PERFORMANCE OF VERMICOMPOST AND INORGANIC FERTILIZERS ON GROWTH, YIELD AND OIL CONTENT OF MUSTARD *(Brassica campestris* var. SAU sharisha-1&4)

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This is to certify that the thesis entitled, **"PERFORMANCE OF VERMICOMPOST AND INORGANIC FERTILIZERS ON GROWTH, YIELD AND OIL CONTENT OF MUSTARD"** 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 AGRICULTURAL CHEMISTRY**, embodies the result of a piece of *bona fide* research work carried out by **MST. TOUFICA YEASMIN, REGISTRATION No. 08-03220** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any other institutes.

I further certify that such help or sources of information, as have been availed during the course of this investigation have duly been acknowledged.

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PERFORMANCE OF VERMICOMPOST AND INORGANIC FERTILIZERS ON GROWTH, YIELD, AND OIL CONTENT OF MUSTARD ***(Brassica campestris* var. SAU sharisha-1&4)**

By

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ABSTRACT

A field experiment was carried out at Sher-e-Bangla Agricultural University Farm, Dhaka during the rabi season of 2010-2011 to evaluate the performance of vermicompost and inorganic fertilizers on growth, yield, and oil content of mustard. The treatments used two varieties such as variety-1=SAU sharisha-1 & variety-2=SAU sharisha-4 and 3 levels of each of vermicomposts viz. F_0, F_1, F_2=(0, 1.5, 2.5) t ha^{-1} and inorganic fertilizers (N, P, K, S, Zn, B)viz. F_3, F_4, F_5 = (40-80-120,15-30-45,20-40-60,10-20-30,1.2-2.4-3.6,1-2-3) kg ha^{-1}.The results demonstrated that high vermicompost (2.5t/ha) and medium doses of inorganic fertilizers (80-30-40-20-2.4-2 kg/ha) increased seed yield of mustard significantly. Considering the varietals effect the highest seed yield (2.045 t ha^{-1}) was found in variety-1 and lowest seed yield (1.78 t ha^{-1}) was observed in variety-2. The highest number of siliqua (180.617) was obtained from variety-1 and on the other hand the lowest number of siliqua (165.792) was obtained from variety-2. Variety-2 showed highest oil content (44.12%) and variety-1 give the lowest oil content (43.1%). Effects of fertilizer showed that the highest seed yield (2.314 t ha^{-1}) was found from medium fertilizer (80-30-40-20-2.4-2 kg/ha) and the lowest seed yield (1.63 t ha^{-1}) was obtained from low vermicompost treatment (1.5 t/ha). The highest number of siliqua (189.8) was obtained from medium fertilizer (80-30-40-20-2.4-2 kg/ha) and on the other hand the lowest number of siliqua (133.5) was obtained from (0 t/ha) control treatment. The treatment medium fertilizer (80-30-40-20-2.4-2 kg/ha) showed the highest oil content (44.4%) and control treatment give the lowest oil content (43.05%).The interaction effect showed that maximum significant seed yield (2.740t ha^{-1}) was obtained from variety-1 by the application of medium fertilizer (80-30-40-20-2.4-2 kg/ha) but the percentage of oil content (45.2%) was maximum at Variety-2 by the application of medium fertilizer (80-30-40-20-2.4-2 kg/ha). Oil percentage was greater in SAU sharisha-4(black) than that of SAU sharisha-1(white).The oil content was not significantly influenced by the difference of treatments.

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Full word
DDE	Dichloro-Diphenyl-Ethane
FAO	Food and Agriculture Organization
BBS	Bangladesh Bureau of Statistics
WB	World Bank
BCSIR	Bangladesh Council of Scientific & Industrial Research
et al.	Et alibi (and others)
i.e.	That is
kg	Kilogram
lb.	Pound
KPa	Kilo Pascal
mt	Metric-ton
µL	Micro liter
µg	Micro gram
ng	Nanogram
No.	Number
OP	organophosphorus
Op	Ortho para
pp	Parapara
Ppb	Parts per billion
ppm	Parts per million
PR	Pesticide residue
%	Percentage
g	Gram
LSD	Least significant difference

Abbreviation	Full word
ai	Active ingredient
t	Ton
cm^2	Square centimeter
yr	Year
m^2	Square meter
cm^3	Cubic centimeter (Solid)
m	Meter
df	Degree of freedom
ha	Hectare
SE	Standard error
p^H	Negative log of Hydrogen ion concentration
Yd	Yard
wk	Week
A	Acre
NS	Not Significant
BARI	Bangladesh Agricultural Research Institute

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Mustard and rapeseed belonging to the genus *Brassica* under the family Cruciferae are important oil crops and currently ranked as the third important oil crops in terms of production and cultivated area. Among the species, *Brassica napus, Brassica campestris* and *Brassica juncea* are regarded as 'Mustard'. *Brassica napus* is a high yielding species recently adopted but shattering occurs at ripening, while *Brassica campestris* is comparatively low yielding but very familiar in Bangladesh. *Brassica juncea* has comparatively high yield potentiality and stable yield when it is late planted. It is non shattering type and can tolerate drought and salinity; but it is a long duration species. Morphological traits and their associations influence yield, resistance or tolerance to biotic and abiotic stresses under varied environmental conditions. The total annual production of *Brassica* worldwide is 44.41 million tons of seed from an area of 27.24 million hectares (FAO, 2004). It has remarkable demand as edible oil in Bangladesh. Mustard is in top position of the list among the oil seed crops grown in this country in respect of both production and acreage (BBS, 2004).

In the year of 2003-04 mustard covered 1.79 lac hectares of land and the production was 2.11 lac metric tons (mt), whereas the total oilseed production was 4.07 lac mt and total area covered by oilseed crops was 3.89 lac hectares in Bangladesh. In the year of 2004-05 it covered 3.95 lac hectares of land and the production was 3.79 lac mt (BBS, 2005).

Bangladesh is suffering from acute shortage of edible oil in terms of domestic production. About two third of the total edible oil consumed in the country is imported. Although the domestic production has considerably increased but the deficiency has not reduced due to increased requirement of edible oil. At present about 0.33 million hectares of land are put to mustard cultivation in Bangladesh with yield of mustard oil in the order of 0.22 million mt per year. This quantity meets only a fraction of the country's cooking oil need.

Varieties of yellow mustard usually mature in 80 to 85 days whereas brown and oriental types require 90 to 95 days. Mustard can be raised on variable soil types with good drainage, but is best adapted to fertile, well-drained, loamy soils. Soils prone to crusting prior to seedling emergence can cause problems. This crop will not tolerate waterlogged soils since growth will be stunted. Dry sand and dry, sandy loam soils should also be avoided. Mustard is a cold loving crop and grows during rabi season (October-February) usually under rain fed condition and low input condition in this country. There is very little scope of expansion for mustard and other oilseed cultivation in the country due to competition from more profitable alternative crops. The cultivation of mustard has to compete with other food grain crops. With increasing growth rate of population, the demand of edible oil is increasing day by day.

Only a few decades ago, mustard oil was the exclusive cooking oil in Bangladesh. Then this oil, still in many places, is squeezed from the seeds by using traditional grinding mills, called 'Ghanee', which is pulled by a bull through long hours of the day and even throughout the night; the tradesman in the business is called '*Kolu*'.

Mustard produces healthy oil which is low in saturated fatty acids. It is also high in Alpha-Linolenic acid (an Omega-3 fatty acid), an important component in a healthy diet. In fact mustard oil is significantly better than canola oil in this regard having a 15% Omega-3 fatty acid content compared to canola oil's 10% content. Edible oil is an essential integral part of the daily diet of the people in Bangladesh. Fats and oils are available from different sources like animal and plant. Animal fats are derived from milk, ghee, butter, etc. but compared to the oil obtained from various oil crops these are very costly. Oil from plants is easily digestible and its nutrition quality is better than that of animal fats. More energy is supplied by plant products than by animal products. In Bangladesh, oilseed crops play a vital role in human nutrition. It is not only a rich source of energy (about 9 Kcal/g) but also rich in soluble vitamins A, D, E and K. *Brassica* vegetables are rich in indole-3-carbinol, a chemical which boosts DNA repair in cells and appears to block the growth of cancer cells. *Brassicas* are also a good source of carotenoids, with broccoli having especially high levels.

Moreover, the average yield of mustard in Bangladesh is very low (0.812 t ha^{-1}) compared to the other countries of the world. The average yield of mustard in Germany, France, UK, Poland, China and Japan is 3.70, 2.75, 2.85, 2.6, 1.8 and 1.6 t ha^{-1}, respectively (FAO, 2006). There is great possibility to increase its production by applying adequate fertilizers, selecting high yielding varieties and adopting proper management practices. One of the common constraints to higher yield is lack of balanced fertilization.

SAU sharisha-1 and SAU sharisha-4 are newly developed varieties by Dr. Md. Shahidur Rashid Bhuiyan, Professor, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University. SAU sharisha-1 is a short term and high yielding variety of sharisha. SAU sharisha-1 is yellow sarson group of the species of *campestris* and SAU sharisha-4 is black sarson group of the species of *campestris.* From the fertilizer recommendation that given in the leaflet of SAU sharisha-1, it is found that sulphur and phosphorous is the important two nutrients affecting yields and contributing characters of this variety. Almost all parts of some species or other have been developed for food, including the root (rutabaga, turnips), stems (kohlrabi), leaves (cabbage, Brussels sprouts), flowers (cauliflower, broccoli), and seeds (many, including mustard seed, and oil-producing mustard). Aracon *et al.* (2006) studied that the effect of application of food waste, paper waste and vermicomposts on some soil chemical and biological properties in field plots planted with strawberry increases in microbial populations and activities.

Vermicompost can be an important tool to the combination of inorganic and organic sources of nutrient. Vermicompost is an organic manure (bio-fertilizer) produced as the vermicast by earth worm feeding on biological waste material; plant residues. This compost is an odorless, clean, organic material containing adequate quantities of N, P, K and several micronutrients essential for plant growth. Vermicompost is a preferred nutrient source for organic farming. It is eco-friendly, non-toxic, consumes low energy input for composting and is a recycled biological product.

In Bangladesh some promising varieties of mustard have been released those are being cultivated under inorganic fertilization. Such promising mustard (*Brassica campestris)* cv. SAU sharisha-1&4 was used in this experiment with combined application of vermicompost and inorganic fertilizers.

Limited information's are available in Bangladesh on the effect of combined application of vermicompost and inorganic fertilizers on the growth, yield, chemical composition and oil content of oil producing *Brassica* spp. Therefore considering the above importance, this experiment was undertaken keeping the following **objectives** in mind:

- To evaluate the growth and yield performances of SAU sharisha-1&4 by the application of vermicompost and inorganic fertilizers and
- To find out the oil content of SAU sharisha-1&4.

Chapter II
Review of Literature

CHAPTER II

RIVIEW OF LITERATURE

Mustard (*Brassica campestris* L.) is one of the most important oil seed crops in our country. It is necessary to improve the cultural practices of mustard to improve the yield and oil content of this crop under Bangladesh condition. A number of research works on the response of crops, especially mustard to different fertilizers and manures have carried out in Bangladesh and other oil seed crops growing countries of the world. The farmers are also advised to use manures and fertilizers irrespective of crops, seasons and soils for boosting up yields, but information on the effect of combined application of vermicompost and inorganic fertilizers on growth, yield, chemical composition and oil content of mustard are very limited in our country. However, some of the works done in our country and elsewhere in the world are briefly reviewed here.

2.1 Effect of inorganic fertilizers on mustard

A field experiment was conducted by Poonam *et al.* (2007) in Kanpur, Uttar Pradesh, India, during rabi seasons of the 2003/04 and 2004/05 to determine the effect of integrated application of S (20, 40 and 60 kg/ha) and Zn (2.5, 5.0 and 7.5 kg/ha) on Indian mustard cultivars Vaibhav, Rohini, Varuna, Kranti and Urvashi. Among cultivars, Varuna gave the highest performance regarding seed yield per plot and per hectare with maximum number of siliqua and 1000-seed weight with higher amount of oil content (41.28%). Urvashi performed next to Varuna in terms of seed yield per plot and per hectare, having the highest number of primary and secondary branches but oil content was slightly low (40.70%). The highest oil content was yielded by Rohini (41.50%) and Kranti (41.52%). Application of 60 kg S and 7.5 kg Zn/ha gave maximum seed yield and quality, but benefits of S was more than Zn application, i.e. 79.29 kg in seed yield/ha and 0.56% in oil content. Urvashi and Kranti were most responsive to nutrient application.

A field experiment was conducted by Ashok *et al.* (2007) during the 2005/06 rabi season in Simbhaboli, Uttar Pradesh, India, to study the effect of different sowing methods (regular and border) and fertilizer rates (0, 30 and 80 kg N/ha; 0 and 15 kg S/ha) on the growth, yield and oil contents of Indian mustard. Border sowing gave maximum plant height and dry matter accumulation at 120 days after sowing, and harvesting index while regular sowing gave maximum seed and stover yields. S at 15 kg/ha and 80 kg N/ha gave the maximum plant height and dry matter accumulation at 120 days after sowing, seed and stover yields and harvesting index. Comparative data on the effect of sowing methods and nutrient application on the oil content, N and S uptake, total N and S, and protein content of Indian mustard are also tabulated.

A field experiment was conducted by Harendra and Yadav (2007) during the two consecutive winter (rabi) seasons of 2000-01 and 2001-02 at Agronomy Research Farm of NDUAT, Faizabad to find out the optimum dose of phosphorus and sulphur for Indian mustard [*Brassica juncea* (L) Czernj. & Coss] cultivars. The treatment consisted of four levels of P (0, 13.1, 26.1 and 39.3 kg/ha) and four levels of sulphur (0, 15, 30 and 45 kg/ha) applied though diammonium phosphate and elemental sulphur in split-plot design replicated thrice. A significant response of crop was observed up to 26.2 kg P and 30 kg

S/ha in seed and stover yields. Nutrient uptake was also highest under these treatments. The optimum dose of S and P was computed as 47.5 and 40.2 kg, and 44.0 and 40.2 kg for the first and second years respectively. Highest net returns of Rs. 12.729 and 13.734/ha were recorded with the application of 39.3 and 45 kg/ha P and S respectively. However, net returns of Rs. 1.10 and 1.18/ha. Reinvested were highest at 26.2 and 30 kg P and S respectively.

