3F_2	17.10 ab	9.34 a	11.00 ab	48.00 ab	1.09 b	2.59 a
Level of Significance	0.05	NS	0.01	0.05	0.05	0.01

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

4.2.4 Weight of 1000-grain

No significant variation was observed in the weight of 1000 grain of mungbean when different doses of vermicompost were applied (Table 5). The highest 1000 grain weight (47.44 g) was recorded in V_2 (2 t ha^{-1}) and the lowest 1000 grain weight (45.67 g) was recorded in the V_0 treatment where no vermicompost was applied.

Different doses of chemical fertilizers did not show significant variations in respect of 1000 grain weight (Table 6). Among the different doses of fertilizers, F_2 (High NPK) showed the highest value of 1000 seeds weight(46.83 g) and the lowest value of 1000 grain weight (46.00 g) was observed with F_0, where no fertilizer was applied.

The combined effect of different doses of vermicompost and fertilizers on the weight of 1000 seeds of mungbean was significant (Table 7). The highest value of 1000 grain weight (49.0 g) was recorded with the treatment combination of V_3F_1 (High vermicompost + Medium NPK). On the other hand, the lowest value of 1000 seeds weight (46.83 g) was found in V_0F_0 treatment combination (no vermicompost and no NPK).

4.2.5 Grain yield

The grain yield as affected by different doses of vermicompost showed statistically significant variation (Table 5 and Appendix Fig. x). Among the different doses of vermicompost the highest grain yield (1.16 t ha^{-1}) was observed in V_3 treatment (4 t ha^{-1}), which was statistically identical with V_2 and V_1 treatments (2 t ha^{-1} and 1 t ha^{-1}). The lowest grain yield (0.87 t ha^{-1}) was recorded in the V_0 treatment where no vermicompost was applied. Probably vermicompost supplied the necessary requirements for the proper vegetative growth that helped in obtaining the highest yield of mungbean. These are in agreement with those of Karmegam *et al.* (1999), Rao *et al.* (2000), Das *et al.* (2002) and Reddy *et al.* (1998) who have reported that different levels of vermicompost significantly increased grain yield. Kumar *et al.* (2003) showed that vermicompost at 5 t ha^{-1} produced 16.5 % grain yield higher than that of FYM with same dose.

Application of fertilizers at different treatment doses showed a significant variation on the of grain yield of mungbean (Table 6 and Appendix Fig. xi). Among the different fertilizer doses, F_2 (High NPK) showed the highest grain yield (1.11 t ha^{-1}), which was different from other NPK doses. On the other hand, the lowest grain yield (0.83 t ha^{-1}) was recorded with F_0 treatment, where no fertilizer was applied. Kumar *et al.* (2003) showed that grain yield was significantly increased with the increasing rate of P and K. Pandey and Sing (2001), Chaubey and Kaushik (2000) found that the highest grain yields were obtained from 50 kg P_2O_5/ha.

Combined effects of different doses of vermicompost and fertilizers on the grain yield showed a statistically significant variation (Table 7 and Appendix Fig. xii). The highest grain yield (1.55 t ha^{-1}) was recorded in the treatment combination of V_3F_1 (High vermicompost + Medium NPK), which was statistically different from all other treatment combinations. On the other hand, the lowest grain yield (0.78 t ha^{-1}) was found in V_0F_0 (control) treatment combination. Rajkhowa *et al.* (2002) found the highest grain yield from vermicompost at 2.5 t ha^{-1} and the recommended fertilizer dose. These are in agreement with those of Tolanur and Badanur (2003) who have reported that combined application of vermicompost NPK fertilizers significantly increased plant height.

4.2.6 Straw yield

Significant variation in straw yield of mungbean was observed with different doses of vermicompost (Table 5 and Appendix Fig. x). Among the different doses of vermicompost V_3 (4 t ha^{-1}) showed the highest straw yield (2.59 t ha^{-1}), which was statistically identical with the treatment V_2 (2 t ha^{-1}). On the other hand, the lowest straw yield (1.57 t ha^{-1}) was observed in the V_0 treatment, where no vermicompost was applied. These are in agreement with those of Yadav and Malik (2005), Das *et al.* (2002) and Rao *et al.* (2000) who have reported that different levels of vermicompost significantly increased straw yield.

Straw yield showed significant variation when different doses of fertilizers were applied (Table 6 and Appendix Fig. xi). Among the different combinations of fertilizer doses, F_2 (High NPK) showed the highest straw yield (2.45 t ha^{-1}), which was closely followed (2.25 t ha^{-1}) by the fertilizer dose F_1 (Medium NPK). The lowest straw yield (1.78 t ha^{-1}) was observed with F_0 treatment, where no fertilizer was applied. Pandey and Sing (2001) found that the highest straw yields were obtained from 50 kg P_2O_5/ha.

Combined effect of different doses of vermicompost and fertilizers showed a statistically significant effect on the straw yield of mungbean (Table 7 and Appendix Fig. xii) .The lowest straw yield (1.62 t ha^{-1}) was observed in the treatment combination of V_0F_0 (No vermicompost and No NPK), which was closely related to V_0F_1 treatment. On the other hand, the highest straw yield (2.62 t ha^{-1}) was recorded with V_3F_1 (High vermicompost + Medium NPK), which was statistically identical with the treatment combinations of V_3F_2 (High vermicompost + High NPK) and V_2F_2 (Medium vermicompost + High NPK), V_2F_1 and V_1F_2.

4.3 Effect of vermicompost and NPK on the nutrient contents in mungbean plants

4.3.1 Nitrogen content

A statistically significant variation was observed in nitrogen content in plants with different doses of vermicompost (Table 8). Considering the different doses of vermicompost the highest nitrogen content in plants (2.79 %) was recorded in V_3 (4 t ha^{-1}), which was statistically similar with V_2 (2 t ha^{-1}). On the other hand, the lowest nitrogen concentration (2.29 %) was recorded in the V_0 treatment where no vermicompost was applied. These are in agreement with those of Das *et al.* (2002) who have reported that different levels of vermicompost significantly increased N uptake of mungbean plant.

The effect of applications of different doses of chemical fertilizers showed a statistically significant variation in the nitrogen content in mungbean plants (Table 9). Among the different fertilizer doses, F_2 (High NPK) showed the highest nitrogen content (2.82 %) in plants, which was significantly higher than other treatments. The lowest nitrogen content (2.13 %) was observed in the fertilizer treatment F_0, where no fertilizer was applied.

Table 8. Effect of vermicompost on nutrient content in mungbean plant

Vermicompost	Nutrient content (%)		
	Nitrogen	Phosphorus	Potassium
V_0	2.29 c	0.29 c	0.44 c
V_1	2.49 bc	0.31 c	0.53 b
V_2	2.75 ab	0.52 b	0.55 ab
V_3	2.79 a	0.84 a	0.62 a
Level of Significance	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 9. Effect of NPK fertilizers on nutrient content in mungbean plant

NPK Fertilizer	Nutrient content (%)		
	Nitrogen	Phosphorus	Potassium
F_0	2.13 c	0.39 b	0.48 b
F_1	2.53 b	0.49 ab	0.54 b
F_2	2.82 a	0.59 a	0.64 a
Level of Significance	0.05	0.01	0.01

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

Significant effect of combined application of different doses of vermicompost and fertilizer on the nitrogen content was also observed in mungbean plants (Table 10). The highest nitrogen content (3.05 %) was recorded in the treatment combination of V_3F_2 (High vermicompost + High NPK) .On the other hand, the lowest nitrogen content (2.06 %) was found in V_0F_0 (No vermicompost + No NPK). The highest concentration of nitrogen in the plant with the highest dose of vermicompost and fertilizer may be due to the higher supply and subsequent assimilation of this element in the plant.

4.3.2 Phosphorous content

Statistically significant variation of phosphorous content in mungbean plants was recorded when different doses of vermicompost were applied (Table 8). The highest phosphorous concentration (0.84 %) was recorded in V_3 (4 t ha^{-1}), which was significantly higher than other treatments. On the other hand, the lowest phosphorous concentration (0.29 %) was recorded in the V_0 treatment where no vermicompost was applied. These are in agreement with those of Reddy *et al.* (2002) who have reported that different levels of vermicompost significantly increased P uptake of mungbean plant.

Table 10. Combined effect of vermicompost and NPK fertilizers on nutrient contents in mungbean plant

Vermicompost × NPK Fertilizer	Nutrient content (%)		
	Nitrogen	Phosphorus	Potassium
V_0F_0	2.06 f	0.12 f	0.15 e
V_0F_1	2.11 f	0.14 f	0.46 d
V_0F_2	2.50 de	0.50 cd	0.63 b
V_1F_0	2.49 e	0.27 e	0.54 c
V_1F_1	2.64 de	0.32 e	0.51 cd
V_1F_2	2.64 de	0.60 c	0.63 b
V_2F_0	2.73 cd	0.45 d	0.55 c
V_2F_1	2.77 bcd	0.58 c	0.66 ab
V_2F_2	2.90 abc	0.72 b	0.62 b
V_3F_0	2.13 f	0.26 e	0.54 c
V_3F_1	2.97 ab	0.92 a	0.70 a
V_3F_2	3.05 a	1.01 a	0.71 a
Level of Significance	0.01	0.01	0.01

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

Application of different doses of chemical fertilizers showed significant variation in respect of phosphorous concentration in mungbean plants (Table 9). Among the different doses of fertilizers, F_2 (High NPK) showed the highest phosphorous concentration (0.59 %) in plant, which was statistically similar with F_1 (Medium NPK). The lowest phosphorous concentration in plants (0.39 %) was recorded in the treatment F_0 where no fertilizer was applied.

The combined effects of different doses of vermicompost and fertilizers resulted a significant change in the phosphorous concentration in mungbean plant (Table 10). The highest phosphorous concentration (1.01 %) was recorded in the treatment combination of V_3F_2 (High vermicompost + High NPK) and the lowest phosphorous concentration (0.12 %) was found in V_0F_0 (No vermicompost + No NPK). This may be due to the fact that the combined effect of both vermicompost and NPK played a positive effect on phosphorus concentration in mungbean plants.

4.3.3 Potassium content

Application of different doses of vermicompost showed a significant variation in the potassium concentration in mungbean plants (Table 8). The highest potassium concentration (0.62 %) was recorded in V_2 (4 t ha^{-1}), which was statistically similar with V_1 (2 t ha^{-1}). On the other hand, the lowest potassium concentration (0.44 %) was recorded in the V_0 treatment where no vermicompost was applied. These are in agreement with those of Yadav and Malik (2005), Reddy *et al.* (1998) who have reported that different levels of vermicompost significantly increased K uptake of mungbean plant.

Application of chemical fertilizers at different doses also showed significant variation in respect of potassium concentration in mungbean plants (Table 9). Among the different doses of fertilizers, F_2 (High NPK) showed the highest potassium concentration (0.64 %) in plants and the lowest potassium concentration (0.48 %) was recorded in F_0 where no fertilizer was applied.

The combined effects of different doses of vermicompost and fertilizers resulted a significant change in the potassium concentration in mungbean plants (Table 10). The highest potassium concentration (0.71 %) was recorded in the treatment combination of V_3F_2 (High vermicompost + High NPK) and the lowest potassium concentration (0.15 %) was found in V_0F_0 (No vermicompost + No NPK). This may be due to the fact that the combined effect of both vermicompost and NPK played a positive effect on potassium concentration in mungbean plants.