An experiment was conducted by Kovacs *et al.* (2007) to determine the effects of different N rates (0.5, 1.0, 1.5 and 2.0 g/pot) and N: S ratios (8, 4 and 2) on the yield and nutrient (N, S, K, Ca, Mg, Mn and Zn) uptake of mustard (*Sinapis alba*). N fertilizer application significantly improved both the grain and straw yields of mustard. Seed yield increased significantly with decreasing N: S ratio (with increasing S application rate). Maximum grain yield of 24.7 g/pot was observed when full rates of N and S were applied, while the lowest (8.7 g/pot) was observed in plots treated with the lowest N rate and N:S ratio. The highest straw yield (59.2 g/pot) was recorded in the treatment with the combination of 2 g N/pot and N: S ratio of 2. Nitrogen application increased the accumulation of all nutrients (except Ca) in straw and increased the quantity of most nutrients except for Ca and K in seed. S application also increased the concentrations of most nutrients but this effect was not as significant as the effect of N application. N, S, Mg, Mn and Zn concentrations in grain were higher than in the vegetative parts of mustard.

Amit and Sandeep (2007) from a field experiment carried out on Indian mustard var. Vardan during Nov., 2003 to March, 2004 at to find out the growth potential with varying levels of nitrogen (0, 60, 80, 100, 120 and 140 kg/ha) and sulphur (0, 20, 40 and 60 kg/ha). It was observed that nitrogen application had significantly increased all the growth characters (plant height, number of branches, number of leaves, leaf area and number of primary secondary and tertiary branches). The application of sulphur up to 20 kg/ha had significant effect in increasing the growth characters, over the control.

Dharvendra and Verma (2007) conducted an experiment on the effect of graded levels of sulfur and nitrogen on Varuna Indian mustard (*Brassica juncea*), grown in pearl millet-mustard cropping system during winter (rabi) seasons of 1992-93 and 1993-94. Seed yield (16.4 q ha^{-1}) was significantly increased with S application @ 90 kg ha^{-1}, but application of 60 kg S ha^{-1} appeared economically better than other levels of S. Similar increases in mean seed yield with N application @ 120 kg over 80, 40 and 0 kg levels was 3.8, 29.2 and 117.6%, respectively. A significantly positive interaction between the two nutrients (S & N) in increasing seed yield was observed, giving the highest seed yield (19.18 q ha^{-1}) due to combined application of N. An improvement in oil yield was noticed significantly up to 60 kg S ha^{-1} and appeared a reasonable level of S. Similarly, 80 kg N ha^{-1} was noticed quite advantageous for production of oil ha^{-1} in mustard.

Singh *et al.* (2007) from a field experiment reported that heterosis over better parent (BP) and standard cultivar (SV) for seed yield and yield components in Indian mustard in Jaunpur (Uttar Pradesh, India) during rabi 2005-06 using line x tester analysis involving

21 genetically diverse strains used as lines and three testers. Data were recorded on days to 50% flowering, days to maturity, plant height, primary and secondary branches per plant, siliquae on main raceme, length of main raceme, length of siliqua, seeds per siliqua, seed yield per plant, 1000-seed weight and oil content. Four crosses RK-01-1 x NDR-8501, NDR-2004 x Varuna, RH-9623 x Varuna and RH-9623 x NDR-8501 showed significant positive heterobeltiosis as well as standard heterosis for seed yield per plant. These crosses also had significant and positive heterosis for secondary branches, and the seeds per siliqua would be more desirable to exploit heterosis in Indian mustard.

A field experiment was conducted by Nagdive *et al.* (2007) in Akola, Maharashtra, India, during the winter season of 2004-05 to study the seed yield, oil yield, protein content and nutrient uptake by Indian mustard (*Brassica juncea*) as influenced by irrigation and nutrient management treatments. The results indicated that among irrigation treatments, application of irrigation at branching, flowering and siliquae development stages recorded maximum seed yield, protein content, oil percentage and oil yield. The same treatment also enhanced the nitrogen and phosphorus uptake. Among nutrient management treatments, application of 75% recommended dose of NPK (45: 22.5: 22.5 kg NPK ha^{-1}), FYM at 5 t ha^{-1}, *Azotobacter*, PSB recorded significantly highest seed, protein and oil yield. Nitrogen, phosphorus and sulfur uptake as well as protein content than 50% (30:15:15 kg NPK ha^{-1}) and 75% (45:22.5:22.5 kg NPK ha^{-1}) RDF alone.

Mehdi and Singh (2007) conducted from a field experiment on the study the growth and yield attributes of Indian mustard (*Brassica juncea*) under various levels of sulfur (0, 20, 40, 60 and 80 kg/ha) during the winter season of 2002-03, on magnetic alluvial soil, in Uttar Pradesh, India. Sulfur fertilization significantly increased the growth attributes, i.e. plant height, dry matter, leaf area index, relative growth rate (at initial vegetative growth stage), primary and secondary branches. Marked improvement was also observed in all yield contributing characters, i.e. 1000-seed weight, seed weight per plant, number of siliquae per plant, siliqua length, seed and straw yield as a result of S application up to 40 kg/ha. Seeds per siliqua and harvest index were improved with application of only 20 kg S/ha. Thus, to obtain higher growth and seed yield of Indian mustard under subtropical western tract of Uttar Pradesh, application of 40 kg S/ha together with recommended doses of other major nutrients was found to be the most appropriate fertilizer combination.

A field experiment was conducted by Reager *et al.* (2006) to determine the effect of N levels and its split application on yield attributes and yield of Indian mustard during the winter season of 2002/03 and 2003/04. The increasing levels of N from 40 to 100 kg/ha significantly enhanced siliquae per plant, seeds per siliqua, siliqua length, test weight, seed yield and NPK uptake of Indian mustard. However, significant increase in stover and biological yields was recorded up to 120 kg N/ha. Further, application of one-third N as basal, one-third at first irrigation, one-third at second irrigation being statistically at par with half basal, one-fourth at first irrigation, one-fourth at second irrigation brought a substantial improvement in siliquae per plant, seeds per siliqua, siliqua length, test weight, seed, stover and biological yield and NPK uptake compared to 2 equal splits, namely half at basal, half at first irrigation, days after planting basal, half of rest at first irrigation, half rest at second irrigation and 100% basal.

Bhat *et al.* (2006) conducted from a field experiment to study the effects of 3 rates of nitrogen and phosphorus combinations, i.e. 60 kg N, 30kg P/ha, 80 kg N, 40 kg P/ha and 100 kg N, 50 kg P/ha on the growth, yield and quality of mustard (*Brassica juncea*) cultivars Pusa Gold and Kranti. Application 100 kg N, 50 kg P/ha significantly improved all the parameters measured compared to the other treatments. Higher fertilizer rates also resulted in a significant increase in number of siliqua per plant, length of siliqua and number of seeds per siliqua, which consequently resulted in a marked increase in harvest index and seed yield of both the cultivars. Application of 100 kg N, 50 kg P/ha also resulted in an over all increase in leaf N, P and K contents and seed protein content. Oil content decreased with increasing N and P rates, although the extent of decrease in seed oil content was lower than the increase in seed yield and thus the total edible oil production was still higher with higher fertilizer rates compared to the normal recommended rates of the fertilizer.

Fodor and Kadlicsko (2006) conducted in Hungary in 2003 to determine the effects of NPK fertilizer application (40:40:30 kg NPK/ha, 80:60:30 kg NPK/ha, 120:80:30 kg NPK/ha, and 80:60:30 kg NPK/ha and liming (0, 1.0 and 4.5 t/ha) on the growth of white mustard (*Sinapis alba*) cultivars Budakalaszi Sarga and Tilney. Because of lack of precipitation and unusual drought in the vegetation period, the effect of fertilizer application and liming was influenced unfavorably in the experiment. Only the differences between two cultivars could be observed in the beginning of the growing season. The effects of different NPK rates on the stand development could be observed at the end of flowering and at the beginning of seed formation. The increasing N and P supply increased the yield of both cultivars on the lime-treated and untreated plots. Mikramid foliar fertilizer resulted in grain yield excess only on plots not treated with lime. Liming improved the efficiency of NPK fertilizer supply. Budakalaszi Sarga recorded higher grain yield than Tilney. The positive effect of liming on the yield information was observed but was not proved statistically. Increasing the fertilizer rates of nutrient treatments resulted in significant yield excess.

Hamlin and Barker (2006) conducted an experiment to determine the effects of Zn supple and different molar ratios of NH_4^+ to NO_3^- on growth and Zn accumulation in Indian mustard accession 182921. The treatments comprised: 0.05 and 4.0 mg Zn/L; N with different molar percentage ratios of NH_4^+ to NO_3^- (0:100, 10:90, 20:80, 30:70, 40:60 and 50:50). Supplementing high proportions of NO_3^- in the nutrient medium stimulated Zn accumulation, whereas increasing proportions of NH_4^+ (up to 80% of the total N) enhanced shoot growth. The pH of the nutrient solutions generally decreased with increasing proportion of NH_4^+ in solutions and with increased Zn supply. The Zn photo-extraction potential of Indian mustard was maximized, at approximately 15 mg Zn per plant, if plants received 10% of the total N as NH_4^+ and 90% as NO_3^-.

Raju and Sinsinwar (2006) conducted that during the winter (rabi) seasons of 2001-02 and 2002-03 in Sewar, Bharatpur, Rajasthan, India, on sandy-loam soil to study the effect of integrated nutrient management on the growth, yield, oil content and nutrient uptake by Indian mustard (*Brassica juncea* cv. RH-30) under 2 levels of farmyard manures (2.5 and 5 t/ha) and inorganic N (0, 40 and 80 kg/ha) in combination with *Azotobacter chroococcum* and *Azospirillum* as biofertilizers. The number of branches, 1000-seed weight, and oil content of Indian mustard, and yields of seed and straw increased significantly with the application of farmyard manure at 5 t/ha, *Azotobacter chroococcum, Azospirillum* over the control. The application of nitrogen resulted in a linear increase in the aforementioned parameters up to 80 kg/ha.

Mohammad and Naseem (2006) observed in a sand culture experiment on mustard (*Brassica juncea* L. Czern. & Coss) cv. Varuna, all tested characteristics at 60 days stage and yield characteristics at harvest were enhanced by K application as its levels increased from 5 to 10, 15, 20, 25, and 30 mm K, with 20 mm K proving best.

Dinesh *et al.* (2006) conducted a field experiment during the rabi season of 1997-98 in Varanasi, Uttar Pradesh, India, to study the growth and nutrient uptake patterns of Indian mustard (*Brassica juncea*) at various levels of N, P and S. Plant height and primary branches per plant increased significantly up to 80 kg N/ha, while secondary branches, dry matter per plant and leaf chlorophyll content increased up to 120 kg N/ha. Application of P up to 60 kg/ha significantly enhanced dry matter per plant. On the other hand, plant height, branches per plant and leaf chlorophyll content increased significantly only up to 40 kg P/ha. All growth attributes increased significantly only up to 40 kg S/ha. The results showed that the uptake of NPK and S by both seed and stover increased significantly with successive increase in nitrogen levels up to 120 kg N/ha, sulfur levels up to 60 kg S/ha, and phosphorus levels up to 60 kg P/ha.

Rao *et al.* (2006) observed a field experiment during rabi 2001-02, on clay loam soils, in Bapatla, Andhra Pradesh, India, to evaluate the response of mustard to zinc (0.5% zinc sulfate), boron (1.0 ppm borax) and molybdenum (0.1% ammonium molybdate) application in addition to the recommended NPK and FYM alone. Data were recorded for dry matter production at harvest, number of siliquae per plant, number of seeds per siliquae, 1000-seed weight, seed yield, stover yield and harvest index. Zn, B, Mo gave the highest values for most yield attributes, closely followed by B, Mo. However, B, Mo recorded the highest 1000-seed weight and seed yield, accounting for 24% increase over the recommended NPK and 56% increase over FYM alone.

Issa and Sharma (2006) conducted a field experiment during the winter season of 2003/04 and 2004/05 in New Delhi , India to the study the effect of 4 levels (0, 15, 30 and 45 kg S per ha) of sulfur on yield attributes, yield and quality of Indian mustard. Yield attributes, seed and straw yields, oil content and oil yield, and sulfur content and uptake in both seed and straw increased significantly with increasing level of sulfur up to 45 kg S per ha. S at 15, 30, 45 kg per ha increased seed yield over the control by 9, 16, and 23%; oil yield by 13, 22, and 33%; and sulfur uptake by 25, 48 and 65%, respectively.

content of seeds increased up to 32.5 kg S/ha. The mean value of recovery on added S varied from 13.8 to 21.6%. S use efficiency was higher with the lower rate of S. [1 quintal=100 kg].

Li Juan *et al.* (2005) carried out and investigation on the effects of N (at 10.3, 100, 200 and 300 kg/hm^2) and S (at 0 and 50 kg/hm^2) on the growth and nutritional quality of 2 cultivars (Xuelihong and Baobao Qingcai) of leaf mustard (*Brassica juncea*). Increasing N application increased the shoot height, shoot fresh mass, yield as well as contents of chlorophyll, beta -carotene, free amino acids, total N and S in shoots of both cultivars, and nitrate content in Xuelihong, but decreased the dry matter and soluble sugar contents in both cultivars. The soluble protein content in the 2 cultivars was significantly increased when 100 kg N/hm^2 was applied. The nitrate content in Baobao Qingcai was not significantly affected by increasing N application when KCl was applied; however, it increased significantly when K and S were applied. S application significantly increased the soluble protein content in Xuelihong, the nitrate content in Baobao Qingcai and the shoot S content in both cultivars.

A field experiment was conducted by Ghadge *et al.* (2005) to study the effect of irrigation, phosphorus and sulfur on the uptake and availability of sulfur (S), nitrogen (N) and phosphorus (P) in Akola, Maharashtra, India, during the 2001/02 rabi season. Five irrigations applied at pre-sowing and at 0.60 IW: CPE ratio recorded the highest S, P and N content in the seed and straw. After harvest, the S, N and P contents in the soil were

Mehdi *et al.* (2006) observed an experiment that when Indian mustard plants were supplied with 20, 40, 60 and 80 kg S per ha in Uttar Pradesh, India during the rabi season of 2002-03 nitrogen and sulfur uptake increased with the growth of the crop but increased with increasing rates of sulfur during harvest. Seed oil content and yield, and protein yield increased with increasing rates of sulfur, whereas sulfur and protein contents of the seeds increased with increasing rates of sulfur up to 60 kg per ha and decreased thereafter.

Jahangir *et al.* (2005) conducted a study in Dhaka, Bangladesh during the winter season of 2002 to investigate the effects of S (0, 10, 20 and 30 kg/ha) on the growth, yield and nutrient content and oil quality of mustard [*Brassica juncea*] cv. Sonali. Seed yield and oil content increased with increasing rate of S. N, P and S contents of seed and straw varied with the treatments. The specific gravity, refractive index, moisture and acid value did not show variation with the treatments.