4.4 Effect of vermicompost and NPK fertilizers on the nutrient contents in the grain of mungbean

4.4.1 Nitrogen content

Statistically significant variation in nitrogen concentration in the grain of mungbean was recorded when different doses of vermicompost were applied (Table 11). The highest nitrogen concentration (7.01 %) was recorded in V_3 (4 t ha^{-1}), which was statistically identical with V_2 (2 t ha^{-1}). The lowest nitrogen concentration (6.40 %) was recorded in the V_0 treatment where no vermicompost was applied. Probably, higher dose of vermicompost helped to increase the nitrogen content in plant. These are in agreement with those of Karmegam *et al.* (1999) and Rao *et al.* (2000) who has reported that different levels of vermicompost significantly increased grain protein.

Different doses of chemical fertilizers showed a statistically significant variation in respect of nitrogen concentration in grain of mungbean (Table 12). Among the different combination of fertilizer doses, F_2 (High NPK) showed the highest nitrogen concentration (7.11 %), which was significantly higher than that obtained by the fertilizer dose F_1 (Medium NPK). The lowest nitrogen concentration (6.49 %) was recorded in the F_0 treatment where no fertilizer was applied. Probably NPK application at higher doses helped to increase the N content in grain of mungbean plants.

Combined application of different doses of vermicompost and fertilizers resulted a significant variation on the nitrogen concentration in grain of mungbean (Table 13). The highest nitrogen concentration (7.76 %) was recorded in the treatment combination of V_3F_2 (High vermicompost + High NPK), which was highly significant compared to other treatments. On the other hand, the lowest nitrogen concentration (5.86 %) was observed in V_0F_0 (No vermicompost + No NPK). The higher nitrogen content in grain of mungbean plants might be due to higher rate of application of vermicompost and NPK.

4.4.2 Phosphorous content

Statistically significant variation was observed in phosphorous concentration in grain of mungbean when different doses of vermicompost were applied (Table 11). Among the different doses of vermicompost the highest phosphorous concentration (0.51 %) was recorded in V_3 (4 t ha^{-1}), which was significantly higher than the V_2 (2 t ha^{-1}) and V_1 (1 t ha^{-1}). On the other hand, the lowest phosphorous concentration (0.10 %) was recorded in the V_0 treatment where no vermicompost was applied. Karmegam *et al.* (1999) showed the same result.

Different doses of chemical fertilizer application for the cultivation of mungbean showed significant variation in respect of phosphorous concentration in grain of mungbean (Table 12). Among the different combination of fertilizer doses, F_2 (High NPK) showed the highest phosphorous concentration (0.39 %) in grain of mungbean, which was significantly higher than the fertilizer dose F_1 (Medium NPK). On the other hand, the lowest phosphorous concentration (0.32 %) was recorded in the F_0 treatment where no fertilizer was applied.

When the combined effect of different doses of vermicompost and fertilizer was considered a significant variation was recorded in the case of phosphorous concentration in grain of mungbean (Table 13). The highest phosphorous content (0.57 %) was recorded in the treatment combination of V_3F_2 (High vermicompost + High NPK) and the lowest phosphorous concentration (0.04 %) was observed in V_0F_0 treatment (No vermicompost + No NPK). It was observed that phosphorus content increased due to higher rate of application of vermicompost and NPK.

Table 11. Effect of vermicompost on nutrient contents in the grain of mungbean

Vermicompost	Nutrient content (%)		
	Nitrogen	Phosphorus	Potassium
V_0	6.40 c	0.10 d	0.33 c
V_1	6.74 b	0.34 c	0.41 b
V_2	6.99 a	0.44 b	0.42 b
V_3	7.01 a	0.51 a	0.50 a
Level of Significance	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 12. Effect of NPK fertilizers on nutrient contents in the grain of mungbean

NPK Fertilizer	Nutrient content (%)		
	Nitrogen	Phosphorus	Potassium
F_0	6.49 c	0.32 b	0.33 c
F_1	6.75 b	0.33 b	0.44 b
F_2	7.11 a	0.39 a	0.48 a
Level of Significance	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 13. Combined effect of vermicompost and NPK fertilizers on nutrient contents in the grain of mungbean

Vermicompost × NPK Fertilizer	Nutrient content (%)		
	Nitrogen	Phosphorus	Potassium
V_0F_0	5.86 h	0.04 f	0.26 g
V_0F_1	6.09 g	0.08 ef	0.27 fg
V_0F_2	6.13 g	0.10 e	0.28 fg
V_1F_0	6.24 f	0.34 c	0.33 ef
V_1F_1	6.92 d	0.35 c	0.43 cd
V_1F_2	7.18 c	0.47 b	0.46 cd
V_2F_0	6.80 e	0.45 b	0.35 e
V_2F_1	6.98 d	0.47 b	0.46 cd
V_2F_2	7.31 b	0.50 b	0.60 b
V_3F_0	6.79 e	0.45 b	0.41 d
V_3F_1	7.34 b	0.50 b	0.48 c
V_3F_2	7.76 a	0.57 a	0.65 a
Level of Significance	0.01	0.01	0.01

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

4.4.3 Potassium content

Statistically significant variation was recorded in potassium concentration in grain of mungbean when different doses of vermicompost were applied (Table 11). Among the different doses of vermicompost the highest potassium concentration (0.50 %) was recorded in V_3 (4 t ha^{-1}), which was significantly higher than the V_2 (2 t ha^{-1}) and V_1 (1 t ha^{-1}). The lowest potassium concentration (0.33 %) was recorded in the V_0 treatment where no vermicompost was applied. It was observed that potassium content increased due to higher rate of application of vermicompost. Karmegam *et al.* (1999) showed the same result.

Application of different doses of chemical fertilizers showed a significant variation in respect of potassium concentration in grain of mungbean (Table 12). Among the different fertilizer doses, F_2 (High NPK) showed the highest potassium concentration (0.48 %), which was highly significant compared to other doses of NPK fertilizers. On the other hand, the lowest potassium concentration (0.33 %) was recorded in the F_0 treatment where no fertilizer was applied.

The different doses of vermicompost and fertilizers in combination showed a significant variation in the potassium concentration in grain of mungbean (Table 13). The highest potassium concentration (0.65 %) was recorded in the treatment combination of V_3F_2 (High vermicompost + High NPK). On the other hand, the lowest potassium concentration (0.2680%) was observed in V_0F_0 (No vermicompost + No NPK) treatment. This may be due to the application of vermicompost and NPK at higher rates of their application which helped to increase the content of more potassium in grain of mungbean.

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

4.5.1 Organic carbon (OC) content of soil

A significant variation was observed on the content of OC after harvest where the vermicompost was incorporated in soil (Table 14). Among the different doses of vermicompost, V_3 (4 t ha^{-1}) treatment showed the highest OC content (1.22 %) after the harvest of crop. On the other hand, the lowest OC content (1.01 %) was observed in the V_0 treatment where no vermicompost was applied and it was closely followed (1.01 %) by the V_1 (1 t ha^{-1}) and (1.08 %) V_2 (1 t/ha) treatments. Vermicompost added more organic carbon in the soil and as a consequence the residual amount of organic carbon showed higher values with the addition of higher amount of vermicompost.

These are in agreement with those of Abraham and Lal (2002) who have reported that different levels of vermicompost significantly increased organic carbon of soil.

There was significant variation in the OC content after harvest when different combinations of fertilizers were applied (Table 15). The highest content of OC in post harvest soil (1.10 %) was obtained from F_3 (High NPK) treatment, which was closely related to F_1 (Medium NPK) treatment. The lowest OC content in soil (1.04 %) after harvest was found in control (F_0).

Combined application of different doses of vermicompost and fertilizers showed significant effect on the OC content of soil after harvest (Table 16). The lowest OC content of the soil (0.84 %) after harvest was recorded in the control treatment. On the other hand, the highest OC content (1.27 %) was recorded in the treatment combination of the highest vermicompost with high fertilizer doses (V_3F_2).

4.5.2 Nitrogen content of soil

Significant variation was recorded on the nitrogen content of mungbean field after harvest of the crop when the field was treated with different doses of vermicompost (Table 14). Among the different doses of vermicompost, V_3 (4 t ha^{-1}) treatment showed the highest N content (0.08 %), which was closely related to V_2 (2 t/ha) and the lowest N content (0.07 %) was observed in the V_0 treatment where no vermicompost was applied. This was due to the fact that vermicompost added N in soil and reduced the loss of nitrogen and conserved more nitrogen in soil. Bangar *et al*. (1990) found that compost enriched the N content of soil.

A significant variation was recorded in the N content of soil after harvest of the mungbean crop when fertilizers in different doses were applied (Table 15). In considering the different combinations of fertilizer doses, F_2 (High NPK) showed the highest N content (0.0873%), which was statistically identical with the fertilizer dose F_1 (Medium NPK). On the other hand, the lowest N content (0.07 %) was observed in the F_0 treatment where no fertilizer was applied.

Combined application of different doses of vermicompost and fertilizers showed a significant effect on the N content of soil after harvest (Table 16). The highest N content of crop-harvested soil (0.09 %) was recorded in the treatment combination of V_3F_2 (High vermicompost + High NPK). On the other hand, the lowest N content (0.06 %) was recorded in V_0F_0 (No vermicompost + No NPK).

Table 14. Effect of vermicompost on nutrient contents in post harvest soil

Vermicompost	Organic carbon (%)	Nutrient content %		
		Nitrogen	Phosphorus	Potassium
V_0	1.018 b	0.0787 b	0.001514 c	0.003450 b
V_1	1.019 b	0.0797 b	0.001542 c	0.003494 b
V_2	1.087 b	0.0877 a	0.002478 b	0.003800 a
V_3	1.221 a	0.0893 a	0.002906 a	0.003956 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 15. Effect of NPK fertilizers on nutrient contents in post harvest soil

NPK Fertilizer	Organic carbon (%)	Nutrient content %		
		Nitrogen	Phosphorus	Potassium
F_0	1.042 b	0.0788 b	0.001608 c	0.003379 c
F_1	1.108 ab	0.0855 ab	0.001877 b	0.003708 b
F_2	1.109 a	0.0873 a	0.002844 a	0.003938 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 16. Combined effect of vermicompost and NPK fertilizers on nutrient contents in post harvest soil

Vermicompost × NPK Fertilizer	Organic carbon (%)	Nutrient content (%)		
		Nitrogen	Phosphorus	Potassium
V_0F_0	0.840 h	0.0670 f	0.000833 i	0.0025 g
V_0F_1	0.907 gh	0.0750 ef	0.001167 h	0.0032 f
V_0F_2	0.9740 fg	0.0870 bc	0.001667 f	0.0034 ef
V_1F_0	1.008 f	0.080 de	0.001383 g	0.0033 ef
V_1F_1	1.143 cd	0.0860 bc	0.002042 d	0.0038 cd
V_1F_2	1.176 bcd	0.0870 bc	0.002083 d	0.0039 bc
V_2F_0	1.109 de	0.0810 cd	0.001708 ef	0.0034 e
V_2F_1	1.109 de	0.0870 bc	0.001750 e	0.0040 bc
V_2F_2	1.210 abc	0.0880 b	0.003050 c	0.0041 ab
V_3F_0	1.042 ef	0.0840 bcd	0.001717 ef	0.0037 d
V_3F_1	1.240 ab	0.0900 ab	0.003583 b	0.0043 a
V_3F_2	1.277 a	0.0940 a	0.004333 a	0.0043 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

4.5.3 Phosphorous content of soil

A significant variation was observed in the P content of soil in the mungbean field after harvest where the field was manured with different doses of vermicompost (Table14). Among the different doses of vermicompost V_3 (4 t ha^{-1}) treatment showed the highest P content (0.002906 %) after the harvest of crop. On the other hand, the lowest P content (0.001514 %) was observed in the V_0 treatment where no vermicompost was applied and it was statistically identical with the V_1 (1 t ha^{-1})

treatment. Guan (1989) reported that the application of compost increased the availability of P in comparison with the control.