Ramesh *et al.* (2005) revealed an experiment in Haryana, India, during the rabi seasons of 2002-03 and 2003-04 to study the effects of S application on the yield attributes, seed yield, S uptake, and seed oil content of Indian mustard (cv. RH-30). Four levels of S (0.0, 32.5, 65.0 and 97.5 kg/ha) were applied through gypsum. S application significantly increased the number of primary branches, number of siliquae per plant, length of siliqua, and 1000-seed weight. Optimum seed yield (14.9 quintal/ha) was obtained with the application of 65.0 kg S/ha. S application also increased the stover and total dry matter yields. The application of S up to 97.5 kg/ha increased the S uptake by seeds. The oil highest with 3 irrigations applied at pre-sowing and at the flowering and grain filling stages (55 and 70 days after sowing, respectively).

Dongarkar *et al.* (2005) conducted a field experiment at Nagpur, Maharashtra, India, during the rabi season of 2003-2004 to study the effect of four levels of nitrogen (0, 25, 50, 75 kg ha^{-1}) and three levels of sulfur (0, 20, 40 kg ha^{-1}) on growth, yield attributes and yield of mustard (*Brassica juncea*). The application of nitrogen and sulfur significantly influenced the growth and yield of mustard. Plant height, number of branches, dry matter production, number of siliquae, test weight and seed yield were significantly superior with the application of 75 kg N ha^{-1} over 25 kg N ha^{-1} and control but at par with 50 kg N ha^{-1} and 40 kg S ha^{-1} over 20 kg S ha^{-1} and control. The interaction effect of nitrogen and sulfur levels at 75 kg N, 40 kg S ha^{-1} in respect to number of siliquae per plant, seed yield per plant and seed yield ha^{-1} was found significantly superior.

A field experiment was conducted by Manoj *et al.* (2005) in India to evaluate the effect of saline water irrigation and phosphorus levels (0, 20, 40, 60 kg P_2O_5/ha) on phosphorus content and uptake of mustard cv. RH30. The saline irrigation treatments in the main plots consisted of four combinations of non-saline water (two irrigations with non-saline water, first non-saline and saline irrigation, first saline and second non-saline irrigation and two irrigations with saline water). Phosphorus uptake was highest under non-saline irrigation than that of other saline irrigation. Application of 60 kg P_2O_5/ha recorded the highest total phosphorus uptake. Among the mustard constituents, seed had the maximum uptake of phosphorus followed by husk and straw.

Rana *et al.* (2005) revealed an experiment during the 2001-03 winter seasons in New Delhi, India, to study the effects of 3 phosphorus levels (0, 25 and 50 kg P_2O_5/ha), 3 sulfur levels (0, 20 and 40 kg S/ha) and 2 boron levels (control and 0.2% spray of borax at 50% flowering) on rain fed Indian mustard (*Brassica juncea* cv. Pusa Barani). Progressive increase in P and S levels increased the yield attributes and seed yield, but the increase in seed yield was significant only up to 25 kg P_2O_5/ha and 20 kg S/ha. Indian mustard removed more S than P. Owing to P and S levels, P, S and B uptake was significant only up to 25 kg P_2O_5 and 20 kg S/ha. The seed yield response to tested levels of P and S was quadratic. Based on the response equation, optimum dose of P_2O_5, response/kg P and returns/reinvestment on P_2O_5 were 45.4 kg P_2O_5/ha, 10.8 kg and Rs 4.82, respectively. Corresponding figures for S application were 30.9 kg S/ha, 13.3 kg seed/kg S and Rs. 5.63/reinvestment on S. Net returns were maximum with 50 kg P_2O_5/ha (Rs. 19.214/ha) and 40 kg S/ha (Rs. 17.664/ha), whereas benefit: cost ratio was highest with 25 kg P_2O_5 (3.30) and 20 kg S/ha (3.35). Boron application also recorded a marked improvement in seed yield (10.6%), uptake of P (8.3%), S (7.30%) and B (14.3%), and net returns (13.9%) and benefit: cost ratio (4.8%).

A field experiment was evaluated by Dinesh *et al.* (2005) in Varanasi, Uttar Pradesh, India, during the rabi seasons of 1997-98 and 1998-99 to study the effect of N (at 40, 80 and 120 kg/ha), P (at 20, 40 and 60 kg/ha) and S (at 20, 40 and 60 kg/ha) on yield and yield attributes of Indian mustard. Siliquae per plant, siliqua length and seed yield per plant increased significantly up to 120 kg N/ha and seeds per siliqua and 1000-seed weight up to 80 kg N/ha. The seed yield increased significantly up to 120 kg N/ha, whereas the harvest index only up to 80 kg N/ha. The yield attributes and yields increased significantly with the increasing levels of P and S up to 40 kg/ha. A non-significant effect on harvest index was recorded with the application of P and S.

A field experiment was conducted by Yadav *et al.* (2005) during the rabi seasons of 2001-02 and 2002-03 in Bawal, Haryana, India to determine the P and S requirements of Indian mustard on a light-textured soil deficient in these nutrients and to compare the sources of P and S, i.e. Diammonium Phosphate (DAP) and gypsum (1/2),elemental S (1/2), with a new multi-nutrient Cargill product (13:33:0:15% N:P:K:S). Three levels of P (0, 33 and 66 kg/ha) and S (0, 15 and 30 kg/ha) were used. The highest seed yield of 24.51 and 21.25 q/ha was recorded with basal application of 66 kg P/ha (through DAP) and 30 kg S (through 1/2 gypsum, 1/2 elemental S), which was at par with yield of 23.86 and 21.11 q/ha obtained with basal application of 66 kg P/ha and 30 kg S/ha applied both through the new multi-nutrient Cargill product during 2001-02 and 2002-03, respectively. Growth and yield attributes also responded in a similar manner. Hence, both the sources of P and S were equally efficient in respect of yield parameters and yield.

Firoz *et al.* (2005) observed an experiment on the effect of basal N (80 and 60 kg/ha) and P (28 and 30 kg/ha) with and without supplemental foliar N (0 and 20 kg/ha), P (0 and 2 kg/ha) and S (0 and 2 kg/ha) on yield characteristics and fatty acid composition of oil of *Brassica juncea* cv. Rohini was studied in a two-year field experiment in Aligarh, India. The data revealed that, of the six treatments, inclusion of N, P and S in the spray, particularly in the form of commercial grade fertilizers, had a significant ameliorating effect on all yield characteristics as well as erucic acid content of the oil.

Singh and Vinay (2005) laid out an experiment at Bichpuri, Uttar Pradesh, India during winter season of 2000-02 to study the response of Indian mustard (*Brassica juncea* cv. Rohini) to different levels of nitrogen (0, 40, 80 and 120 kg/ha), sulfur (0, 20, 40 and 60 kg/ha) and zinc (0 and 5 kg/ha). The seed yield of Indian mustard significantly increased with increasing levels of applied N, S and Zn. Nitrogen application increased the mean seed yield by 36.2%, but decreased the oil content by 0.5% from the control. Sulfur application increased the mean seed yield and oil content by 35.6 and 6.3% and zinc application increased 12.0 and 0.7%, respectively over the control. Nitrogen, S and Zn application increased significantly the protein content in seeds.

Dharam and Phogat (2005) conducted a field experiment that during 2000-2001 at the research farm of the CCS Haryana Agricultural University, Hisar, Haryana, India, to investigate the effect of deep tillage and application of gypsum (as source of S) in a S-deficient sandy loam soil (Haplustepts) with a plough sole on N, P, K and S uptake by mustard (*Brassica juncea*). The tillage treatments consisted of conventional tillage comprising one dicing to 10 cm depth and one run of a cultivator followed by planking; and deep tillage with disc plough comprising 20-25 cm sub soiling followed by CT. The gypsum treatments, consisting of control and application of gypsum at 250 kg/ha, i.e., 45 kg S/ha were superimposed on the tillage treatments. Deep tillage and gypsum application showed significantly increase N, P, K and S content of grain and straw. The interactive effect of tillage and gypsum on the concentration of these nutrients was not significant, except on the S content in straw. The concentration of these nutrients in grain and straw was highest in deep tillage gypsum followed by deep tillage and conventional tillage gypsum treatment and least in the conventional tillage treatment. Results revealed that when a sandy loam soil having plough sole at 15-20 cm depth was deep-ploughed, the yield of mustard was increased by 0.28 t/ha, which was further increased by 0.34 t/ha upon application of gypsum at 250 kg/ha.

Saxena *et al.* (2005) conducted an experiment during the rabi season of 2002-03 in Uttar Pradesh, India to determine the effects of phosphorus and iron on the growth, yield and oil content of Indian mustard (*Brassica juncea*) cv. Varuna at 30, 60, 90 and 120 days after sowing (DAS). Treatments comprised: 0 and 40 kg P/ha; and 0, 15 and 30 kg Fe/ha. Treatment with 40 kg P/ha recorded higher leaf area per plant, chlorophyll content, dry matter per plant, number of branches per plant, siliquae per plant, seed yield per plant and oil content than treatment without P. Dry matter accumulation increased as time progressed. Iron promoted leaf area index, chlorophyll content, dry matter at 60, 90 and 120 DAS, branches and seed yield per plant, while siliquae per plant, oil percentage and dry matter at 30 DAS were not significantly affected. There was no marked distinction between 15 and 30 kg Fe/ha, although both were superior to the control (0 kg Fe/ha). Interaction effect of phosphorus and iron was not significant.

An experiment was conducted by Singh and Singh (2005) to study the effects of irrigation level (irrigation at 30 days after sowing or DAS, irrigation at 30 and 60 DAS, or irrigation at 30, 60 and 90 DAS) and NPK rate (0:0:0, 30:20:15, 60:40:30 or 90:60:45 kg/ha) on the incidence of downy mildew disease (caused by *Peronospora parasitica*) and on the performance of Indian mustard (cv. Varuna) were studied in Kumarganj, Faizabad, Uttar Pradesh, India, during 1993-94. N, P and K were supplied as urea, single super phosphate and muriate of potash, respectively. The increase in irrigation level and NPK rate increased the disease incidence and the yield of Indian mustard. The highest grain yields were obtained with irrigation at 30, 60 and 90 DAS (9.18 quintal/ha), and with the application of NPK at 90:60:45 kg/ha (10.94 quintal/ha). The lowest percent disease incidence on leaves (8.04%) was obtained with irrigation at 30 DAS. Among the fertilizer treatments, downy mildew incidence on cotyledons (10.24%) and leaves (5.41%) was lowest when NPK was applied at 0:0:0 kg/ha.

An experiment was obtained by Rajiv *et al.* (2005) in Haryana, India to study the effects of salinity (0, 8 or 12 ds/m) and the use of phosphorus (20, 40 and 60 kg/ha) and sulfur fertilizers (10, 20 and 30 kg/ha) and their combinations to mitigate salinity effects on various physiological characteristics of *Brassica juncea* cv. RH-30. Under saline conditions, plant height and dry weight of leaves declined compared to the non-saline control. Fertilizers applied in combined form (60 kg P/ha, 30 kg S/ha) exhibited the maximum alleviation of the adverse effects of salinity. Salt stress showed significant reduction in plant water status in terms of relative water content, leaf water potential and leaf osmotic potential. Application of both P and S improved the water status but the highest Sulphur level (30 kg/ha) showed the poorest response. Yield and its attributes (number of siliqua per plant, test weight, number of seeds per siliqua) were adversely affected by salinity. Both P and S fertilizers individually improved the yield under saline conditions up to some extent however the combination of two fertilizers proved better in reviving the yield characters. The mean seed yield was highest with the highest rates of P and S (1.82 g/plant).

Nepalia (2005) conducted a field experiment during the 1993/94 and 1994/95 winter seasons, at Udaipur, Rajasthan, India, to determined the impact of herbicidal weed control on the growth, productivity and economics of mustard (*Brassica juncea*). The treatments comprised: weedy check, oxidized (0.5 kg/ha), oxyfluorfen (0.125 kg/ha), pendimethalin (0.75 kg/ha), isoproturon (0.5 kg/ha), hand-weeding 30 days after sowing (DAS) and four levels of sulfur (0, 30, 60 and 90 kg/ha). The herbicides were sprayed as pre-emergence treatments 1 DAS. Pre-emergence application of oxidizer proved superior in increasing the growth and yield of mustard. Hand weeding, oxyfluorfen and pendimethalin also gave satisfactory results. Application of sulfur up to 60 kg/ha significantly increased crop dry matter, leaf area index and productivity of mustard.

Kumar and Singh (2003) carried out an experiment during two rabi seasons (1989/90 and 1990/01) in Patna, Bihar, India, to study the effect of sowing date (20-25 October, 5-15 November and 20-25 November), row spacing (20, 30 and 40 cm) and N rate (0-50, 100 and 150 kg/ha) on seed yield of Indian mustard (*Brassica juncea*) cv. Varuna. There was a significant decrease in seed yield with the advancement of sowing date. The maximum seed yield was obtained from 20-25 October-sown crop (1735 kg/ha). Significantly highest yield of 1617 kg/ha was obtained from 150 kg N/ha treatment. The closest spacing (20 cm) recorded the highest seed yield of 1342.90 kg/ha. Interaction of sowing date x row spacing x N was found significant and the maximum yield (24.51 q/ha) was obtained from 20-25 October-sown crop with 40 cm row spacing and supplied with 150 kg N/ha.

Lanjewar and Selukar (2005) observed a field experiment to evaluate the effect of application of sulfur at 0, 20,40 and 60 kg ha^{-1} and phosphorus at 30, 40, 50 kg ha^{-1} on nutrient uptake of mustard on Verticals in a farm at the Department of Agronomy, College of Agriculture, Nagpur, Maharashtra, India. It was found that increasing application of phosphorus and sulfur significantly increased the nutrient uptake and content of P and S up to 50 kg P_2O_5 and 60 kg S ha^{-1}. 50 kg P_2O_5 ha^{-1} proved most superior over rest of the P_2O_5 levels in case of uptake of N, P and K. Similarly, 60 kg S ha^{-1} was better than 20 kg S ha^{-1} in these respects. Thus, 50 kg P_2O_5 and 60 kg S followed by 40 kg S ha^{-1} appears to be appropriate doses to increase the uptake. But for yield, only 50 kg P_2O_5 ha^{-1} and 60 kg S ha^{-1} appeared most superior.

Bandopadhy and Bose (2004) conducted an experiment to determine the effects of irrigation and phosphorus fertilizer on Indian mustard cv. B-85 during the rabi season of 2002 on sandy loam soil in West Bengal, India. Treatments comprised: three P rates (0, 40 and 80 kg/ha) along with constant N and K rates (60 and 30 kg/ha, respectively); and four irrigation levels (no irrigation, one irrigation at branching stage, two irrigations at branching and flowering stages, and three irrigations at branching, flowering and siliqua development stages). Phosphorus application increased the oil content. Increasing irrigation level gradually increased the oil content. No significant differences in crop growth rates due to increase in irrigation level were observed, except at 45-60 days after sowing. The highest crop growth rate was recorded upon treatment with three irrigations, and with 80 kg P/ha concentration at 45-60 days after sowing. At all irrigation levels, phosphorus significantly increased seed yield over the control, except in twice irrigation, 80 kg P/ha treatment combination.

Tiwari *et al.* (2004) conducted a field experiment during the rabi of 2000-01 and 2001-02 under rain fed condition of Kymore plateaux and Satpura hill agro climatic zone in Madhya Pradesh, India, to study the effects of nitrogen (0, 40, 60, 80 or 100 kg/ha) and sulfur (0, 60, 80 or 100 kg/ha) on the leaf chlorophyll content of Indian mustard (cv. Pusa Bold). The soil application of nitrogen and sulfur up to 100 and 60 kg/ha, respectively, singly or in combination resulted in the highest chlorophyll a, chlorophyll b and total chlorophyll concentrations in Indian mustard leaves. However, the chlorophyll a/b ratio was highest when additional nitrogen and sulfur were not applied to the soil.

Jakhar and Singh (2004) laid out a field experiment that the agronomy farm of the SKN College of Agriculture, Jobner, Jaipur, Rajasthan, India, during the rabi seasons of 2000-01 and 2001-02 to study the residual influence of graded levels of FYM (0, 5 and 10 tones ha^{-1}) phosphorus (0, 20, 40 and 60 kg P ha^{-1}) and zinc (0, 5 and 10 kg Zn ha^{-1}) on growth, yield and quality of mustard (*Brassica juncea*). The pooled mean plant height, number of siliquae per plant, test weight, seed and stover yield, protein and oil content and oil yield increased significantly due to the residual effect of 10 t FYM ha^{-1} Residual effect of 40 kg P ha^{-1} significantly increased the pooled mean plant height, number of siliquae per plant, test weight, seed yield, stover yield. 10 kg Zn ha^{-1} which was applied to preceding crop, recorded perceptible improvement in plant height, number of siliquae per plant, test weight, seed and stover yields, protein and oil content and oil yield.

A field experiment was conducted by Maurya *et al.* (2004) in Bahraich, Uttar Pradesh, India, during the 2000/01 and 2001/02 winter seasons to study the effect of N fertilizer (0, 50, 100 and 150 kg/ha) on high-yielding Indian mustard cultivars Vardan, Varuna and Pusa Bold. Pusa Bold, 150 kg N/ha gave the highest germination percentage while Vardan, 150 kg N/ha gave the maximum plant height, number of branches per plant, number of siliqua per plant, number of grains per plant, 1000-grain weight, grain yield and straw yield.

Bhartendu and Gajendra (2004) revealed a field experiment during the rainy and winter seasons of 2001-02 and 2002-03 in New Delhi, India. The treatments consisted of 6 practices in preceding season, i.e. maize cv. Ganga Safes 2 (Navjot), sunflower hybrid Paras (MSFH 1051) and urban (*Phaseolus mungo* [*Vigna mungo*] cv. T 9) grown with and without fertilizer and 4 levels of fertilizer (control, 40 kg P_2O_5; 40 kg N, 40 kg P_2O_5 and 80 kg N, 40 kg P_2O_5). The 3 crops were grown on 19 June and 15 July during 2001-02 and 2002-03, respectively. The 3 crops were supplied with the recommended dose of 120 kg N, 50 kg P_2O_5; 60 kg N, 40 kg P_2O_5 and 20 kg N, 50 kg P_2O_5/ha. In subsequent winter season, Indian mustard cv. Pusa Jagannath was sown on 20 and 30 October in respective season. Fertilization of maize, sunflower and urban increased the seed or grain yield of the 3 crops by 31, 54 and 38%, respectively. The direct application of N and P to Indian mustard also enhanced the growth and seed and oil yields. On an average, 46, 28 and 11% increase in seed yield was recorded owing to application of 80 kg N, 40 kg P_2O_5 over the control, 40 kg P_2O_5 and 40 kg N, 40 kg P_2O_5, respectively. However, oil content of Indian mustard decreased significantly due to fertilization of preceding crops and direct application of N and P to mustard crop.

Jagvir *et al.* (2004) conducted field experiments to study the direct and residual effects of sulfur (S) application in cotton-mustard cropping system during the kharif and rabi seasons of 1998/99 and 1999/2000, in Sirsa, Haryana, India. Cotton dry matter and seed yield, mustard stover and seed yield, and S and protein contents in seeds of both crops increased significantly with the application of recommended NPK with S at 30 kg/ha applied to both crops over NPK alone (no sulfur). Pooled data revealed significant increases in seed cotton (22.5%), mustard seed (31.4%), protein content in seeds of cotton (4%) and mustard (3.4%) and oil content in mustard seed (5.3%) by the application of NPK with S over NPK alone to both the crops. Yield and yield components of mustard were also increased by residual S applied in the preceding crop. However, marginal increase in oil content of cotton seed was observed by S application. Monetary gross returns calculated on mean yield basis indicated higher values of returns in treatments NPK, S where S was applied to both crops.

Birbal *et al.* (2004) conducted two field experiments during the 1996/97 and 1997/98 winter seasons in Jabalpur, Madhya Pradesh, India to determine the effects of S fertilizer rates (0, 20, 40 and 60 kg per ha) on the yield and yield components of Indian mustard cv. Pusa Bold. S at 60 kg/ha S gave the maximum plant height, number of primary branches, leaf area index at 60 days after sowing, siliquae per plant, seeds per siliqua, 1000-seed weight, grain yield and stalk yield. The highest net monetary returns and benefit: cost ratio were obtained with 40 kg/ha S.

A field experiment was conducted by Hidyatulah *et al.* (2004) during rabi 2000 in Uttar Pradesh, India to study the effect of 4 levels of sulfur (0, 7, 14 and 21 kg per ha) on the growth, yield and biochemical parameters of Indian mustard (*Brassica juncea*). Application of sulfur produced a significantly consistent increase in number of siliqua per plant, seed yield and oil content of mustard with increasing levels of sulfur up to 21 kg per ha, whereas 1000-seed weight and number of seeds per siliqua showed significant improvement with sulfur application only up to 14 kg/ha. Plant height and seed protein content did not respond to the sulfur application.

Jakubus (2004) evaluated a field experiment to the effects of sulfur application on the sulfur content of white mustard in a pot experiment with elusive soil. Samples of plants and soil were collected at 4 stages of plant development. The application of sulfur to the soil resulted in a slightly greater increase in dry matter of green tops over the control (without sulfur application). The concentrations of sulfur in plants and in the soil significantly varied during the growth period. The total sulfur concentration in plants treated with sulfur varied from 5.08 g/kg at the first developmental stage to 10.93 g/kg in seeds. Among the forms of soil sulfur, the greatest fluctuations were recorded for sulfate and available sulfur. However, changes in all forms of sulfur during the growth period were similar regardless of the sulfur extraction method and quantitative differences.

A field experiment was conducted by Ruchi *et al.* (2004) in Pantnagar, Uttar Pradesh, India, to study the effect of nitrogen (60, 90 and 120 kg N/ha) and sulfur (0 and 40 kg S/ha) on the incidence of Sclerotinia rot (*Sclerotinia sclerotiorum*) on mustard (*Brassica juncea* cultivars Kranti and TERI M-21). Recommended rates of P, K and S were applied as basal and the remaining N was applied as top dressing after the first irrigation. Results showed that increasing the level of N (60-90 kg/ha) in soil led to the significant increase in disease incidence (from 26.3 to 37.7%). However, the disease incidence was reduced at the highest level of N (120 kg/ha). S decreased the disease incidence (from 33.0 to 24.1%) when applied at 40 kg/ha. The combination 120 kg N/ha and 40 kg S/ha significantly reduced the disease incidence. Kranti showed lower disease incidence than TERI M-21. The interaction among cultivars, nitrogen and sulfur was not significant.

An experiment was observed by Thanki *et al.* (2004) in Indian mustard cv. Gujarat Mustard plants were supplied with 25, 50 or 70 kg N/ha, 0, 25 or 50 kg P/ha and 0 or 10 kg farmyard manure/ha in a field experiment conducted in Gujarat, India during the rabi seasons of 1995-98. Plant height, number of branches per plant, number of siliqua per plant, 1000-seed weight, seed yield, oil yield and net returns increased, whereas oil content decreased with increasing rates of N. The values for all the parameters measured were highest with the application of 50 kg P/ha and 10 kg farmyard manure/ha. N, P and K uptake increased with increasing rates of N, P and farmyard manure rates.

Shah *et al.* (2004) conducted an experiment in Tandojam, Pakistan, to investigate the effect of NP combinations (0:0, 50:15, 75:30, 100:45, 125:60 and 150:75 kg/ha) on yield and oil content of Indian mustard cultivars Early Raya, P-53/48-2 and S-9. Pods per plant, seeds per pod, seed yield and oil content percentage was highly significantly affected by cultivars, NP levels and their interactions. Both yield contributing traits and oil content increased with increasing NP levels, and were maximum with the highest NP combination (150:75 kg/ha). The highest seed yield (1820.10 kg/ha) and oil content (43.50%) at this NP level were recorded from S-9 and Early Raya, respectively.

Singh *et al.* (2004) conducted an experiment in Bikaner, Rajasthan, India, during winter season of 1999-2000 to study the response of Indian mustard cv. T-59 to nitrogen and sulfur rates. Treatments comprised: five nitrogen levels (0, 30, 60, 90 and 120 kg/ha) and four sulfur levels (0, 20, 40 and 60 kg/ha). Nitrogen application did not affect the oil content in mustard but oil yield and chlorophyll content were increased up to 90 kg N/ha over the control. Nitrogen application increased the seed yield of mustard. Nitrogen and sulfur content both in seed and straw and total N and S uptake enhanced due to application of 90 kg N/ha over its preceding rates. The increased nitrogen and sulfur content enhanced the total uptake of nitrogen and sulfur. Sulfur fertilizer application at 20 kg/ha increased oil content in mustard over the control. Oil yield and chlorophyll content were enhanced up to 40 kg S/ha.

Amar and Meena (2004) evaluated a field experiment during the winter season of 1996/97 and 1997/98 in Rajasthan, India to study the effect of N and S on seed yield, plant height, primary and secondary branches and dry-matter accumulation of Indian mustard (*Brassica juncea*). Nitrogen at 80 kg/ha, S at 60 kg/ha significantly increased siliquae per plant, seeds per siliqua, length of siliqua and test weight of seeds and also resulted in highest seed (2109 kg/ha) yield on pooled basis. On pooled basis, optimum dose of N and S was 88.24 and 74.86 kg/ha respectively. N at 80 kg/ha resulted in net income and benefit: cost ratio of Rs. 15.799/ha and 2.69, respectively, during the first year and Rs. 18M 193/ha and 2.87 during the second year. Sulfur at 60 kg/ha gave a net income of Rs. 14.774/ha and benefit: cost ratio 2.95 during the first year and Rs. 17.058/ha and 2.76 during the second year. The increase in N uptake under 40, 60, and 80 kg N/ha was 30, 57 and 74% respectively, over the control (20 kg N/ha), whereas it was 17, 28 and 34% under 20, 40 and 60 kg S/ha. Content (%) of N and S, in seed stalk increased with the increase in N and S levels. The residual available N and S also improved with the increasing N and S application.

A field experiment were conducted by Sharma and Singh (2003) in Udaipur, Rajasthan, India, during the winter of 1998/99 and 1999/2000 to study the effect of weed management (hand weeding at 30 days after sowing, or application of 1.0 kg fluchloralin, 0.75 kg pendimethalin, 1.5 kg alcohol or 0.125 kg oxyfluorfen/ha) and phosphorus levels (0, 8.8, 17.6 and 26.4 kg/ha through Diammonium Phosphate) on the yield and quality of Indian mustard (cv. Pusa Bold). The weed management practices significantly increased the yield attributes (number of siliquae per plant, number of seeds per siliqua, siliqua length, seed weight per plant and 1000-seed weight) and yield of Indian mustard over the control. Weed management practices increased the seed yield of Indian mustard by 54-80% over the weedy control (11.42 quintal/ha). Among the weed management treatments, oxyfluorfen gave the highest seed yield (21.04 and 20.10 quintal/ha during 1998/99 and 1999/2000, respectively); this treatment was superior to the other treatments except pendimethalin. The increase in the rate of P from 0 to 17.6 kg/ha significantly increased the yield attributes, seed oil and protein contents, and stover and biological yields. The application of 17.6 kg P/ha increased the mean seed yield of Indian mustard by 40% over the control (14.29 quintal/ha). [1 quintal=100 kg].

A field experiment was studied by Kamta *et al.* (2003) that the effects of N, P, S and Zn fertilizers on the nutrient uptake, quality and yield of Indian mustard (cv. Vaibhav) in Kanpur, Uttar Pradesh, India, during the rabi seasons of 1997/98 and 1998/99. The treatments consisted of 60 N/ha singly or in combination with 30 kg P, 20 kg S, 5 kg Zn, 30 kg P; 20 kg S, 30 kg P; 5 kg Zn, 20 kg S; 5 kg Zn, or 30 kg P; 20 kg S; 5 kg Zn/ha. N, P, S and Zn were applied through urea, diammonium Phosphate, gypsum and zinc oxide, respectively. The application of 60 kg N, 30 kg P, 20 kg S, 5 kg Zn and 60 kg N, 30 kg P, 20 kg S gave the highest mean stick and straw yield (43.58 and 42.51 quintal/ha), N uptake by seed (35.64 and 34.26 kg/ha) and stover (34.14 and 33.08 kg/ha), P uptake by seed (11.35 and 10.77 kg/ha) and stover (8.72 and 8.47 kg/ha), K uptake by seed (6.04 and 5.85 kg/ha) and stover (54.23 and 52.79 kg/ha), S uptake by seed (16.55 and 15.92 kg/ha), oil content (39.98 and 39.90% in 1997/98 and 39.90 and 39.80% in 1998/99), oil yield (483.0 and 467.05 kg/ha in 1997/98 and 466.02 and 450.46 kg/ha in 1998/99) and seed yield (13.55 and 13.13 quintal/ha). They also stated that N at 30 kg/ha, P at 20 kg/ha, Zn at 5 kg/ha, and N at 60 kg/ha, P at 30 kg/ha, S at 20 kg/ha produced the highest growth, yield and productivity, and also good cost: benefit ratio.

Amar and Meena (2003) conducted a field experiment during the 1996/97 and 1997/98 winter seasons in Bharatpur, Rajasthan, India, to determine the effect of N and S fertilizers on the oil and protein yield of Indian mustard cv. Varuna. The treatments comprised 20, 40, 60, 80 and 100 kg N/ha and 0, 20, 40, 60 and 80 kg S/ha. Pooled analysis of data showed that 40 kg N and 80 kg S/ha gave the highest oil content (39.61 and 39.48%, respectively). N at 80 kg and 80 kg S/ha gave the highest oil yield (774.0 and 721.5 kg/ha, respectively). N at 100 kg/ha gave the highest protein content (20.60%) and protein yield (388.5 kg/ha). S at 80 and 60 kg/ha also gave the highest protein content (19.99%) and protein yield (369.0 kg/ha), respectively. The most profitable rates of N and S during 1996/97 and 1997/98 were 79.08 and 79.83, and 70.08 and 68.65 kg/ha, respectively.