There was a significant variation in the P content of soil after harvest of the crop when fertilizers at different doses were applied (Table 15). Among the different combinations of fertilizer doses, F_2 (High NPK) showed the highest P content (0.002844 %). The lowest P content (0.001608 %) was observed in the F_0 treatment where no fertilizer was applied.

Combined effect of different doses of vermicompost and fertilizers produced significant variarion in respect of P content of soil after the harvest of mungbean crop. (Table 16). The lowest P content of crop harvested soil (0.0008333 %) was recorded in the treatment combination of V_0F_0 (No vermicompost + No NPK). On the other hand, the highest P content (0.004333 %) was recorded in V_3F_2 (High vermicompost + High NPK) treatment.

4.5.4 Potassium content of soil

Significant variation was recorded in the K content of soil in the mungbean field after harvest of the crop where different doses of vermicompost were applied (Table 14). Application of vermicompost at the rate of 4 t ha^{-1} showed the highest K content (0.003956 %), which was closely followed by V_2 (2 t ha^{-1}). On the other hand, the lowest K content (0.003450 %) was observed in the V_0 treatment where no vermicompost was applied.

There was a significant variation in the K content of soil after harvest when different combinations of fertilizers were applied (Table 15). Fertilizer dose F_2 (High NPK) showed the highest K content (0.003938 %) and the lowest K content (0.003379 %) was recorded in the F_0 treatment (No NPK). Robinson *et al.* (1992) showed that with the application of vermicompost it was easy to transfer of nutrients to plants.

The effect of combined application of vermicompost and fertilizers showed significant differences in respect of K content of soil after harvest (Table 16). The lowest K content of crop-harvested soil (0.0025 %) was recorded in the treatment combination of V_0F_0 (No vermicompost+ No NPK) and the highest K content (0.0043 %) was recorded with V_3F_2 (High vermicompost + High NPK) treatment combination, which was same as V_3F_1 (High vermicompost + Medium NPK).

CHAPTER V

SUMMARY AND CONCLUSION

CHAPTER 5

SUMMARY AND CONCLUSION

An experiment was conducted at the Sher-e-Bangla Agricultural University Farm (SAU Farm), Dhaka 1207 (Tejgaon series under AEZ No.28) during the *Kharif* season of 2007 to study the effect of vermicompost on the yield of mungbean. The soil was silty loam in texture having pH 6.0, organic matter 0.88%. Randomized complete block design was followed with twelve treatments having unit plot size of 3m x 3m (9m^2) replicated thrice. The treatments were V_0F_0 control (No vermicompost + No NPK), V_0F_1 (No vermicompost + Half of the recommended dose of NPK), V_0F_2 (No vermicompost + Full of the recommended dose of NPK), V_1F_0 (Low vermicompost + No NPK), V_1F_1 (Low vermicompost + Full of the recommended dose of NPK), V_1F_2 (Low vermicompost + Full of the recommended dose of NPK), V_2F_0 (Medium vermicompost + No NPK), V_2F_1 (Medium vermicompost + Half of the recommended dose of NPK), V_2F_2 (Medium vermicompost + Full of the recommended dose of NPK), V_2F_3 (Medium vermicompost + High NPK), V_3F_0 (High vermicompost + No NPK), V_3F_1 (High vermicompost + Half of the recommended dose of NPK), V_3F_2 (High vermicompost + Full of the recommended dose of NPK). Nitrogen from urea, P from TSP and K from Muriate of potash were used. Full required amounts of urea, TSP and MP were applied at the time of final land preparation and vermicompost was applied in line during sowing. Mungbean seeds cv. BARI MUNG-6 were sown on 10th April, 2007, and the crop was harvested on 10th June 2007. Intercultural operations were done when required. The data were collected plot wise for plant height, number of leaves/ plant, number of branches/ plant, number of pods/ plant, pod length, number of seeds/pod, weight of 1000 grains, grain and straw yields. The post harvest soil samples were analyzed for organic carbon, N, P and K contents. All the data were statistically analyzed following F-test and the mean comparison was made by DMRT at 5% and 1% level. The results of the experiment are stated below.

Different plant and yield parameters were significantly influenced by different vermicompost levels except the number of leaves/plant, number of branches/plant, pod length and 1000-grain weight. The highest plant height (57.60 cm), number of pods/plant (16.37), number of seeds/pod (11.33), grain yield (1.167 t/ha) and straw yield (2.591t/ha) produced by V_3 (High vermicompost) and the lowest plant height (51.10 cm), number of pods/plant (14.49), number of seeds/pod (10.11), grain yield (0.87 t/ha) and straw yield (1.57 t/ha) produced by control (V_0) treatment.

Different doses of NPK fertilizers had significant effects on plant and yield parameters except number of leaves per plant and 1000-grain weight. The high dose of NPK fertilizers (F_2) gave the highest plant height (57.19 cm), number of branches/plant (1.45), pod length (9.35 cm), grain yield (1.11 t/ha) and straw yield (2.45 t/ha) and the lowest plant height (50.90 cm), number of branches/plant (1.17), number of pods/plant (14.92), number of seeds/pod (10.20), grain yield (0.83 t/ha) and straw yield (1.78 t/ha) were produced by control (F_0) treatment.

Grain yield of mungbean responded significantly to the combined application of vermicompost and NPK fertilizers. The highest grain yield of 1.55 t ha^{-1} was obtained in V_3F_1 (High vermicompost + Medium NPK) treatment. The lowest grain yield (0.78 t ha^{-1}) was observed in the control viz.V_0F_0 (No vermicompost + No NPK) which received neither vermicompost nor fertilizer. The result revealed that when vermicompost is applied with NPK fertilizers, the effect is better on yield product rather applying vermicompost or NPK fertilizer alone. Like grain yield the highest straw yield (2.62 t ha $^{-1}$) was recorded in V_3F_2 (High vermicompost + High NPK) treatment and the lowest (1.62 t ha $^{-1}$) in V_0F_0 control (No vermicompost + No NPK). Tallest plant (60.03 cm) and shortest plant (51.90 cm) were recorded from V_3F_2 and V_0F_0 treatments, respectively. The treatment combination V_3F_1 (High vermicompost + Medium NPK) produced highest number of leaves/plant (10.77), number of branches/plant (1.70), number of pods/plat (18.40), pod length (9.51 cm), number of seeds/pod (11.83), 1000-grain weight (49.0 g) and straw yield (2.627 t/ha). The control treatment V_0F_0 (no vermicompost + no NPK) produced lowest number of leaves/plant (7.77), number of branches/plant (0.96), number of pods/plat (13.17), pod length (8.70 cm), number of seeds/pod (10.22), 1000-grain weight (43.33 g) and straw yield (1.62 t/ha).

The N, P and K content in mungbean plant and grain were influenced significantly by the combined application of vermicompost and chemical fertilizers. The highest N, P and K contents in plants (3.05 %, 1.01 % and 0.71 %, respectively) were recorded in V_3F_2 (High vermicompost + High NPK) treatment. The lowest N, P and K contents (2.069%, 0.125% and 0.157%, respectively) were obtained with V_0F_0 (No vermicompost + No NPK) treatment. In grain, the highest N, P and K content (7.76 %, 0.57 % and 0.65 %, respectively) were obtained with V_3F_2 (High vermicompost + High NPK) treatment. And the lowest N, P and K content in grain (5.86 %, 0.04 % and 0.26 %, respectively) were found in control treatment. Again in soil after harvest the highest OC, N, P and K concentrations (1.27 %, 0.094 %, 0.004333 % and 0.00430 %, respectively) were obtained in the treatment combination V_3F_2 (High vermicompost + High NPK). The lowest OC, N, P and K concentration in post harvest soil (0.84 %, 0.06 %, 0.000833 % and 0.0025 %, respectively) were observed in control (V_0F_0) treatment.

CHAPTER VI

REFERENCES

REFERENCES

Abraham, T. and R. B. Lal. 2002. Sustainable enhancement of yield potential of mustard (*Brassica juncea* L. Czern. Coss.) through Integrated Nutrient Management (INM) in a legume based cropping system for the Inceptisols. *Cruciferae Newsletter*. (24): 99-100.

Abraham, T. and R. B. Lal. 2003. Strategies for INM technology in sustainable edapho-cultivar management for a legume based (blackgram-wheat-greengram) cropping system for the Inceptisols in the NEPZ. *Crop Res. Hisar.* **26**(1): 17-25.

Arancon, N. Q., C. A. Edwards, R. Atiyeh and J. D. Metzger. 2004. Effects of vermicomposts produced from food waste on the growth and yields of greenhouse peppers. *Bioresource Techn.* **93** (2): 139-144.

Arancon, N. Q. C. A. Edwards, P. Bierman, C. Welch and J. D. Metzger. 2004. Influences of vermicomposts on field strawberries: 1. Effects on growth and yields. *Bioresource Techn.* **93** (2): 145-153.

Arancon, N. Q., P. A. Galvis and C. A. Edwards. 2005. Suppression of insect pest populations and damage to plants by vermicomposts. *Bioresource Techn.* **96** (10) : 1137-1142.

Arvadiya, L. K., C. L. Patel and M. K. Arvadiya. 1996. Effect of irrigation, weed management and phosphorus on yield of summer green gram (*Vigna radiata* L.). *Gujarat Agric. Univ. Res. J.* **21**(2): 104-106.

Asghar, Ali, M. A. Malik, Rashid Ahmad and T. S. Atif. 1996. Response of mungbean (*Vigna radiata*) to potassium fertilization. *Pakistan J. Agric.Sci.* **33**(1/4): 44-45.

Atiyeh, R. M., S. Lee, C. A. Edwards, N. Q. Arancon and J. D. Metzger. 2002. The influence of humic acids derived from earthworm-processed organic wastes on plant growth. *Bioresource Techn.* **84** (1): 7-14.

Atiyeh, R. M., N. Q. Arancon, C. A. Edwards and J. D. Metzger. 2002. The influence of earthworm-processed pig manure on the growth and productivity of marigolds. *Bioresource Techn.* **81** (2): 103-108.

Atiyeh, R. M., N. Arancon, C. A. Edwards and J. D. Metzger. 2000. Influence of earthworm processed pig manure on the growth and yield of greenhouse tomatoes. *Bioresource Techn.* **75** (3): 175-180.

Atiyeh, R. M. C. A. Edwards, S. Subler and J. D. Metzger. 2001. Pig manure vermicompost as a component of a horticultural bedding plant medium: Effects on physicochemical properties and plant growth. *Bioresource Techn.* **78** (1): 11-20.

Balachandran, P. V. and V. K. Sasidhar. 1991. Phosphorus nutrition of green gram. *Agric.Res. J. Kerala.* 1991; **29** (1-2): 49-52.

Bali, A. S., K. N. Singh, M. H. Shah and B. A. Khanday. 1991. Effect of nitrogen and phosphorus fertilization on yield and plant characters of moongbean (*Vigna radiata*) under the late sown conditions of Kashmir Valley. Fertiliser News. **36** (7): 59-61.

Bangar, K. C., S. Shanker, K. K. Kapoor, K. Kukreja and M. M. Mishra, 1990. Preparation of nitrogen and phosphorus enriched paddy straw carry out and its effect on yield and nutrients uptake by wheat. *Biol. Fert. Soils.* **8** (4): 339-342.

Bansal, S. and K. K. Kapoor, 1999. Effect of composts prepared from different farm wastes on growth and N and P uptake of mungbean. *Environment and Ecol.* **17**(4): 823-826.