Sihag *et al.* (2003) conducted a field experiment in Bikaner, Rajasthan, India, during the 1998/99 rabi season to determine the combined effect of S fertilizer (0, 25, 50 and 75 kg/ha) and sowing date (15 October, 30 October, 14 November and 29 November) on the yield, yield components and quality of Indian mustard. The highest dry matter accumulation at 90 days of crop growth (31.07 g per plant) and at harvest (42.40 g per plant) was obtained in 15 October-sown crops supplemented with 75 kg S/ha. The highest seed (21.50 q/ha) and oil yields (839.17 kg/ha) were obtained in 15 October-sown crops supplemented with 50 kg S/ha while the highest biological yield (65.23 q/ha) was obtained in 15 October-sown crops supplemented with 75 kg S/ha. The 15-October-sown crops supplemented with 75 kg S/ha also gave the highest N (104.50 kg/ha) and S uptake (10.783 kg/ha).

A field experiment was revealed by Akbari *et al.* (2003) during rabi season of 1988-89 and 1989-1990 to investigate the effect of cationic micronutrients (Zn, Fe, Mn and Cu), sulfur and gypsum on post harvest soil fertility and yield of mustard on red loam soil of Mewar, Rajasthan, India. Treatments include control (with N and P), 5 and 10 ppm each of Zn, Fe, Mn and Cu, 20 and 40 ppm of elemental sulfur and 2 and 4 tones/ha of gypsum. The seed yield of mustard was significantly improved by 10.5, 17.2, 14.5 and 17.9%, respectively, due to application of 10 Zn and Fe ppm, 40 sulfur ppm and 4 tones gypsum/ha as compared to NP fertilizer application. The application of manganese and copper had no significant effect on the yield of mustard. The available status of Zn, Fe, Mn, Cu and S was significantly improved due to application of their respective elements. The availability of all elements, more or less, improved due to gypsum application.

Misra (2003) studied an experiment on mustard crop (cv. Varuna) with four levels each of sulfur (S) (0, 20, 40 and 60 kg S ha^{-1}) and potassium (K) (0, 30, 60 and 90 kg K_2O ha^{-1}) on Udic Haplustepts of Kanpur, Uttar Pradesh, India during rabi seasons of 1998-99 and 1999-2000. Results showed that mustard crop responded significantly to the application of S and K. The seed and stover yields increased in the linear order up to 40 kg S and 60 kg K_2O ha^{-1}. The highest seed yield (20.35 kg ha^{-1}) at 40 kg S ha^{-1} was

27.59% higher in comparison to the yield at control. Similarly, application of 60 kg K_2O ha^{-1} produced highest seed yield (20.85 kg ha^{-1}) which was 35.48% higher in comparison to the yield in control. Sulfur showed synergistic relationship with potassium. The uptake of N, K and S at maturity was significantly affected with treatments. The P uptake significantly increased up to 40 kg S ha^{-1} and thereafter, decreased significantly. Percent utilization of added K and S was maximum when lowest levels of K and S were applied. Oil, protein and total S-amino acid contents increased significantly with the application of S and K. Sulfur and K addition also significantly influenced the fatty acids composition; oleic and linoleic acid contents increased and erucic acid decreased showing improved quality of mustard oil.

Tripathi and Tripathi (2003) conducted an experiment in Uttar Pradesh, India in 1994-95 and 1995-96 to investigate the effects of N levels (80, 120, 160 and 200 kg/ha) on the growth, yield and quality of Indian mustard cv. Varuna. N was applied at 3 equal splits, at sowing, at first irrigation and at 60 days after sowing. Results showed that all the yield characters except number of branches increased with increasing N levels up to 160 kg N/ha, The number of branches per plant increased up to 200 kg N/ha. Net returns were maximum (Rs. 19.901/ha) at 160 kg N/h because seed yield was also maximum at this N rate. The benefit: cost ratio increased up to 160 kg N/ha, with a maximum of Rs. 209 earned per rupee investment.

Singh and Ramkala (2003) observed a screen house pot experiment that to study Zn-S interrelationship in mustard on loamy sand (Ustipsamment) soil with Zn (0, 5, 10, 20 and

40 mg/kg soil) and S (0, 10, 20, 40 and 80 mg/kg). The highest yield was recorded when 40 mg S was applied in combination with 20 mg Zn/kg soil. The concentration of Zn and S increased significantly with their application. The interaction effect of Zn and S was synergistic with the concentration of both the nutrients. The concentration of N and K in mustard increased significantly with both Zn and S. The application of Zn reduced the P content but S increased the concentration of P in mustard significantly.

Abdin *et al.* (2003) reported that the yield and quality of rapeseed-mustard can be optimized with the split application of 40 kg S per ha during the appropriate phonological stages of crop growth and development.

Bharati and Prasad (2003) observed that seed yield, 1000-seed weight and net returns did not significantly vary with the S rate. The application of 45 kg S per ha resulted in the highest oil content (41.84%) and oil yield (0.63 t /ha). The highest dry matter production was found by S uptake for 15 and 30 kg S per ha.

Raut *et al.* (2003) conducted an experiment during the rabi season of 1996-97 in Akola, Maharashtra, India to investigate the effects of irrigation and S on the growth and yield attributes of Indian mustard cv. Pusa Bold. Irrigation treatments were: I_1, irrigation at 50% flowering, seed filling stages; I_2, irrigation at pre-flowering and siliquae setting stage; I_3, irrigation at pre-flowering, 50% flowering, siliquae setting stage; I_4, irrigation at pre-flowering, 50% flowering and seed filling stages; and I_5, irrigation at pre-flowering, 50% flowering, seed filling stage, siliquae setting stage. The Sulphur rates were 0, 20, 40 and 60 kg/ha (S_0, S_1, S_2 and S_3, respectively). The highest siliquae number, seed yield per plant, plant height, branch number, leaf number and leaf area were obtained under S_2. I_4 resulted in the highest number of siliquae per plant and seed yield. I_5 recorded the maximum leaf area ($21.39 dm^2$). The combination of treatments I_4 and S_2 resulted in higher seed yield per plant (17.87 kg/ha) compared to the other treatment combinations.

Om and Singh (2002) reported that the effects of sulfur rate (0, 20, 40, and 60 kg/ha) on Indian mustard cultivars (Varuna, PBM-16, Rohini, and Pusa Bahar) in Agra, Uttar Pradesh, India, during the winter seasons of 1996/97 and 1997/98. Sulfur as gypsum was incorporated into the soil one month before sowing. Pusa Bahar recorded the highest seed yield, weight, protein and oil contents, and total oil yield, whereas Rohini registered the highest number of leaves per plant. The highest number of branches per plant was recorded for Pusa Bahar and Varuna in the first year and for Pusa Bahar in the second year. The number of secondary branches was highest in Pusa Bahar and Varuna in the first year and in Pusa Bahar and Rohini in the second year. The tallest plants were obtained from Pusa Bahar in the first year and from Pusa Bahar, PBM-16, and Rohini in the second year. Seed yield, protein and oil contents and oil yield increased with the increase in sulfur rate up to 40 kg/ha only.

Chauhan *et al.* (2002) carried out a field investigation with Indian mustard (*Brassica juncea* cv. 'RH-30') during the winter seasons of 1995/96 and 1996/97 at Gurgaon, Haryana, India with 2 irrigation treatments and 2 sources (gypsum and single superphosphate) and 3 levels (0, 30 and 60 kg S/ha) of S fertilizer. Irrigation applied at the branching, flowering and grain-filling stages significantly increased the seed yield of Indian mustard over that at the pre-flowering, pod-formation and grain-filling stages. Gypsum proved to be a better source of S than single superphosphate, as the former gave significantly higher seed yield. Increasing S levels significantly improved the growth, yield attributes (plant height, primary branches per plant, siliqua length, siliquae per plant and seeds per siliqua), seed yield and oil content of Indian mustard. The highest seed yield, oil content and net returns were obtained with 60 kg S/ha.

Sandeep *et al.* (2002) revealed that the effects of N (0, 40, 80 or 120 kg/ha) and S (0, 10, 20 or 30 kg/ha) fertilizer rate on the yield and oil content of *B. juncea* cv. Varuna in Lakhaoti, Uttar Pradesh, India during winter of 2000/2001. The yield and oil content generally increased with the increase in N and S rate. N at 120 kg/ha resulted in the highest number of siliquae per plant (397.25), weight of siliquae per plant (33.32 g), number of seeds per siliqua (14.80), seed yield per plant (368.75g), 1000-grain weight (17.33g), seed yield per ha (17.33 quintal) and oil content (38.39%). The application of 30 kg S/ha also gave the highest number of siliquae per plant (360.35), weight of siliquae per plant (28.67g), number of seeds per siliqua (13.72), seed yield per plant (337.17g), 1000-grain weight (4.93g) and seed yield per ha (15.14 quintal). The highest oil contents were obtained with S at 20 (37.89%) and 30 kg/ha (37.95%).

A field experiment was conducted by Varma *et al.* (2002) to determine the effect of different rates of sulfur (15, 30, and 45 kg/ha) and potassium (20, 40, and 60 kg/ha) on yield and oil content of Indian mustard, during 1998-99 and 1999-2000 at Varanasi, India. Sulfur significantly increased seed yields, oil content, and yield attributing characters of Indian mustard such as siliqua per plant, seeds per siliqua and length of siliqua and test weight only up to 30 kg ha^{-1}. Potassium application up to 40 kg ha^{-1} had a significant improvement of seed yields, and siliqua per plant compared to 20 kg ha^{-1} but was at par with 60 kg ha^{-1}.

A field experiment was conducted by Singh (2002) in Azamgarh, Uttar Pradesh, India, during rabi 1998-99 and 1999-2000 to investigate the effect of different levels of N (0, 30, 60, 90 and 120 kg/ha) and P (1, 15, 30, 45 and 60 kg/ha) on yield, yield components and oil content of Indian mustard cv. Varuna. Application of N and P increased the length of siliqua, number of siliquae per plant, seeds per siliqua, seed yield and 1000-seed weight. However, the significant increase in yield and yield components was recorded in 60, 90 and 120 kg N/ha and 30, 45 and 60 kg P/ha treatments. The maximum seed yield was recorded from application of 45 kg P/ha (11.43 and 13.85 q/ha in 1999 and 2000, respectively) and 120 kg N/ha (12.98 and 13.83 q/ha in 1999 and 2000, respectively). The oil content also increased with the application of N and P, but was insignificant.

Chaubey *et al.* (2001) conducted a field experiment during the rabi season of 1993-94, 1994-95 and 1995-96 on an Entisol of Ujhani (U.P.) to evaluate the response of mustard (*Brassica juncea* (L.) Czornj & Cosson) cv. Rohini to phosphorus (0, 40 and 60 kg $P_2O_5ha^{-1}$) and sulphur (0, 15, 30, 45 and 60 kg S ha^{-1}) fertilization in R.B.D. the growth attributes (plant height, number of branches/plant) and yield attributes (Siliquae/plant, length of siliqua, seed/siliqua and 1000-seed weight) increases significantly with the increasing level of P and S up to 60 kg P_2O_5 and 30 kg S ha^{-1} respectively. Phosphorus application increased significantly seed yield over control. The increase was 19.60, 15.34 and 41.67 percent respectively in all the three years. Similarly sulphur also increased the seed yield by 17.06, 14.68 and 22.07 per cent respectively.

Davaria *et al.* (2001) conducted a field experiment during the 1994/95 rabi season in Junagadh, Gujarat, India, to determine the effects of P and S on the yield and biochemical composition of Indian mustard cv. Gujarat Mustard. The treatments comprised P_2O_5 at 0, 25, and 50 kg/ha and S at 0, 25, 50, and 100 kg/ha. In the P treatments, numbers of primary branches per plant (6.9), secondary branches per plant (12.6), siliquae per plant (278) and seeds per siliqua (12.1), seed yield (15.43 q/ha) were highest with 50 kg P_2O_2/ha. S had no significant effects on growth and yield, except for seed yield, which was highest at 50 and 100 kg/ha (13.28 and 14.12 q/ha, respectively). P_2O_2 at 50 kg/ha significantly increased leaf chlorophyll content and P and S contents of seeds, but decreased leaf sap pH. S significantly increased leaf chlorophyll content and decreased leaf sap pH, whereas seed composition of oil, protein, fatty acid, N, P, and S did not change.

A field experiment was conducted by Malewar *et al.* (2001) in Maharashtra, India to investigate the effects of four levels of zinc sulfate (0, 10, 20 and 30 kg/ha) and three levels of borax (0, 5 and 10 kg/ha) on yield, nutrient uptake and seed quality of mustard (*Brassica juncea* cv. Pusa Bold). Stover and seed yield significantly increased with each levels of either zinc or boron which was attributed to the positive interaction of the two.

Highest total mustard uptake of Zn and B was at 30 kg $ZnSO_4$ and 10 kg borax/ha, respectively. Zn and B interaction was also reflected in terms of improved seed quality of mustard. Oil and protein content was significantly increased with 30 kg $ZnSO_4$ x 10 kg borax/ha treatment.

Sharma and Jalali (2001) reported that the response of Indian mustard cv. RLM 198 to S and P during the winter season of 1994-95 and 1995-96 under rain fed condition in Rajouri, Jammu and Kashmir, India. There were 16 treatments consisting of 4 S levels (0, 20, 40 and 60) through $CaSO_4$ levels (0, 20, 40 and 60) through triple super phosphate, alone or in combination. The seed and straw yield increased significantly with increase in levels of S. Similarly, P also enhanced the grain and straw yield. However, the effect was limited to P application up to 40 kg/ha. The total uptake of S increased significantly with increase in each dose of S up to 60 kg/ha. The per cent increase in total S uptake was 42, 61 and 74 over the control with application of S at 20, 40 and 60 kg/ha, respectively. S uptake also increased from 18.09 to 27.12 kg/ha due to application of P at 0 and 40 kg P/ha, respectively. The maximum S uptake (31.86 kg/ha) and P (9.82 kg/ha) uptake was recorded with S and P, respectively. The oil content increase significantly with increasing levels of S. Application of P decreased the oil content, which ranged between 39.80% at 0 level of P and 39.33% at 60 kg P/ha, while oil yield increased significantly. The interaction effect of S and P on oil content was found to be non-significant, while oil yield was increased significantly due to combined application of S and P.

Pawar *et al.* (2001) conducted a field experiment during the winter season of 1996-97 and 1997-98 on clayey soils in Parbhani, Maharashtra (India) to study the effect of irrigation schedules and fertilizers on growth, yield and quality of Indian mustard grown on Vertisols. Irrigations scheduled at 0.6 IW: CPE ratio significantly influenced the dry matter production, secondary branches, and number of developed siliquae per plant. During 1996-97, maximum seed yield of mustard was recorded in F treatment (50 kg N, 40 kg P, 40 kg S per ha). The reduction in recommended levels of N and P along with 40 kg S gave higher seed yield.

Altaf et *al.* (2001) stated an experiment that the interactive effect of N and S application on nitrogen accumulation, its distribution in various plant parts and nitrogen harvest of rapeseed-mustard (*Brassica juncea* cv. Pusa Jai Kisan V; *Brassica campestris* cv. Pusa Gold V, in New Delhi, India using three combinations of S and N viz. 0 S, 100 N; 40 S, 100 N and 60 S, 150 N kg/ha. The results showed that combined application of S and N (40 S, 100 N and 60 S, 150 N kg/ha) increased the nitrogen accumulation in both the genotypes at all the growth stages over N alone (0 S, 100 N). This increase in N accumulation was due to the improvement in the reduction of nitrate into reduced N as evident from higher nitrate reductive (NR) activity in the leaves of plants grown with both S and N, compared with N alone. Nitrate-N content in the leaves of plants grown with only N was higher compared to those grown with both S and N, showing that application of S, along with N, appreciably reduced the nitrate content in the leaves due to the higher NR activity. This decline in NO was followed by an overall increase in N-accumulation in the plants. Consequently, the N content in the plant was increased by

11.7-57.6 and 11.0-58.9% in V, respectively, with the application of S, along with N, compared to the application of N alone. N harvest index was also higher in plants grown with both S and N, compared to those grown with N alone. It is evident from these results that the application of S, along with N, not only increased N accumulation, but also its mobilization towards economic sinks. Among the different combinations of S and N (40 S, 100 N) proved to be the optimum for higher N accumulation and N harvest in rapeseed and mustard.

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

2.2 Effect of vermicompost on mustard

Santosh *et al.* (2007) carried out an experiment with Indian mustard during the crop season of 2004-05 and 2005-06 in Bagpat, Uttar Pradesh, India, comprising 10 treatments: control, farmyard manure (FYM) at 5 t/ha, distillery effluent and press mud compost (DEPC) at 1, 2 and 3 t/ha; FYM and DEPC at 3 t/ha; FYM and DEPC at 2 t/ha; FYM and DEPC at 1 t/ha and N at 40 and 60 kg/ha. The DEPC, FYM, combinations of DEPC and FYM and inorganic fertilizer significantly increased the seed yield, biological yield and quality content of Indian mustard. Among the various treatments, application of FYM and DEPC at 3 t/ha recorded the highest seed yield, biological yield and all the quality contents (oil, protein, nitrogen and sulfur contents in seeds, and N content in seed) in both years.

Satyajeet *et al.* (2006) conducted a field experiment in pearl millet-mustard cropping sequence during the years 2003-04 and 2004-05 at CCSHAU Regional Research Station, Bawal, Haryana, India. The experiment was laid out in split plot design with four pearl millet varieties in main plot and eight fertility levels in sub-plots having three replications. The objective of the experiment was to evaluate the integrated nutrient management treatments in pearl millet-mustard cropping system in loamy sand soils. Different treatments were applied during kharif season, while in rabi season only residual effect on succeeding mustard (cv. RH-30) crop was recorded. In pearl millet, hybrid HHB-117 recorded highest growth, yield and attraction index over rest of the varieties. The grain yield was recorded highest with 100% recommended dose (RD) in conjunction with vermicompost and biofertilizer. Application of 100% RD and 75% RD, vermicompost, biofertilizer also gave comparable yields. Application of inorganic nutrients integrated with organic fertilizers to pearl millet crop left behind sufficient residual effect, which tended significant increase in growth and seed yield of mustard during the two years of study.

An experiment was conducted by Santosh *et al.* (2006) during 2004-05 in Baghpat, Uttar Pradesh, India to evaluate the effect of distillery effluent based press mud compost (DEBPC; at 1, 2 and 3 t/ha) with and without farmyard manure (FYM; at 5 t/ha) and inorganic N (at 40 and 60 kg/ha) on Indian mustard. The organic manure with FYM resulted in significant improvement in yield attributes such as number of pods per plant, number of branches and plant height were recorded with 3 t DEBPC, 5 t FYM/ha treatment. The highest seed and biological yields (7.07 and 25.80, respectively) were recorded with this treatment. In respect of inorganic fertilizer, the 60 kg N/ha recorded higher yield attributes and seed yield (6.87) compared to the 40 kg N/ha.

Premi *et al.* (2005) conducted a field experiment during rabi 2002/03 and 2003/04 in Rajasthan, India to study the effect of organic and inorganic nutrients on the growth, yield attributes, seed yield and oil content of Indian mustard. Application of vermicompost at 5.0 t/ha, 75% recommended dose of fertilizer (80 kg N and 40 kg P_2O_5/ha) recorded maximum plant height, number of primary and secondary branches per plant, number of siliquae per plant and number of seeds per siliqua, which in turn resulted in higher seed yield. It was at par with farmyard manure at 10.0 t/ha, 75% recommended fertilizer and recommended dose of fertilizer.

Abraham and Lal (2002) from an experiment was conducted to study the yield attributes, oil and protein content of mustard seed (var. Pusa Bold) and compared after application of different fertilizers in a cropping system of soybean (kharif)/mustard (rabi)/fodder cowpea (zaid) on a sandy loam alluvium at the Allahabad Agriculture Institute, India. Treatments were 33% recommended dose of NPK, 100% recommended dose of NPK, and combinations of 33% NPK with farm compost, Vermicompost; farm compost, poultry manure; phosphate solubilizing bacteria (PSB), *Rhizobium* or *Azospirillum* and PSB, foliar application of 33% cows urine. At the end of the experiment, seed yield and biological yield were 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.

Rautaray (2002) conducted a field experiment for two years (1996-98) with rice (*Oryza sativa*) cv. IR-36 in the wet season and mustard (*Brassica napus* var. glauca (*Brassica campestris* var. sarson) cv. B9) in the dry season in an acid (pH 5.29) lateritic soil low in available N, P and K in West Bengal, India. The rice crop was provided with a uniform fertilizer dose of 90:26:33 kg N: P: K/ha through chemical fertilizers or organic materials, chemical fertilizers. Residual effect of fertilization sources was studied on mustard. The highest seed and oil yield was obtained under the residual effect of integrated fertilization system involving pond ash, organic materials and chemical fertilizers and was superior to the fertilization system involving either of the 2 sources or single source. Results were similar for nutrient content in plants and nutrient use efficiency. However, residual benefit alone could not produce sufficient yield and direct fertilization was essential for getting economic yield.

2.3 Effect of vermicompost on other crops

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 physical-chemical properties, conserved higher amount of moisture and increased winter sorghum yield to a greater extent than farmyard manure and vermicompost. Grain yield increased significantly by 20% with application of 25kg N ha^{-1} and further increase in nitrogen does up to 50 kg ha^{-1}, increased the grain yield by 30.5% in the pooled data.

Arancon *et al.* (2004) from an experiment was carried out 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.

Atiyeh *et al.* (2002) accomplished to study the 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.

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}.

A field experiment was conducted by Das *et al.* (2002) 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 fertilizer 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 or crossandra compared to the untreated plants. The impact of compost was also beneficial but a little less distinct than the positive impact of 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 fuliflora*, coir pith and farmyard manure.

Chapter III

Materials and Method

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Agronomy Field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from 8th November 2010 to 17th March 2011. Details of different materials used and methodology followed for conducting this experiment have been presented in this chapter.

3.1 Site and soil

The experiment was laid out in the non calcarious dark gray floodplain soil of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. This soil belongs to the Modhupur tract under Agro-Ecolological Zone 28 (AEZ-28) was presented in Appendix-IV. The site of the experimental plot is in the $23^{0}74$ N latitude and $90^{0}35$ E longitudes with an elevation of 8.2m above flood level (Anonymous, 2006). Detail the morphological, physical and chemical properties of soil are presented in table 1 and 2.

Table 1. Morphological characteristics of experimental field

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

Table 2. Physical and chemical properties of the experimental soil

		Soil Properties	Value
A		**Physical properties**	
	1.	Particle size analysis of soil	
		% Sand	30.56
		%Silt	37.26
		% Clay	32.15
	2.	Soil texture	Clay loam
B		**Chemical properties**	
	1	Soil P^H	5.55
	2	Organic matter (%)	0.75
	3	Total N (%)	0.073
	4	Available P (%)	0.0015
	5	Exchangeable K (me/100g soil)	0.0013
	6	Available S (%)	0.0011
	7	Available Zn (ppm)	0.016
	8	Available B (ppm)	0.013

3.2 Climate

Experimental site was located on the sub-tropical zone where rainfall is maximum during the kharif season (April to September). The rainfall is scanty in association with moderately low temperature and plenty of sunshine in the rabi season (October to March). The meteorological data recorded at the weather yard during November 2010 to February 2011.

3.3 Variety used

SAU sharisha-1 a high yielding variety under yellow sarson group and SAU sharisha-4 also a high yielding variety under brown sarson group of *Brassica campestris* developed by Professor Dr. Md. Shahidur Rashid Bhuiyan, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, was used for the experiment. Before sowing, germination test was carried out in the laboratory and percentage of germination was found to be over 90%.

3.4 Fertilizer treatments under investigation

The experiment consists of two factors i.e. mustard varieties and vermicompost & inorganic fertilizers each have three levels. Details of factors and their combinations are presented below:

Factor A= two varieties (2)

a. SAU sharisha-1 (V_1)
b. SAU sharisha-4 (V_2)

Factor B=Manure & Fertilizer (F_0, F_1, F_2, F_3, F_4, F_5)

a. Rates of organic fertilizers (Vermicompost): 3

F_0=0 t ha^{-1}(no vermicompost)

F_1=1.5 t ha^{-1}(medium vermicompost)

F_2=2.5 t ha^{-1}(high vermicompost)

b. Rates of inorganic fertilizers (N, P, K, S, Zn, B): 3

F_3= (40 kg N + 15 kg P + 20 kg K + 10 kg S + 1.2 kg Zn + 1.0 kg B) ha^{-1}(low fertilizer)

F_4= (80 kg N + 30 kg P + 40 kg K + 20 kg S + 2.4 kg Zn + 2.0 kg B) ha^{-1}(medium fertilizer)

F_5= (120 kg N + 45 kg P + 60 kg K + 30 kg S + 3.6 kg Zn + 3.0 kg B) ha^{-1}(high fertilizer)

Treatments

T_1 (V_1F_0) = (SAU sharisha-1 with no vermicompost)

T_2 (V_1F_1) = (SAU sharisha-1 with medium vermicompost)

T_3 (V_1F_2) = (SAU sharisha-1 with high vermicompost)

T_4 (V_1F_3) = (SAU sharisha-1 with low fertilizer)

T_5 (V_1F_4) = (SAU sharisha-1 with medium fertilizer)

T_6 (V_1F_5) = (SAU sharisha-1 with high fertilizer)

T_7 (V_2F_0) = (SAU sharisha-4 with no vermicompost)

T_8 (V_2F_1) = (SAU sharisha-4 with medium vermicompost)

T_9 (V_2F_2) = (SAU sharisha-4 with high vermicompost)

T_{10} (V_2F_3) = (SAU sharisha-4 with low fertilizer)

T_{11} (V_2F_4) = (SAU sharisha-4 with medium fertilizer)

T_{12} (V_2F_5) = (SAU sharisha-4 with high fertilizer)

3.5 Layout of the experiment

The experiment was laid in a Randomized Complete Block Design (factorial) with three replications to reduce the heterogenetic effect of soil. Each replication was divided into 12 unit plots as treatments. Thus the total number of unit plots was 36(12×3). The unit plot size was $6m^2$ (3.0m×2.0m). The distance between the blocks was 1.0 m. The distance between the plots was 0.5m. Allocation of all the treatments was made at random in each block. The layout of the experiment has been shown in Fig-1.

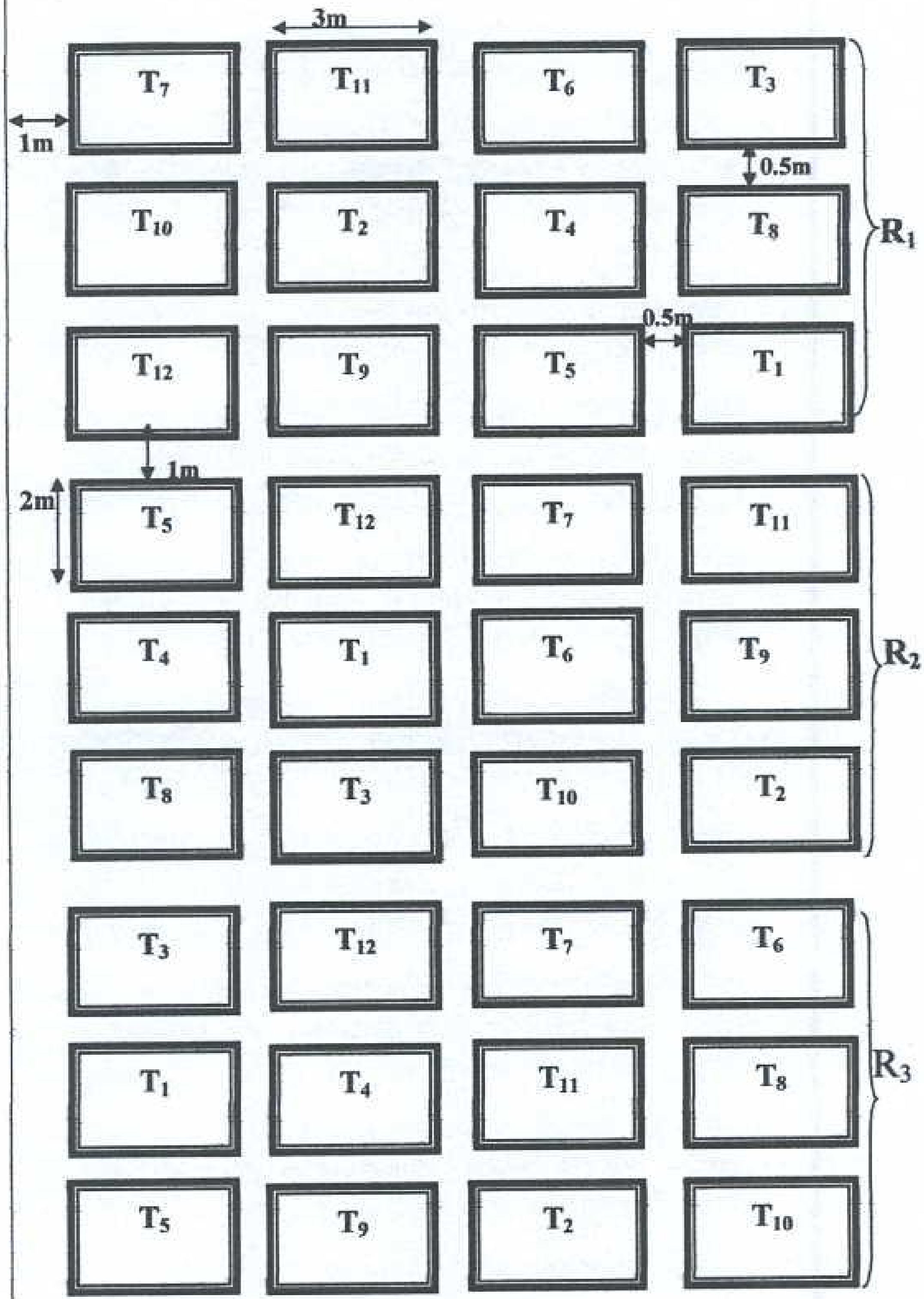

Fig 1: Layout of the experimental plot

3.6 Land preparation

The land preparation was done with power tiller and country plough. Ploughed soil was then brought into fine tilth condition by four operations of ploughing and harrowing with country plough and ladder. The stubbles of the previous crops and weeds were removed. The first ploughing and final land preparation were done on 6th and 7th November 2010, respectively. The plots were laid out in the field on 8th November 2010.