BARI (Bangladesh Agricultural Research Institute). 2003. Annual Report for 2003/ Mungbean in Bangladesh, 2004. p: 27.

BBS. 1994. Statistical Year Book of Bangladesh. Statistics Division, Ministry of Planning, Government of the Peoples Republic of Bangladesh. Dhaka. p: 133.

BBS. 2005. Year Book of Agricultural Statistics of Bangladesh. Statistics Division, Ministry of Planning, Government of Peoples Republic of Bangladesh. Dhaka. p: 141.

Bhalerao, G. A., A. Hamid, D. J. Jiotode and M. Sajid. 2002. Quality, uptake and availability of N, P and K as influenced by integrated nutrient management with vermicompost in rainfed sorghum. *Res. on Crops* **3** (3): 498-501.

Bhattacharyya, J. and A. K. Pal. 2001. Effect of Rhizobium inoculation, phosphorus and molybdenum on the growth of summer greengram (*Vigna radiata* L. Wilezek). *J. Inter. Academicia.* **5**(4): 450-457.

Bray, R. H. and L. T. Kurtz. 1945. Determination of total organic and available forms of phosphorus in soils. Soil Sci. 59: 39-45.

Chanda, N., S. S. Mondal, Arup Ghosh, K. Brahmachari and A. K. Pal. 2002. Effect of potassium and sulphur on mungbean [*Vigna radiata (L.) Wilczek*] in relation to growth, productivity and fertility build up of soil. *J. Interacademicia.* **6**(3): 266-271.

Chandel, R. S., R. Singh, R. S. Singh and O. N. Singh. 2002. Influence of nitrogen levels and Rhizobium inoculation on yield, quality and nitrogen uptake of French bean (*Phaseolus vulgaris* L).*Res. on Crops.* **3** (3): 524-528.

Chaubey, A. K. and M. K. Kaushik, 2000. Influence of levels and sources of phosphorus on yield and nodules dry weight of summer green gram. *Madras Agric. J.* **87**(10/12): 717-719.

Chowdappa, P., C. C. Biddappa and S. Syjatha. 1999. Efficient recycling of organic waste in Arecanut (*Areca catechu*) and coco (*Thedroma cacao*) plantation through vermicomposting. *Indian J. Agric. Sci.,* **96** (8): 563-566.

Chowdhury, M. M. U., M. H. Ullah and Z. U. Mahmmud. 2000. Dry matter production in mungbean (*Vigna radiata* L. Wilczek) as influenced by Bradyrhizobium inoculation and phosphorus application. *Legume Res.* **23**(1): 15-20.

Das, P. K., M. K. Jena and K. C. Sahoo, 2002. Effect of integrated application of vermicompost and chemical fertilizer on growth and yield of paddy in red soil of South Eastern Ghat Zone of Orissa. *Environment and Ecol.* **20** (1): 13-15.

Das, P. K., D. Sarangi, M. K. Jena and S. Mohanty, 2002. Response of green gram (Vigna radiata L.) to integrated application of vermicompost and chemical fertilizer in acid lateritic soil. *Indian Agriculturist.* **46**(1/2): 79-87.

Dey, J. and T. K. Basu, 2004. Response of green gram variety (B-1) to different levels of potassium and sulphur with regards to growth, nodulation, yield and quality. *Indian Agriculturist.* **48**(3/4): 161-165.

Dhillon, N. S., B. S. Brar and A. C. Vig. 1994. Effect of available P, texture and organic carbon contents of soils on response of green gram to applied phosphate. *J. Indian Soc. Soil Sci.* **42**(4): 579-582.

Donahue, R. L., R. W. Miller and J.C. Shickluna. 1987. Soils: An introduction to soils and plant growth. 5th Edn. Prentice Hall of India Private Limited. New Delhi.

Dost, Muhammad, A. H. Gurmani and Khan. Matiullah. 2004. Effect of phosphorus and rhizobium inoculation on the yield and yield components of Mungbean under the rainfed condition. *Sarhad J. Agric.* **20** (4): 575-582.

Duary, B., A. K. Ghosh, D. Hazra and D. Mandal, 2004. Effect of nitrogen, phosphorus and seed inoculation on green gram (*Vigna radiata* L.). *Indian Agriculturist.* **48** (3/4): 167-169.

Dusserre, C. 1992. On the effect of earthworm on the chemical condition of soil. *Landw J. B. Schweiz* 16: 75-78.

Edwards, C. A. and P. J. Bohlen. 1996. Biology and Ecology of Earthworms. Capman and Hall, London.

Edwin, Luikham, Lhungdim, Jamkhogin and A I. Singh. 2005. Influence of sources and levels of phosphorus on growth and yield of green gram (*Vigna radiata* L. Wilczek). *Legume Res.* **28**(1): 59-61.

FAO (Food and Agricultural Organization). 1984. Mungbean. A Guide Book on Production of Pulses in Bangladesh. FAO Project Manual, Khamarbari, Farmgate, Dhaka.

Gajalakshmi, S. and S. A. Abbasi. 2002. Effect of the application of water hyacinth compost/vermicompost on the growth and flowering of *Crossandra undulaefolia*, and on several vegetables. *Bioresource Techn.* **85**(2): 197-199.

Gajalakshmi, S. and S. A. Abbasi. 2004. Neem leaves as a source of fertilizer-cum-pesticide vermicompost. *Bioresource Techn.* **92**(3): 291-296.

Garg, V. K. and P. Kaushik. 2005. Vermistabilization of textile mill sludge spiked with poultry droppings by an epigeic earthworm Eisenia foetida. *Bioresource Techn.* **96**(9): 1063-1071.

Ghosh, C. 2004. Integrated vermi-pisciculture - an alternative option for recycling of solid municipal waste in rural India. *Bioresource Techn.* **93**(1): 71-75.

Gomez, A. K. and A. A. Gomez. 1984. Statistical Procedures for Agricultural Research. Second Edition. John Wiley and Sons, New York, U.S.A.

Gowda, C. L. L. and A. K. Kaul. 1982. Pulses in Bangladesh, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. p: 119-472.

Guan, S. Y. 1989. Studies on the factors influencing soil enzyme activities. I. Effects of organic manures on soil enzyme activities and nitrogen and phosphorus transformations. *Acta pedol. Sinice.* **26**(1): 72-78.

Harris, G. 1990. Use of earthworm biotechnology for the management of effluents from intensively housed livestock. *Out look on Agriculture*, 180 (2): 72-76.

Ijaz, Ahmad, Alvi Alamgir, F. S. A. Tarar, A. G. Awan, Z. H. Tarar and Tariq Mehmood. 2005. Yield and yield component's response of mungbean to different P levels and row spacings. *Indus J. Biological Sci*. 2005; **2**(1): 27-31.

Jackson, M. L. 1973. Soil Chemical Analysis. Prentice Hall of India Private Limited. New Delhi.

Jat, R. S. and I. P. S. Ahlawat. 2004. Direct and residual effect of vermicompost, Biofertilizers and Phosphorus on Soil Nutrient Dynamics and Productivity of chickpea-fodder maize sequence. *Indian J. Soil Sci.* **12** (2): 41-54.

Jeyabal, A. and G. Kuppuswamy. 2001. Recycling of organic wastes for the production of vermicompost and its response in rice-legume cropping system and soil fertility. *European J. Agronomy.***15**(3): 153-170.

Kanwar, K. 2002. Recycling of organic wastes by vermicompositing and its utilization in agriculture in Himachal Pradesh. *Indian J. Soil Sci.* **24** (2): 12-25.

Karmegam, N. K. Alagumalai, and T. Daniel. 1999. Effect of vermicompost on the growth and yield of green gram (*Phaseolus aureus Roxb.*). *Tropical Agriculture*. **76**(2): 143-146.

Khan, E. A., F. U. Khan, M. A. Khan and Abdul Karim. 2004. Effect of phosphorus levels on the yield and yield components of mungbean. *Indus J. Plant Sci*. **3**(4): 446-449.

Kumar, R., V. P. Singh, R. C. Singh and S. N. Singh. 2003. Monetary analysis of N and P fertilization to mungbean during summer season. *Annals Biology*. **19**(2): 123-127.

Kumar, S., R. C. Singh and V. S. Kadian. 2003. Performance of mungbean as influenced by seed inoculation with Rhizobium and levels of organic and inorganic sources of nutrients. *Indian J. Pulses Res*. **16**(1): 67-68.

Kumar, R., V. P. Singh and R. C. Singh. 2002. Effect of N and P application on nutrient content and their uptake and yield of summer planted mungbean. Research on Crops. **3**(3): 519-523.

Kumar, V. and K. P. Singh. 2001. Enriching vermicompost by nitrogen fixing and phosphate solubilizing bacteria. *Bioresource Techn*. **76**(2): 173-175.

Kumari, M. S. S. and K. U. Kumari. 2002. Effect of vermicompost enriched with rockphosphate on growth and yield of cowpea (*Vigna unguiculata L. Walp*). *J. Indian Soc. Soil Sci*. **50**(2): 223-224.

Lima, R. M., T. A. Santos, G. R. Espinosa and F. R. Cerrato. 2000. Yield of potato and soil microbial biomass with organic and mineral fertilizers. *Agrociencia*. **34**(3).261-269.

Luo, Y. J., X. J. Chen and Q. L. Fu. 1995. The nutrient return effect of green gram grown on red earth soil. *Acta Agric. Zhejiangensis*. **7**(1): 35-37.

Malik, M. A., M. F. Saleem, Asghar Ali and Mahmood Ijaz. 2003. Effect of nitrogen and phosphorus application on growth, yield and quality of mungbean (*Vigna radiata* L.). *Pakistan J. Agric. Sci*. **40**(3/4): 133-136.

Mandal, R. and B. C. Sikder. 1999. Effect of nitrogen and phosphorus on growth and yield of mungbean grown in saline soil of Khulna, Bangladesh. *J. Phytol. Res.* **12** (1/2): 85-88.

Manpreet, Singh., Jagrup Singh and H. S. Sekhon. 2005. Nutrient and quality studies of different mung bean (*Vigna radiata* L. Wilczek) genotypes in relation to phosphorus application. *Env. and Ecol.* **23**(2): 408-411.

Marimuthu, R., S. Babu and K. Vairavan. 2002. Utility of different sources of vermicompost and its nutrient status on the growth and yield of groundnut *cv. VRI 2*. *Legume Res.* **25**(4): 266-269.

Marinari, S., G. Masciandaro, B. Ceccanti and S. Grego. 2000. Influence of organic and mineral fertilizers on soil biological and physical properties. *Bioresource Techn.* **72** (1): 9-17.

Mozumder, S. N., M. Salim, A. K. Podder, M. M. Zaman and M. I. Haque. 2005. Effect of nitrogen and Bradyrhizobium on the yield of mungbean. *J. Agric. Rural Dev. Gazipur.* **3**(1/2): 73-78.

Meena, O. H. R. Khafi, M. A. Shekh, Asha Mehta and B. K. Davda. 2007. Effect of vermicompost and nitrogen on content, uptake and yield of *rabi* maize. *Crop Res.* **33**(1, 2 & 3): 53-54.

Murphy, J. and J. P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Acta.* 27: 31-36.

Nayyar, V. K. and I. M. Chibba. 1992. Interactions of zinc with other plant nutrients in soils and crops. In: Management of Nutrient Interactions in Agriculture. (Ed. H. L.S. Tandon). FDCO, New Delhi, India. pp. 116-142.

Oad, F. C. and U. A. Buriro. 2005. Influence of different NPK levels on the growth and yield of mungbean. *Indus J. Plant Sci.* **4**(4): 474-478.

Oad, F. C. A. N. Shah, G. H. Jamro and S. H. Ghaloo. 2003. Phosphorus and potassium requirements of mungbean (*Vigna radiata*). *J. Applied Sci.* **3**(6): 428-431.

Pandey, S. P. and R. S. Singh. 2001. Responses of phosphorus and sulphur on yield and quality of summer moong (*Vigna radiata* L.). *Crop Res. Hisar*. **22**(2): 206-209.

Pathak, K., M. K. Kalita, U. Barman, B. N. Hazarika and N. N. Saha. 2001. Response of summer greengram (*Vigna radiata*) to inoculation and N nitrogen levels in Barak Valley Zone of Assam. *Annals Agric. Res.* **22**(1): 123-124.

Patil, S. L. and M. N. Sheelavantar. 2004. Effect of cultural practices on soil properties, moisture conservation and grain yield of winter sorghum (*Sorghum bicolar L. Moench*) in semi-arid tropics of India. *Agric. Water Management*. **64**(1): 49-67.

Patro, H. and P. N. Sahoo. 1994. Response of mungbean genotypes to phosphorus. *Indian J. Pulses Res*. 7(2): 191-192.

Prasad, M. R., A. P. Singh and B. Singh, 2000. Yield, water use efficiency and potassium uptake by summer mungbean as affected by varying levels of potassium and moisture stress. *J. Indian Soc. Soil Sci*. **48**(4): 827-828.

Rajkhowa, D. J., M. Saikia and K. M. Rajkhowa. 2002. Effect of vermicompost with and without fertilizer on greengram. *Legume Res.* **25**(4): 295-296.

Ramalingam, R. 1999. Vermicomposting of crop residue sugarcane trash using an Indian epigeic earthworm, *Perionyx encavatus. J. Experimental Zoology, India*. **4** (2): 267-272.

Ram, S. N. and Dixit, R. S. 2001. Growth, yield attributing parameters and quality of summer green gram (*Vigna radiata* L. Wilczek) as influenced by dates of sowing and phosphorus. *Indian J. Agric. Res*. **35**(4): 275-277.

Ram, S. N. and R. S. Dixit. 2000. Effect of dates of sowing and phosphorus on nodulation, uptake of nutrients and yield of summer greengram (*Vigna radiata* L.Wilczek). *Crop Res. Hisar*. 19(3): 414-417.

Rani, R. and O. P. Srivastava. 1997. Vermicompost: a potential supplement to nitrogenous fertilizer in rice nutrition. *Int. Rice Res. Notes*. **22** (3): 30-31.

Rajput, H. A., Tahir Masood, Moazzam Jamil and C. M. Afzal. 1992. Response of mungbean (*Vigna radiata*) to NPK fertilizers under irrigated conditions. *J. Agric. Res. Lahore*. **30**(4): 485-488.

Rao, K. R., P. A. Rao and K. T. Rao. 2000. Influence of organic manure and fertilizers on the incidence of groundnut leafminer. *Approacrema Modicella Dev Annals of Plant Protection Sciences*. **9** (1): 12-15.

Reddy, B. G. and M. S. Reddy. 1998. Soil health and crop productivity in alfisols with integrated plant nutrient supply system. *J. Australian Agric*. **96** :55-59.

Reddy, R., M. A. N. Reddy, Y. T. N. Reddy, N. S. Reddy and M. Anjanappa. 1998. Effect of organic and inorganic sources of NPK on growth and yield of pea (*Pisum sativum*). *Legume Res*. **21**(1): 57-60.

Ahmad, R., M. Ikraam, Ehsan Ullah and Asif Mahmood. 2003. Influence of different fertilizer levels on the growth and productivity of three mungbean (*Vigna radiata* L.) cultivars. *Int. J. Agric. Biology*. **5**(3): 335-338.

Robinson, C. H., P. Ineson, T. G. Piearce and A. P. Rowland. 1992. Nitrogen mobilization by earthworm in limed peat soils under *Picea sitchensis*, *J. Applied Ecol*., **29**: 226-237.

Sharma, S., R. G. Upadhyay, C. R. Sharma and S. Rameshwar. 2003. Response of various levels of nitrogen and phosphorus application on growth, physiological parameters and yield of *Vigna radiata* (L.) Wilczek under rainfed and mid-hill conditions of Himachal Pradesh. *Indian J. Agric. Res*. **37**(1): 52-55.

Sharma, S., N. S. Daramwal, C. R. Sharma and R. G. Upadhyay. 2001. Influence of various doses of nitrogen and phosphorus on protein content, yield and its attributes of mungbean (*Vigna radiata* L. Wilczek). Research on Crops. **2**(2): 108-111.

Simanaviciene, O., J. Mazvila, Z. Vaisvila, E. Ryliakiene, J. Arbacauskas and L. Eitminavicius. 2001. Comparison of the efficacy of NPK fertilizer rates, calculated by different methods and the effect of farmyard manure and straw in the crop rotation.**75** (14): 14-28.

Singh, R. K. K., H. S. Athokpam, Changte Zoliana and N. G. Singh. 2005. Integrated management of Azolla, vermicompost and urea on yield of and nutrient uptake by rice and soil fertility. *J. Indian Soc. Soil Sci*. **53**(1): 107-110.

Singh, Bharat, C. P. Singh and Manish, Singh. 2003. Response of summer moong (*Vigna radiata* L.) to levels of phosphorus and PSM inoculation in sandy loam soil. *Annals of Agric. Res.* **24**(4): 860-866.

Singh, A. K. and Ram. Humuman. 2001. Effect of phosphorus and zinc fertilization on growth and quality of mungbean (*Vigna radiata*). *J. Interacademicia*. **5**(3): 314-317.

Singh, A. K., Mandhata Singh and R. Hanuman. 1993. Effect of phosphorus and zinc fertilization on chemical composition of mungbean (*Vigna radiata*). *J. Appl. Biology.* 1995; **3**(1/2): 28-32.

Singh, D. and Mukand Singh. 1991. Response of mungbean to phosphorus. *Indian J. Pulses Res.* **4**(1): 113-114.

Sohrab, A. and J. M. Sarwar. 2001. Production of vermicompost and its use in upland and horticulture crops. Project Report of Rajshahi University.

Srikanth, K. C. A. Srinivasamurthy, R. Siddaramappa and V. R. R. Parama. 2000. Direct and residual effect of enriched composts, FYM, vermicompost and fertilizers on properties of an Alfisol. *J. Indian Soc. Soil Sci.* **48** (3): 496-499.

Srinivas, M. and Mohammad Shaik. 2002. Performance of greengram (*Vigna radiata* L. Wilczek) and response functions as influenced by different levels of nitrogen and phosphorus. *Crop Res. Hisar.* **24**(3): 458-462.

Subhendu, Mandal, K. C. Biswal and P. K. Jana. 2005. Yield, economics, nutrient uptake and consumptive use of water by summer greengram (*Vigna radiata* L.) as influenced by irrigation and phosphorus application. *Legume Res.* **28**(2): 131-133.

Tandon, H.L.S. 1992. Management of nutrient interactions in agriculture. Fertilizer Development and Consultation Organization, New Delhi, India.

Teotia, U. S., V. S Mehta, D. Ghosh and P. C. Srivastava. 2001. Phosphorus-sulphur interaction in moongbean (Vigna radiata L. Wilczek). II. Yield, nitrogen, potassium, calcium and magnesium contents. *Legume Res.* **24**(4): 272-274.

Thakur, V. R., D. G. Giri and J. P. Deshmukh. 1996. Influence of different sources and levels of phosphorus on yield and uptake of greengram (*Vigna radiata* L.). *Annals Plant Physiology.* **10**(2): 145-147.

Tiwari, V. N., L. K. Lehri, K. N. Tiwari and, R.M. Upadhyay. 2001. Integrated nitrogen management through natural green manuring under wheat-mungbean cropping sequence. *J. Indian Soc. Soil Sci.* **49**(2): 271-275.

Tolanur, S. I. and V. P. Badanur. 2003. Effect of integrated use of organic manure, green manure and fertilizer nitrogen on sustaining productivity of *rabi* sorghum-chickpea system and fertility of a Vertisol. *J. Indian Soc. Soil Sci.* **51**(1): 41-44.

Tomar, S. S., R. K. Sharma, O. P. Verma, S. S. Bhadouria and A. S. Tomar. 1996. Effect of seed rate, irrigation and phosphorus levels on the growth attributes and net return of summer mung (*Vigna radiata*). Bhartiya Krishi Anusandhan Patrika. **11**(3): 136-140.

Vasanthi, D. and K. Kumaraswamy. 1997. Efficacy of vermicompost to improve soil fertility and rice yield. *J. Indian Soc. Soil Sci.* **47**(2): 268-272.

Vennila, C. and C. Jayanthi. 2007. Effect of integrated nitrogen management on yield, nutrient uptake and soil fertility under wet seeded rice + dhaincha-greengram system. Crop Res. **33**(1, 2 & 3): 21-24.

Vishwakarma, B., C. S. Singh and R. Singh. 2002. Response of French bean (*Phaseolus vulgaris* L.) varieties to nitrogen application. *Res. Crops.* **3**(3): 529-532.

Yadav, R. D. and C. V. S. Malik. 2005. Effect of Rhizobium inoculation and various sources of nitrogen on growth and yield of cowpea [*Vigna unguiculata* L. Walp.]. Legume Research. **28**(1): 38-41.

Yadav, S. S. 2004. Growth and yield of green gram (*Vigna radiata* L.) as influenced by phosphorus and sulphur fertilization. *Haryana J. Agron*. **20**(1/2): 10-12.

Yakadri, M., Tahatikunta Ramesh and A. Latchanna. 2004. Dry matter production and nutrient uptake of greengram (*Vigna radiata* L. Wilczek) as influenced by nitrogen and phosphorus application during wet season. *Legume Res.* **27**(1): 58-61.

Zahid, H. M. 2001. Production of vermicompost and its use in upland and horticultural crops. Annual Report of Bangladesh Agricultural Research Council, Framegate, Dhaka.