3.7 Application of vermicompost and inorganic fertilizers

Fertilizers were used as urea, T.S.P., MOP, gypsum, zinc oxide and boric acid for N, P, K, S, Zn and B respectively. The total required amounts of P, K, S, Zn, B and 50% N were applied plot wise as per treatments after final land preparation and layout of the experiment and were mixed with the soil through hand spading. The rest of the N (urea) was applied as top dressing after 22 days of germination and just before flowering. The required amounts of vermicompost as per treatment combinations were applied uniformly in the canals opened just before sowing the seeds in lines.

3.8 Sowing of seeds

The seeds at the rate of 8 kg ha^{-1} (SAU sharisha-1&4) were sown in rows 30 cm apart by hand. The distance of row to row was 30 cm. After sowing, the seeds were covered with soil and slightly pressed by hand. The seeds were sown on 8th November 2010. Sowing was done at suitable condition of soils, which ensured satisfactory germination of seeds. The seeds germinated after 12 days of sowing.

3.9 Intercultural operations

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

3.9.1 Irrigation

Two irrigations were given once on 8th December 2010 and 25th December 2010, respectively after 30 days and 48 days of sowing in order to maintain enough moisture in the field. There was scanty rainfall in the period of cultivation of the crop.

3.9.2 Weeding and thinning

Two weeding and thinning were done at 12 and 25 days after germination on 12th November 2010 and 6th December 2010, respectively. Thinning was done in all unit plots carefully to maintain a uniform plant population per plot.

3.9.3 Insect and pest control

The crop was found infested with aphids (*Lipaphis ersimi*) at the time of siliqua filling. The insects were controlled successfully by Marshal 30 @ 1ml/Litre. The insecticide was sprayed on 5th February 2011. The crop was kept under constant observations from sowing to harvesting.

3.10 Sample collection and harvesting and threshing

The crop maturity varied with fertilizer treatments, when around 80% of the siliquae in terminal raceme turned golden yellow in color then crops were harvested. Collection of sample was done as per requirement. Samples were collected randomly i.e. from different places of each plot leaving undisturbed one meter square in the centre. After collection of the sample, harvesting and threshing were done on 4th to 7th March 2011. The harvested crops were tied into bundles and carried to the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.11 Collection of experimental data

For the convenience of collecting data, ten sample plants per plot were selected at random and were tagged for the data collection. Data were collected at maturity stage and post harvest stage. The sample plants were uprooted prior to harvest and dried properly in the sun before collecting data. The seeds and straw yield per plot were recorded after cleaning and drying them properly in the sun.

The procedures followed to collect the data for different characters are given below:

A. Growth data

Plant height

The height of 10 plants of each plots were measured from the ground level to the tip of the topmost siliquae and average was taken and expressed in centimeter (cm).

Number of branches per plant

The number of branches was counted and recorded. The primary branches were counted from the ten tagged plants in each plot at harvest and average was taken.

The ten tagged plants in each plot were also used for counting the number of secondary branches at harvest.

B. Yield data

Number of siliquae per plant

The number of siliquae from ten tagged plants were counted after the harvest and expressed on per plant basis.

Length of siliquae

Ten siliquae were randomly selected from the five plants and the average length of siliquae was calculated.

Number of seeds per siliquae

Ten siliquae were randomly taken from all siliquae of each plot and the seeds were counted. The average number of seeds per siliquae was determined.

Seed yield per plant

The separated seeds of ten plants were collected, cleaned, dried and weighed properly. The average seed yield per plant was then recorded in gram.

3.12 Seed yield

The seed weights were taken by threshing the harvested plants of each plot and converted the yield to t ha^{-1}.

3.13 Oil content of seed

Oil content of seed was determined by Soxhlet method and expressed in percentage (%). For this purpose 25g clean seed sample was used. This was done in Oil Seed Research Centre, BARI, Joydebpur, Gazipur-1701.

3.14 Oil yield

Yield of oil was calculated from the percent of oil in the seed samples multiplied by seed yield kg/ha.

3.15 Vermicompost

Vermicompost was analyzed for organic matter, total N, available P, K and S contents following the methods. Vermicompost contained 11.06% organic matter, 0.6298% total N, 0.02249% available P, 0.07826% available K and 0.0313% available S.

3.16 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 means was estimated by Duncan Multiple Range Test (DMRT) at 5% and 1% level of probability and DMRT (Gomez and Gomez, 1984).

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

In this chapter, experimental results pertaining of the effects of different levels of vermicompost and inorganic fertilizer and their combinations on different components of mustard cv. SAU sharisha-1&4 have been presented along with discussion in this chapter.

4.1 Plant height

4.1.1 Varietal effects on plant height

The effect on the plant height of mustard varieties is presented in appendix-II. Variety-1 (SAU sharisha-1) produced shortest plant (99.69333 cm) and variety-2 (SAU sharisha-4) produced the tallest plant (107.65 cm).

4.1.2 Effect of fertilizers

The effect of vermicompost and inorganic fertilizers alone on the height of mustard plant is presented in Figure 2 and appendix-III. Significant variations were observed in plant height of mustard when the field was incorporated with different doses of fertilizers. Among the different fertilizer doses, F_5 (120 kg N + 45 kg P + 60 kg K + 30 kg S + 3.6 kg Zn + 3.0 kg B) ha^{-1} high inorganic fertilizer showed the highest result (112.45 cm, average). On the contrary, the lowest (95.815 cm) result was observed in F_0 treatment where no vermicompost and inorganic fertilizer was used.

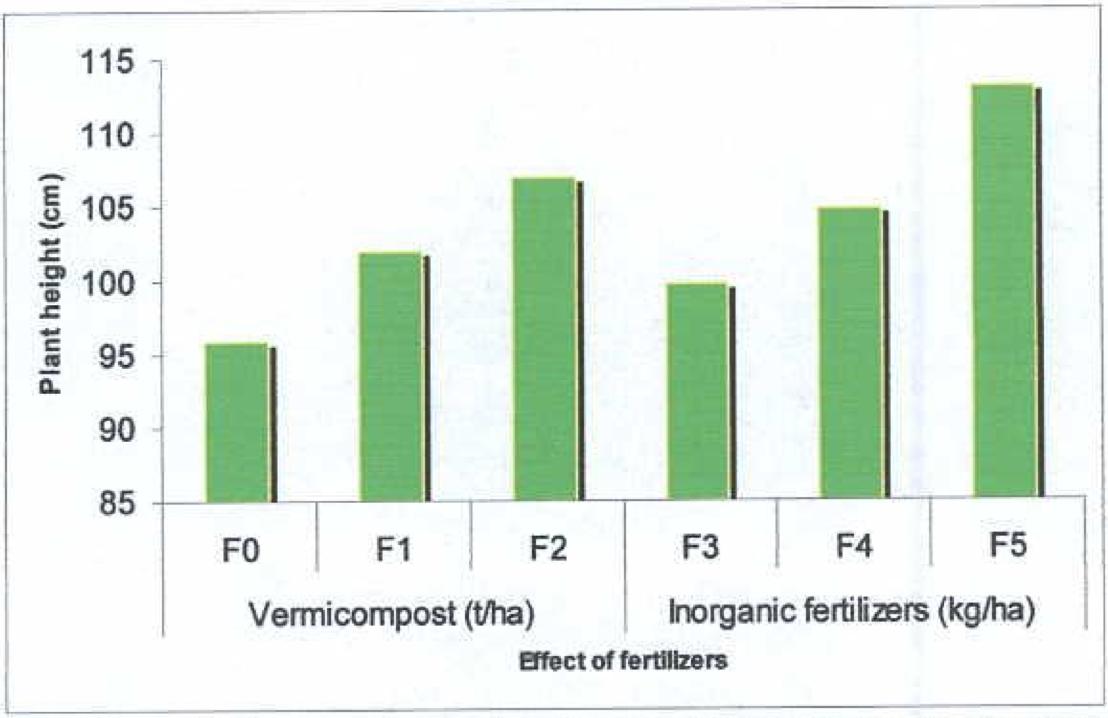

Fig. 2 Effects of different vermicompost and inorganic fertilizer doses on the plant height of mustard

4.1.3 Effects between varieties and fertilizers

The interaction effect of varieties and fertilizers alone on the height of mustard plant is presented in Figure 3 and appendix-I. In comparison with variety-1 (SAU sharisha-1) and variety-2 (SAU sharisha-4), application of F_5 (high inorganic fertilizer) produced tallest plant (118.8 cm) in variety-2 and F_0 (control treatment) gave the lowest plant (94.53 cm) in variety-1. These findings are in agreement with those of Singh *et al.* (2002), Tripathi and Tripathi (2003), Nagdive *et al.* (2007) and Hidyatulah *et al.* (2004).

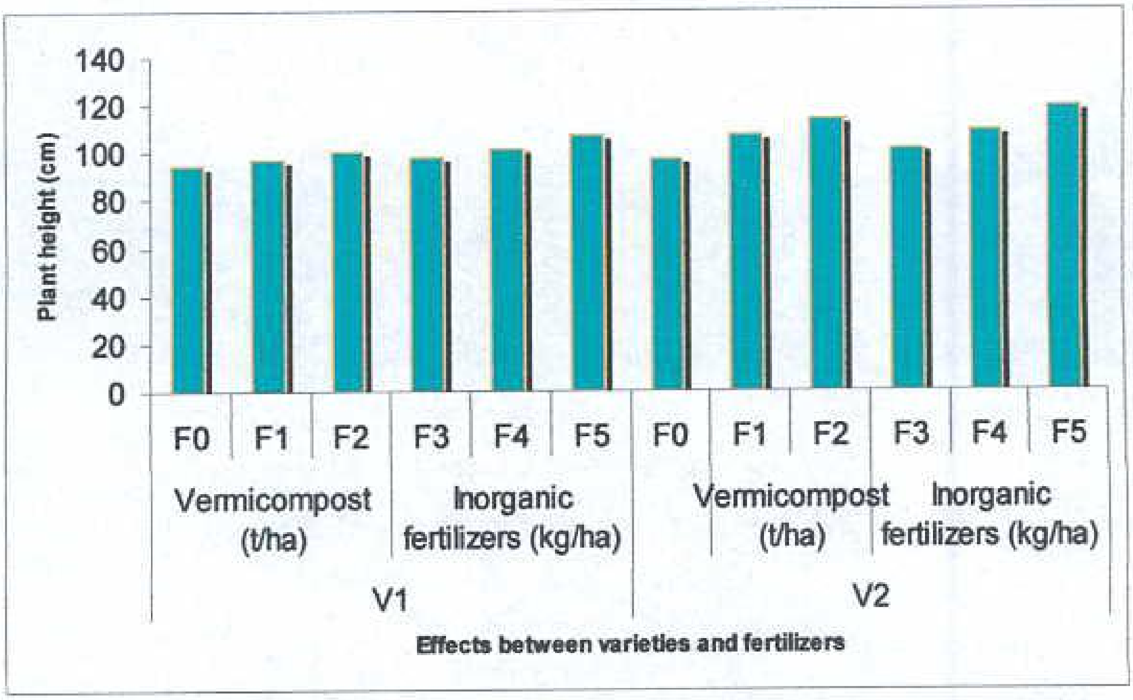

Fig. 3 Effects of different vermicompost and inorganic fertilizer doses on the plant height of mustard varieties (SAU sharisha-1&4)

4.2 Number of primary branches per plant

The effect of fertilizers alone on the number of branches per plant of mustard is presented in appendix-III. Significant variations were observed in number of branches per plant of mustard when the field was incorporated with different doses of fertilizers.

4.2.1 Varietal effects on primary branches per plant

The varietals effect alone on primary branches per plant is presented in appendix-II. Variety-2 (SAU sharisha-4) produced highest number of primary branches per plant (6.672333) which differs significantly in comparison to others. Whereas variety-1 (SAU sharisha-1) showed the lowest number of primary branches per plant (6.12783333).

4.2.2 Effect of fertilizers

Mustard plants showed significant variation in primary branches per plant in respect of when different vermicompost and inorganic fertilizer doses were applied. The fertilizer effect alone on primary branches per plant is presented in appendix-III and Figure 4. Among the different fertilizer doses, F_1 (low vermicompost) showed the highest result (6.867). On the contrary, the lowest primary branches per plant (5.833) was observed in F_3 (40 kg N + 15 kg P + 20 kg K + 10 kg S + 1.2 kg Zn + 1.0 kg B) ha^{-1} where low inorganic fertilizer was used.