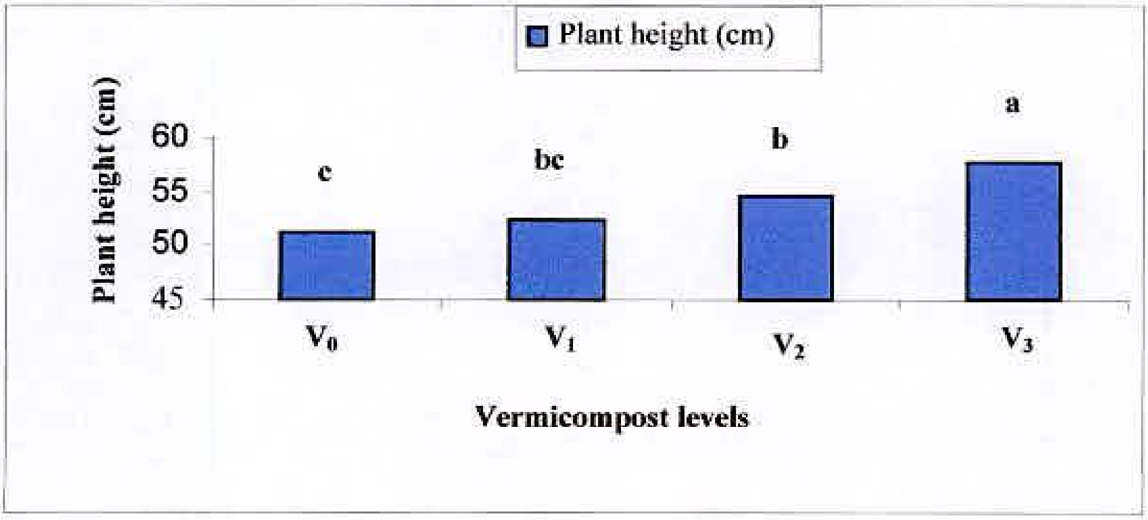
APPENDICES

APPENDICES

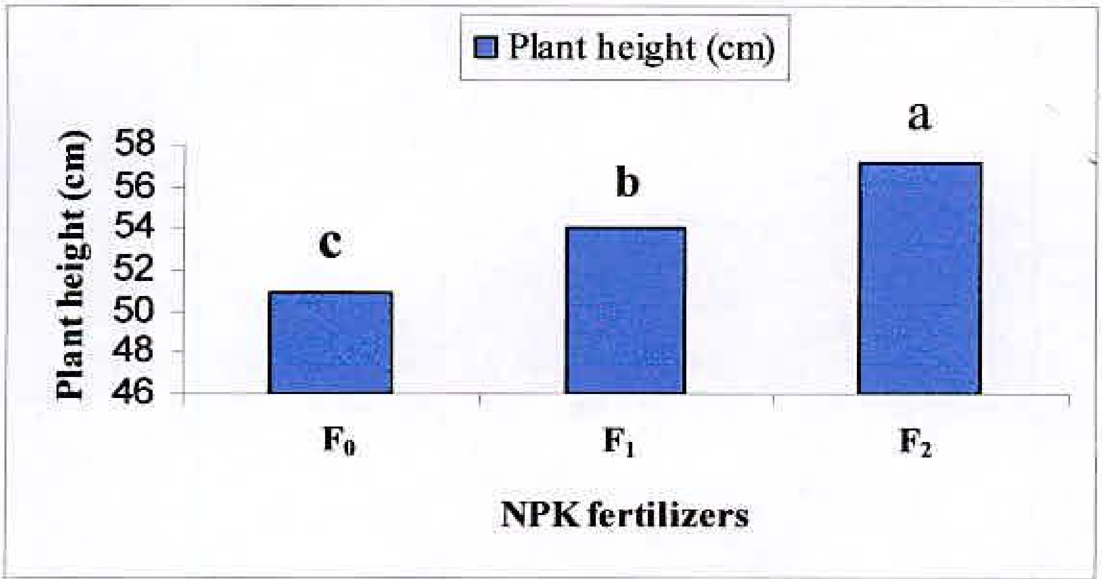
Appendix Table i. Monthly records of meteorological observation at the period of experiment (April, 2007 to June, 2007)

Month	Temperature		Humidity (%)	Precipitation (mm)
	(Maximum, ^{O}C)	(Minimum, ^{O}C)		
April	30.60	19.5	76.50	45
May	31.90	20.13	78.00	52
June	33.60	22.5	82.7	65

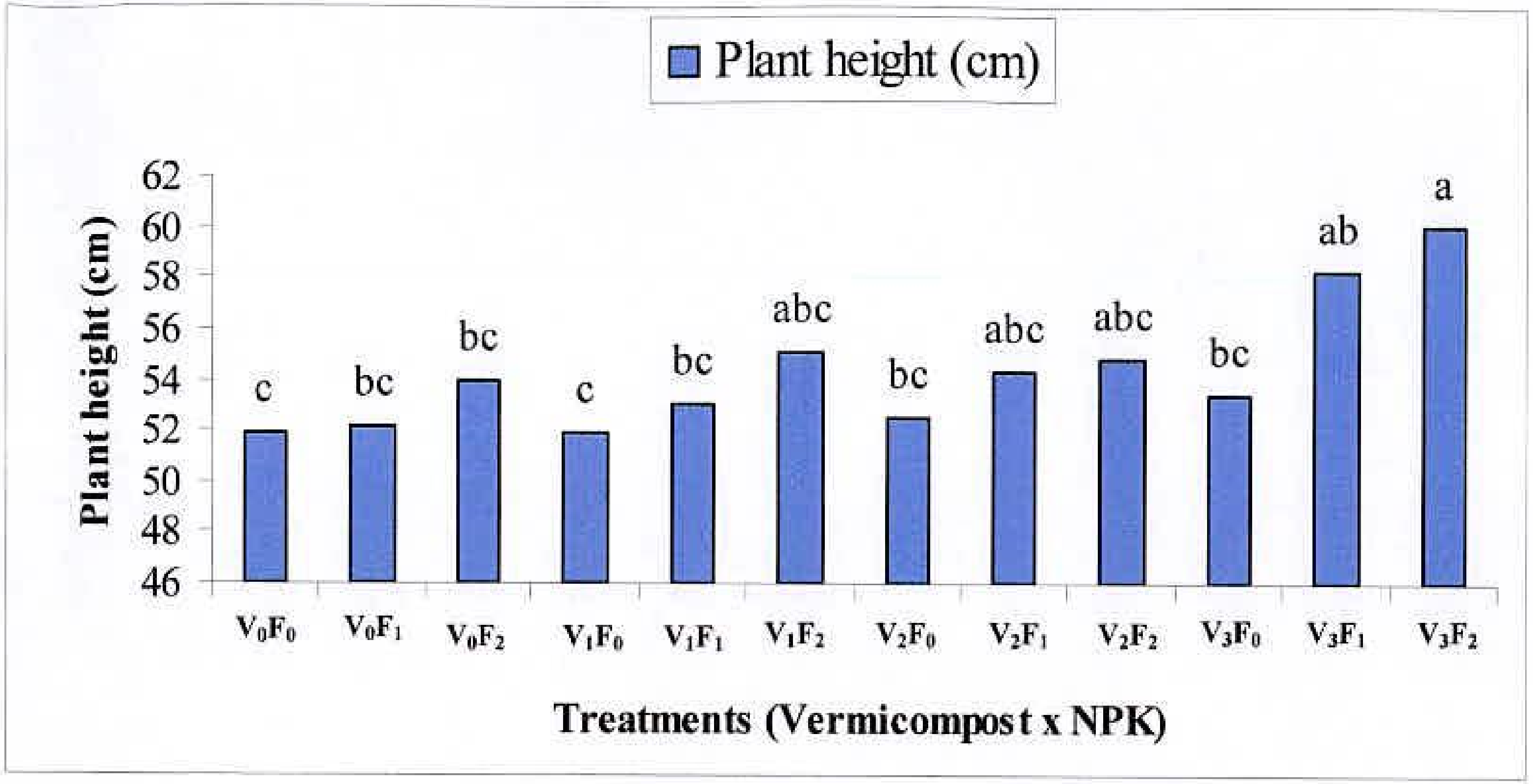
Source : Weather Yard, Bangladesh Meteorological department, Dhaka.



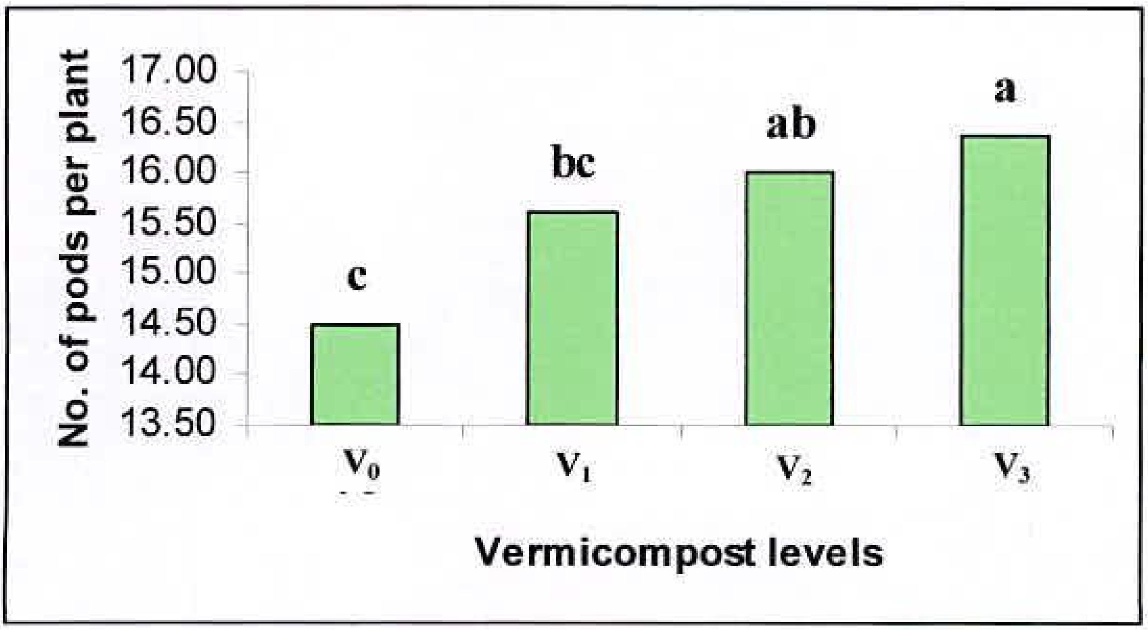
Appendix Fig. i. Effect of vermicompost on the plant height of mungbean.



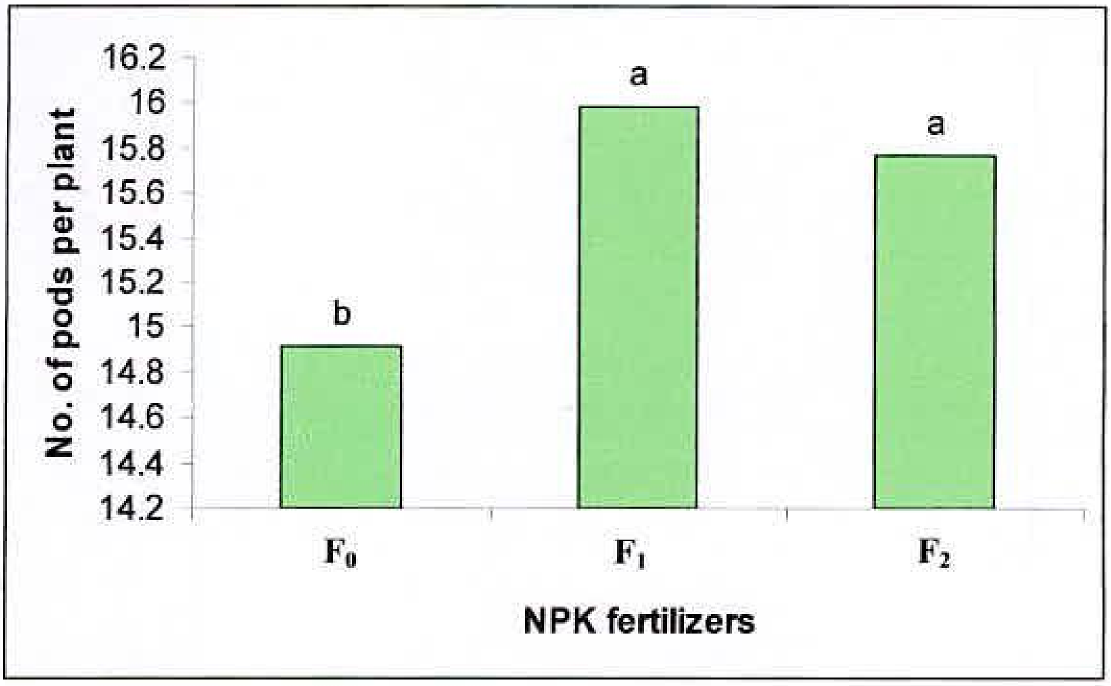
Appendix Fig. ii. Effect of NPK fertilizers on the plant height of mungbean.



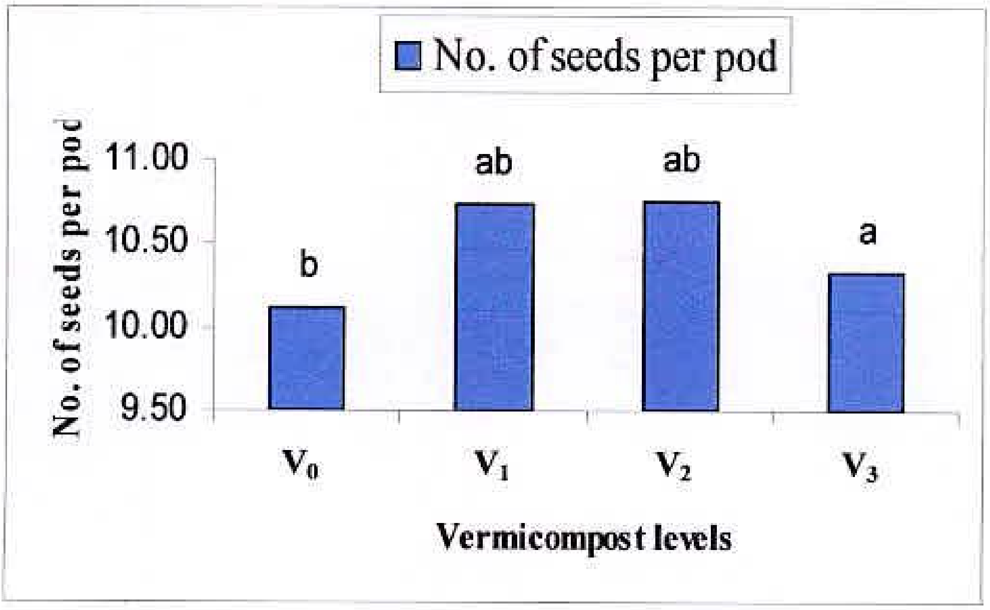
Appendix Fig. iii. Combined effect of vermicompost and NPK fertilizers on the plant height of mungbean.



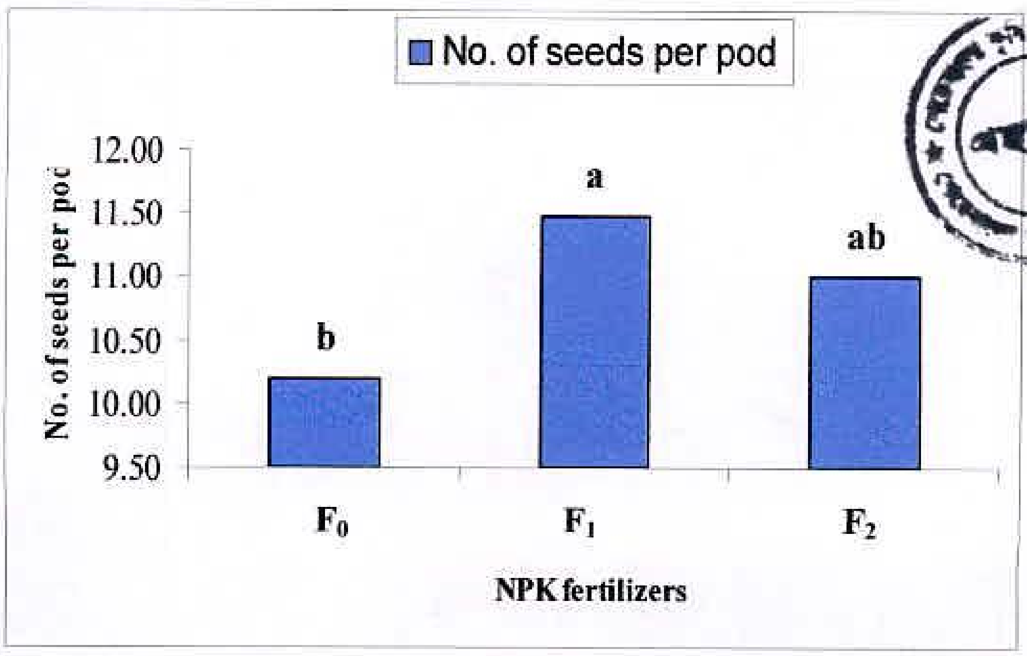
Appendix Fig. iv. Effect of vermicompost on the number pods/plant of mungbean.



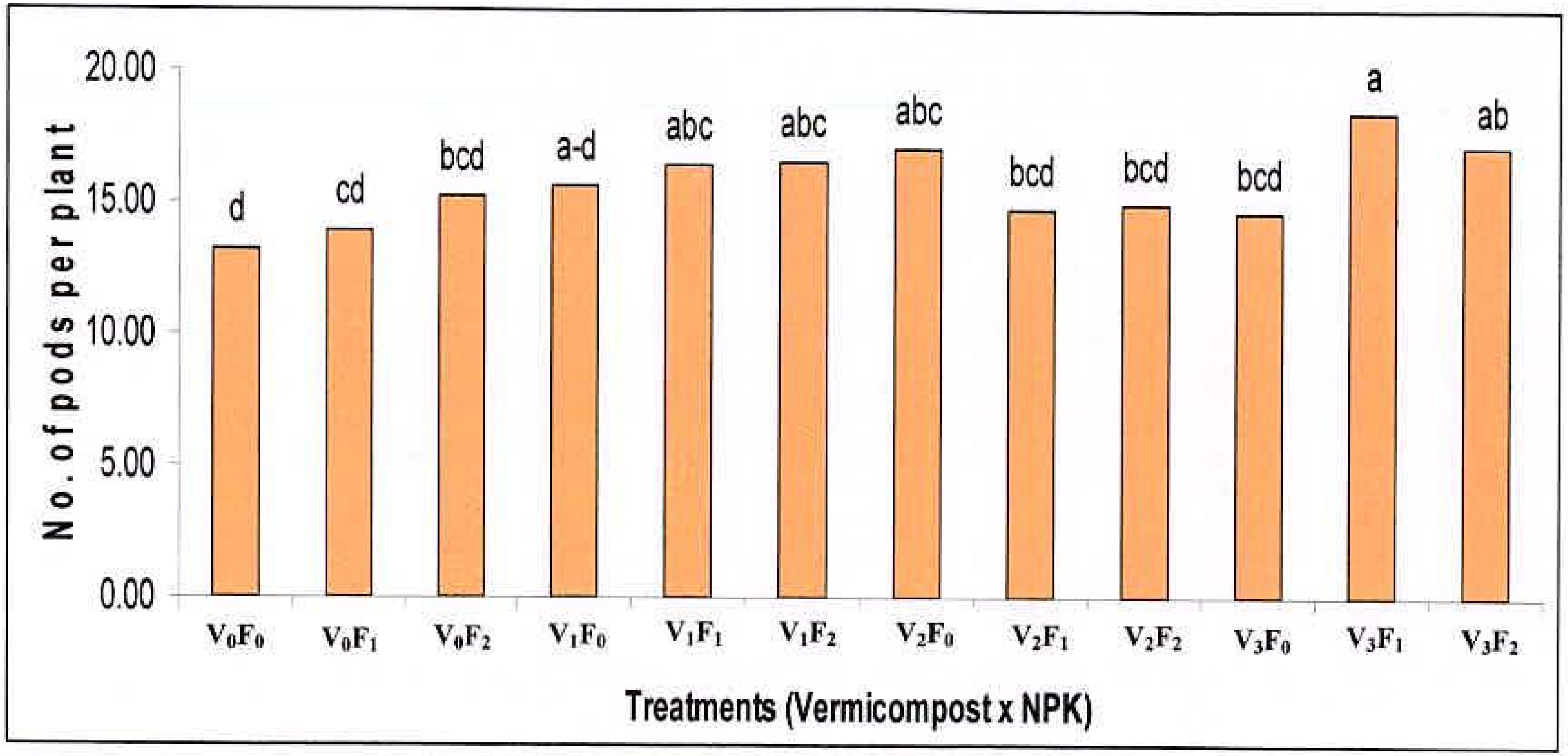
Appendix Fig. v. Effect of NPK fertilizers on the number pods/plant of mungbean.



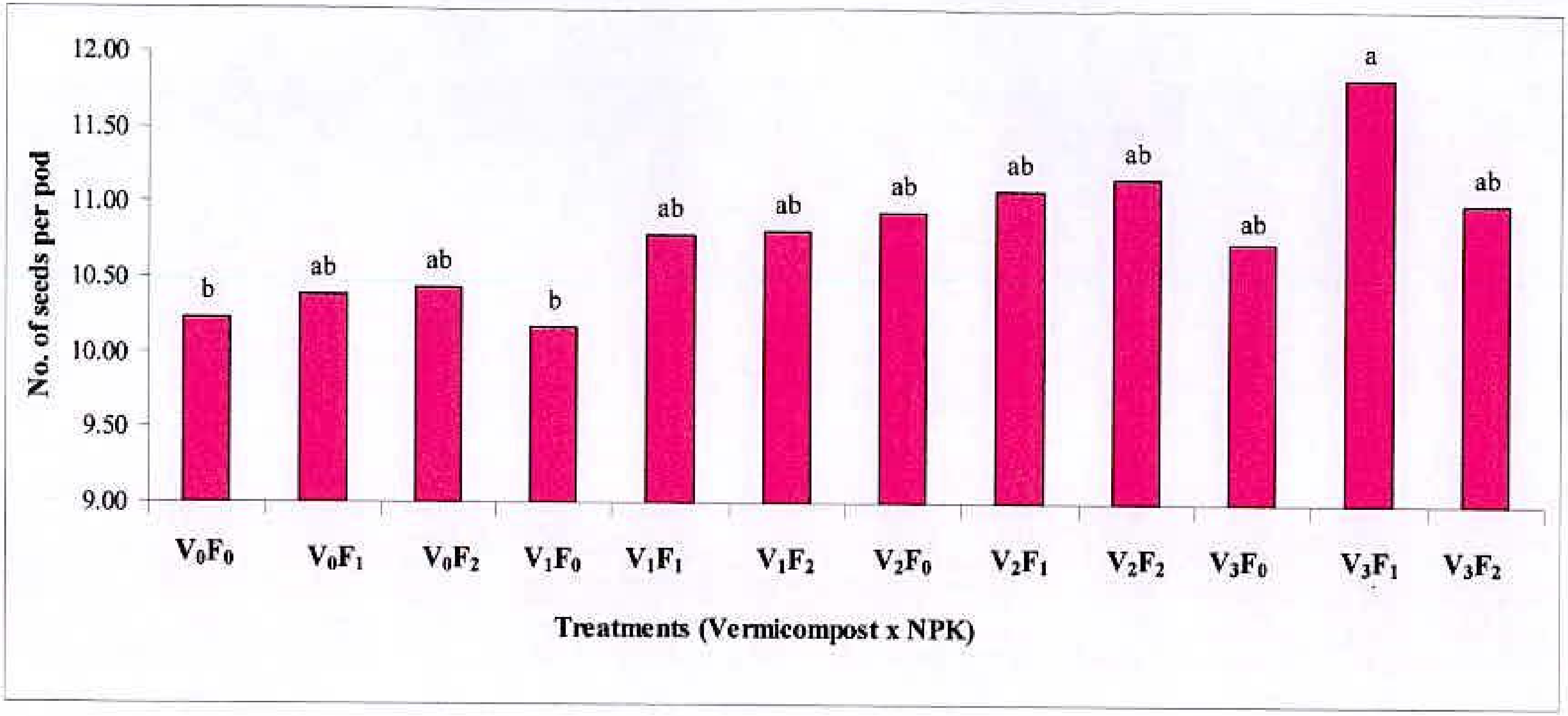
Appendix Fig. vi. Effect of vermicompost on the number seeds/pod of mungbean.



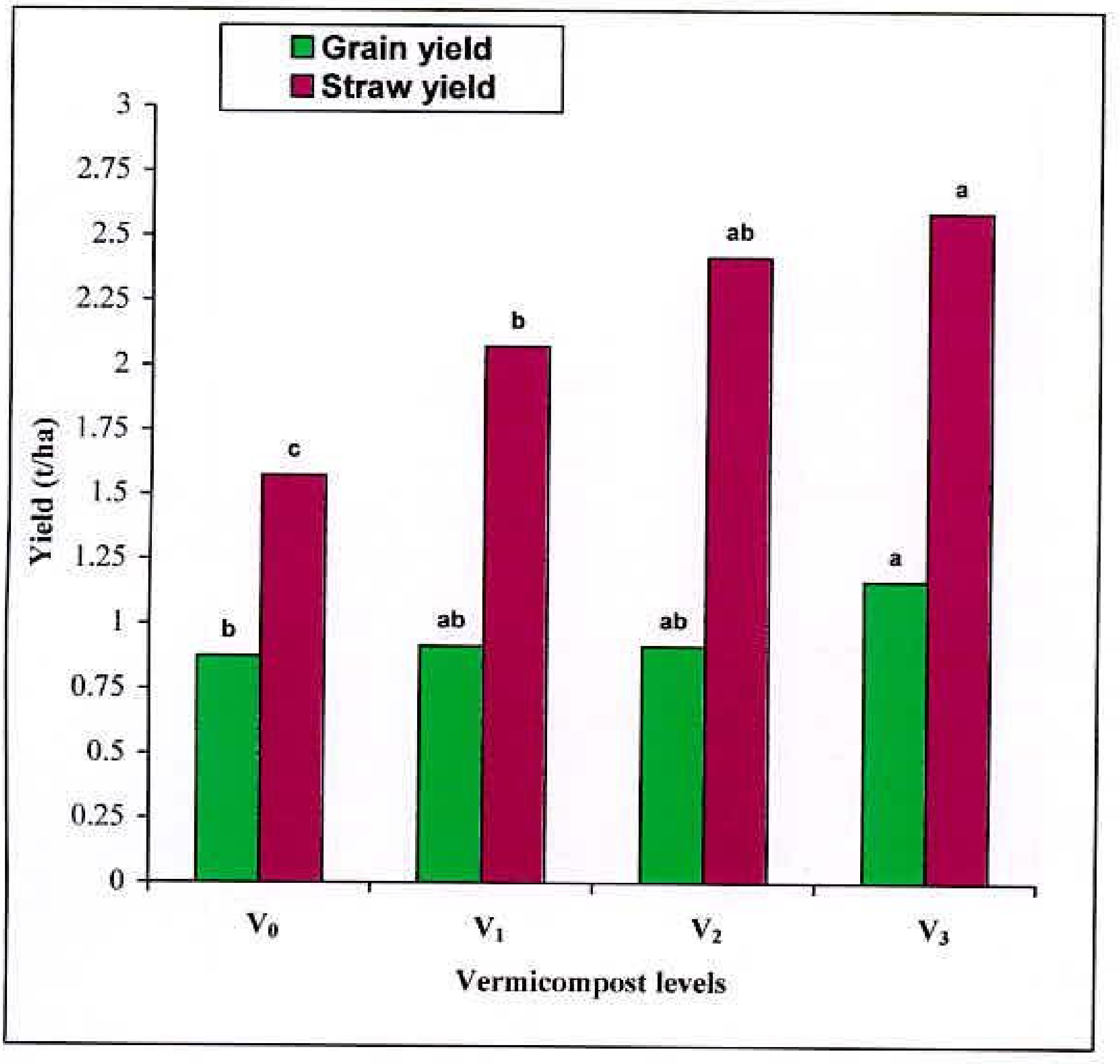
Appendix Fig. vii. Effect of NPK fertilizers on the number seeds/pod of mungbean.



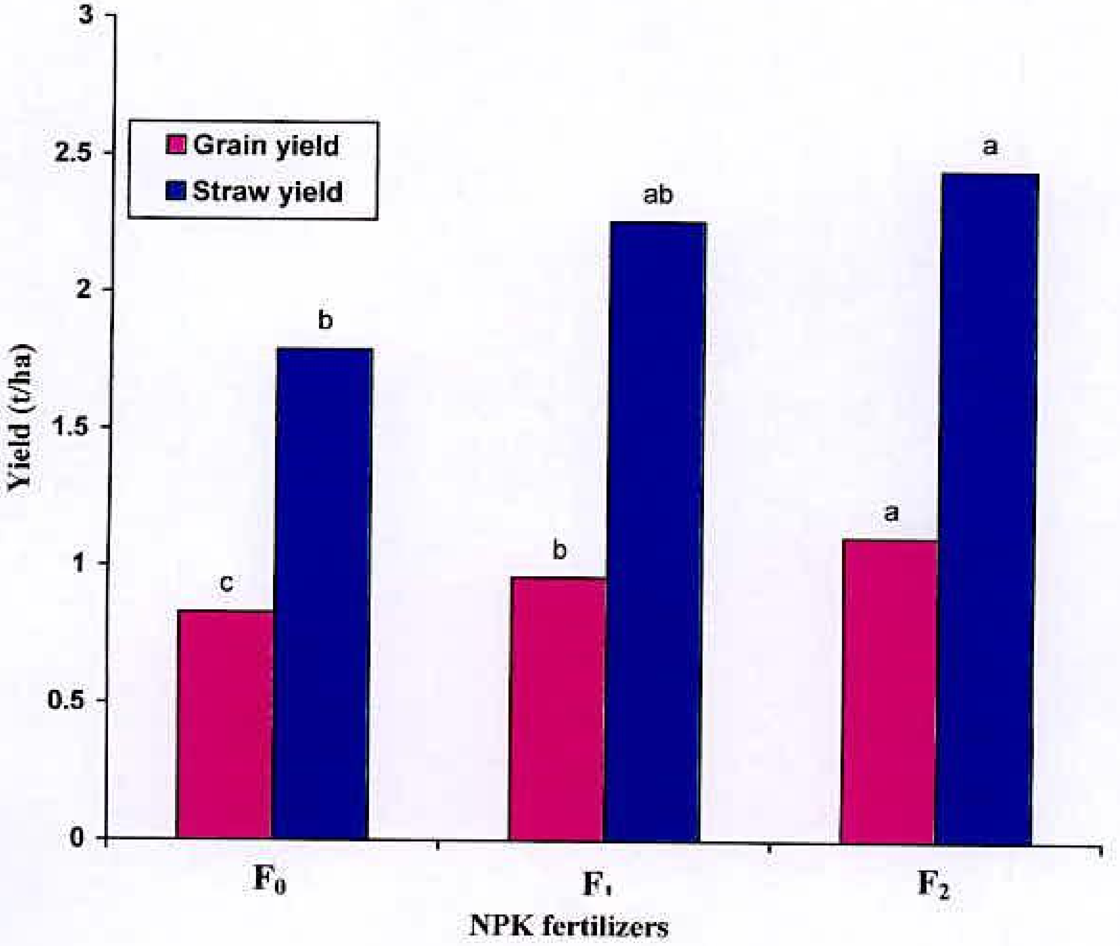
Appendix Fig. viii. Combined effect of vermicompost and NPK fertilizers on the number pods/plant of mungbean.



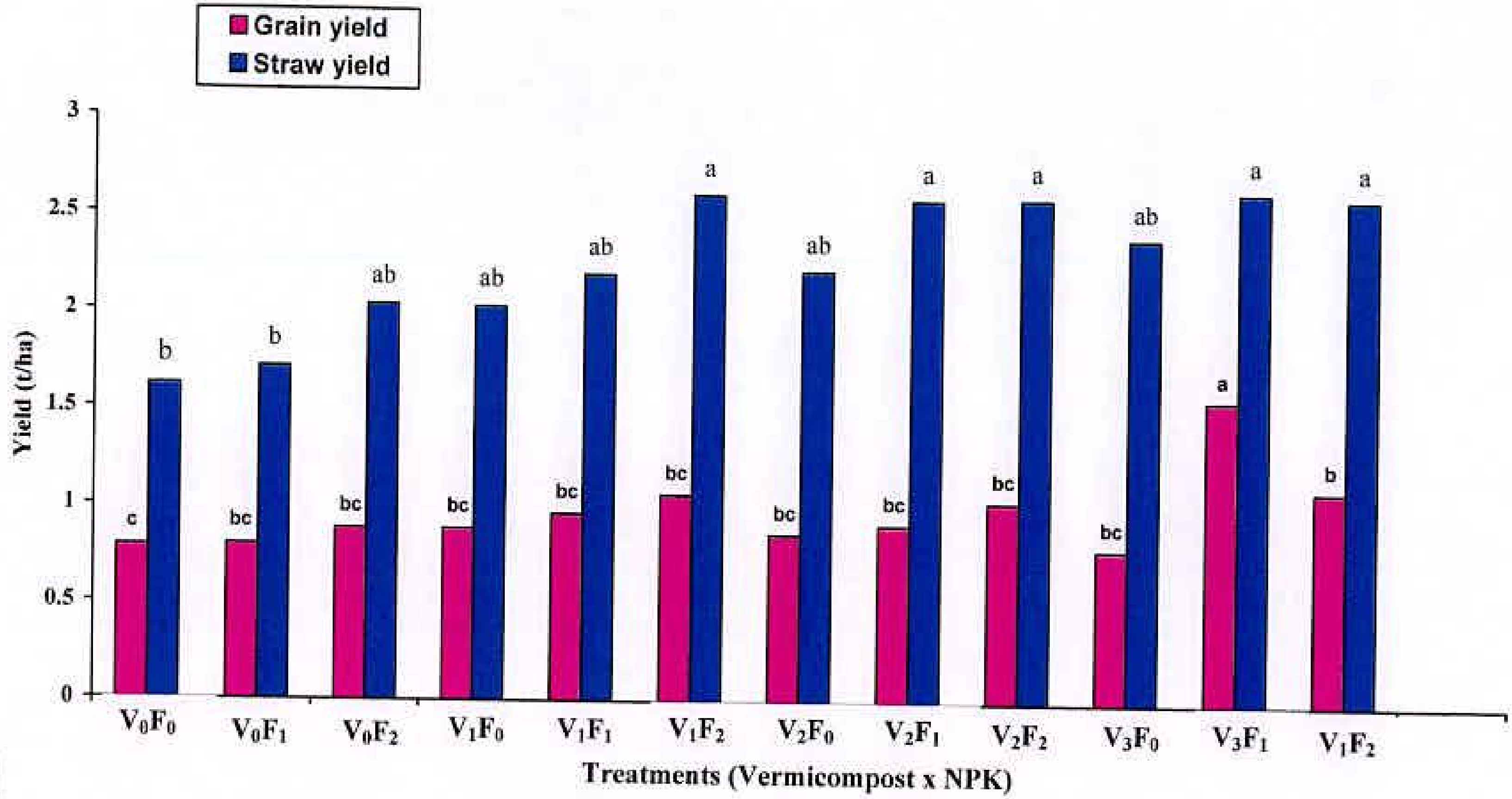
Appendix Fig. ix. Combined effect of vermicompost and NPK fertilizers on the number seeds/pod of mungbean.



Appendix Fig. x. Effect of vermicompost on the grain and straw yield of mungbean.



Appendix Fig. xi. Effect of NPK fertilizers on the grain and straw yield of mungbean



Appendix Fig. xii. Combined effect of vermicompost and NPK fertilizer on the grain and straw yield of mungbean