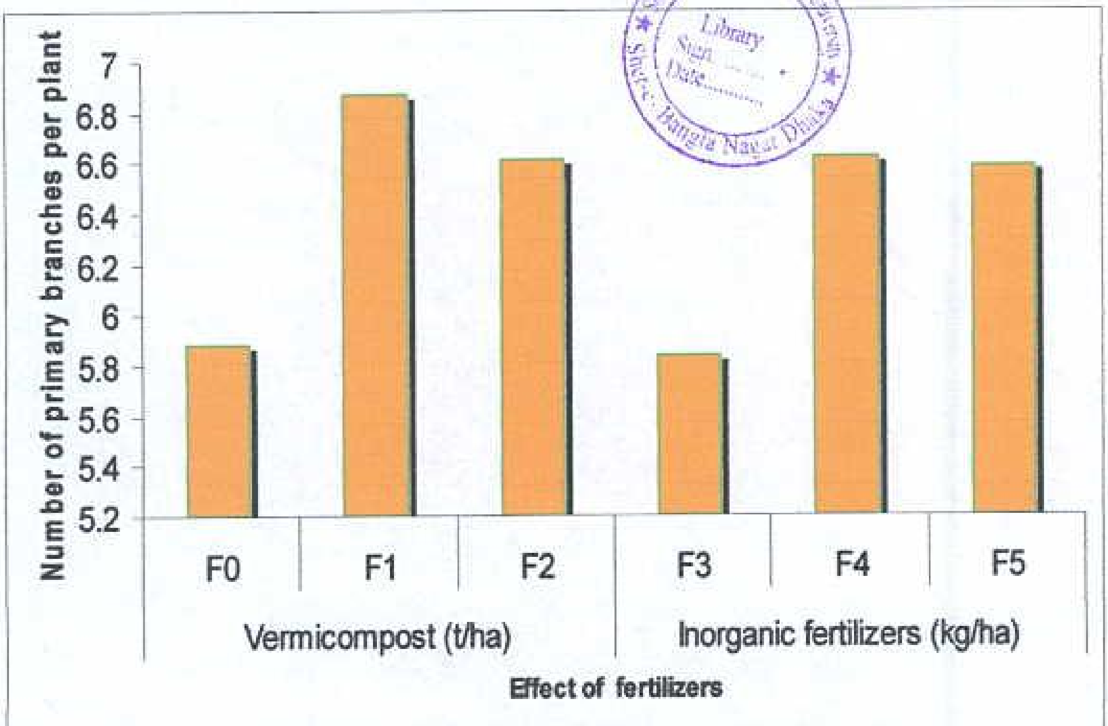

Fig. 4 The effect of different doses of vermicompost and inorganic fertilizer on the number of primary branches per plant of mustard

4.2.3 Effects between varieties and fertilizers

In comparison with varieties and fertilizers, highest number of primary branches per plant (7.367) was obtained from the application of medium inorganic fertilizer (F_4) and the lowest number of primary branches per plant (6.000) by the application of control treatment (F_0) in SAU sharisha-4. Highest number of primary branches per plant (7.000) was obtained from the application of high inorganic fertilizer (F_5) and the lowest number of primary branches per plant (4.833) by the application of low inorganic fertilizer (F_3) in SAU sharisha-1. The interaction effect alone on primary branches per plant is presented in appendix-I and Figure 5. These findings are in agreement with those of Amit and Sandeep (2007) and Santosh *et al.* (2006) also obtained highest number of branches per plant.

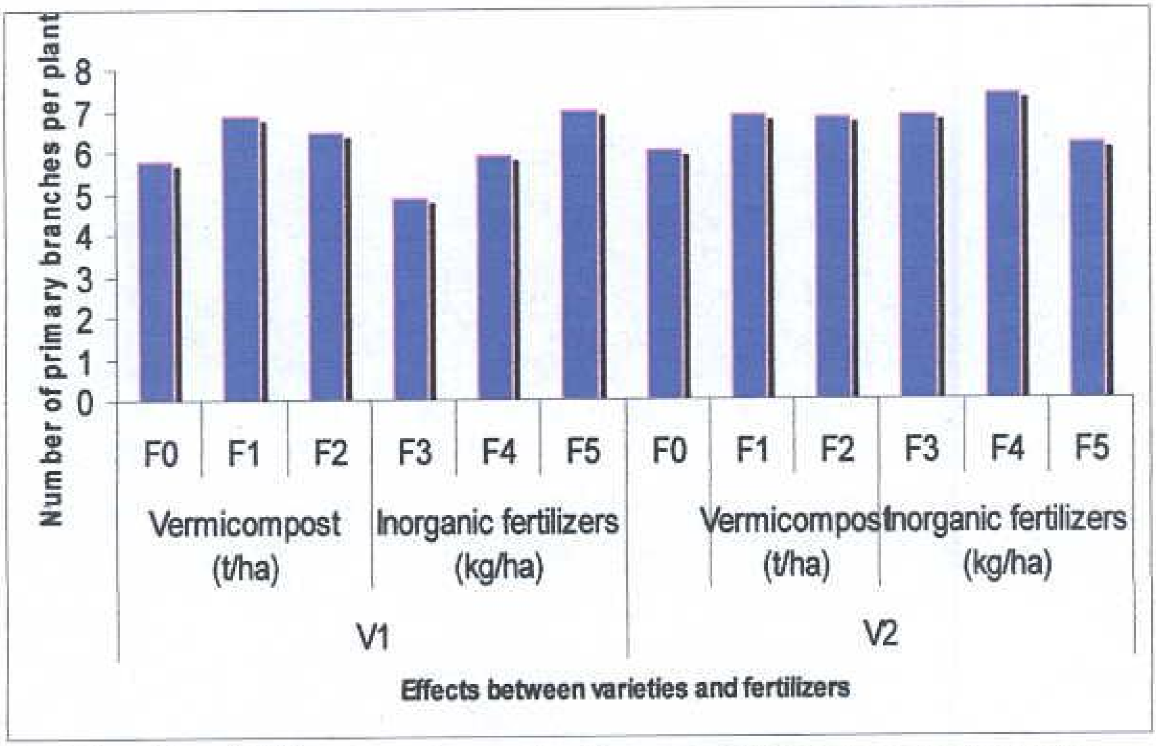

Fig. 5 The effect of different vermicompost and inorganic fertilizer doses on the number of primary branches per plant of mustard varieties (SAU sharisha-1&4)

4.3 Number of secondary branches per plant

4.3.1 Varietal effects on secondary branches per plant

The varietals effect on the number of secondary branches per plant of mustard plants are presented in appendix-II. In variety-2 (SAU sharisha-4), gave highest number of secondary branches per plant (6.222167) and on the other hand, the lowest number of secondary branches per plant (1.861) was found in variety-1 (SAU sharisha-1).

4.3.2 Effect of fertilizers

Mustard plants showed significant variation in secondary branches per plant in respect of different vermicompost and inorganic fertilizer doses. The fertilizer effects on the number of secondary branches per plant of mustard plant are presented in appendix-III and Figure 6. Among the different fertilizer doses highest number of secondary branches per plant (4.65) was obtained from fertilizer treatment F_2 (high vermicompost) and the lowest number of secondary branches per plant (3.583) from control treatment (F_0).

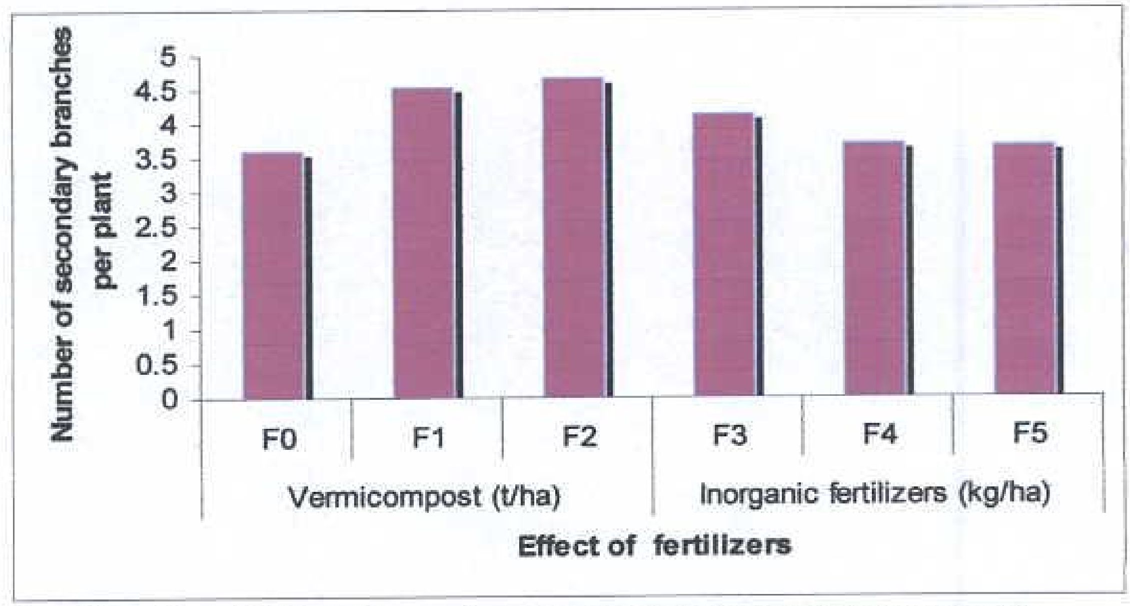

Fig. 6 The effect of different doses of vermicompost and inorganic fertilizer on the number of secondary branches per plant of mustard

4.3.3 Effects between varieties and fertilizers

The effects of varieties and fertilizers on number of secondary branches per plant of mustard are presented in appendix-I and Figure 7. In the interaction between varieties and fertilizers, highest number of secondary branches per plant (7.100) was obtained from the application of high vermicompost (F_2) in SAU sharisha-4 and lowest number of secondary branches per plant (1.000) by the medium fertilizer (F_4) treatment in SAU sharisha-1. These findings are in agreement with those of Amit and Sandeep (2007) and Santosh *et al.* (2006) also obtained the highest number of branches per plant.

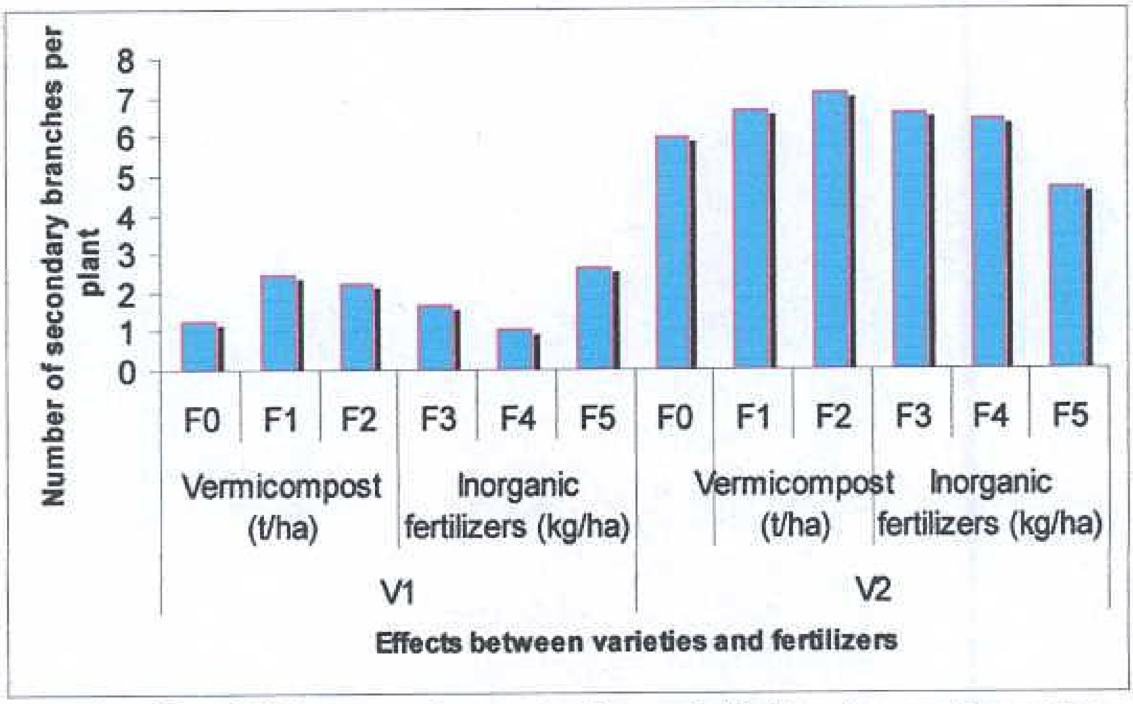

Fig. 7 The effect of different vermicompost and inorganic fertilizer doses on the number of secondary branches per plant of mustard varieties (SAU sharisha-1&4)

4.4 Number siliquae per plant

4.4.1 Varietal effects on siliquae per plant

Number of siliquae per plant is one of the most important yield contributing characters in mustard. The varietal effects on number of siliquae per plant of mustard are presented in appendix-II. Variety-1 (SAU sharisha-1) produced highest number of siliquae per plant (180.6167) which is not differing significantly to others and the lowest number of siliquae per plant (165.7913) was observed from variety-2 (SAU sharisha-4).

4.4.2 Effect of fertilizers

The number of siliquae per plant was highly affected by different levels of vermicompost and inorganic fertilizers. The fertilizer effects on number of siliquae per plant of mustard are presented in appendix-III and Figure 8. Application of medium inorganic fertilizer dose (F_4) produced the highest number of siliquae per plant (189.8). Whereas the application of control fertilizer dose (F_0) showed the lowest number of siliquae per plant (133.5).

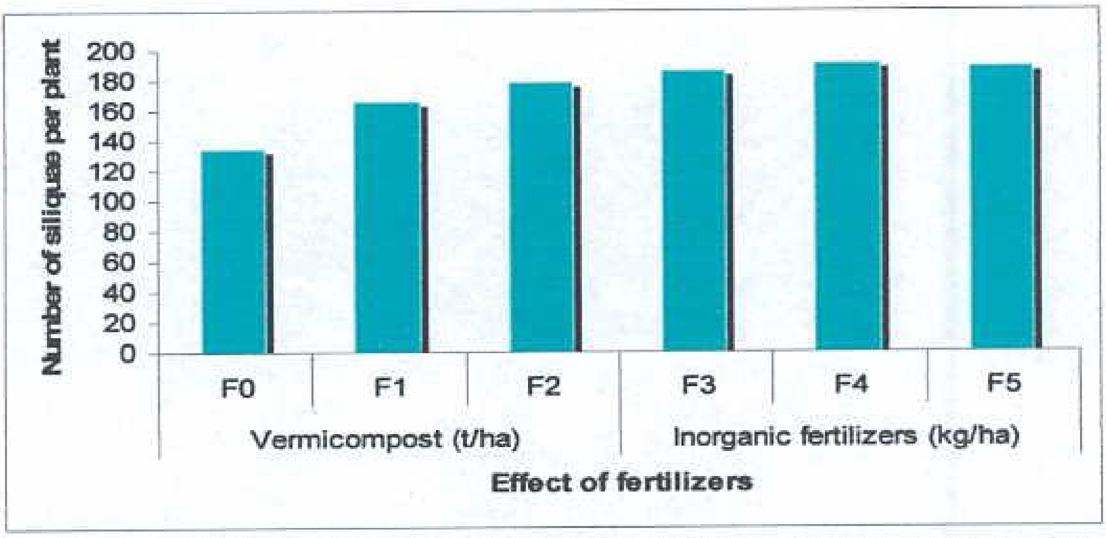

Fig. 8 Effects of different doses of vermicompost and inorganic fertilizer on the number of siliquae per plant of mustard

4.4.3 Effects between varieties and fertilizers

The interaction effects on number of siliquae per plant of mustard are presented in appendix-I and Table 3. In comparison with varieties and fertilizers, F_4 (medium fertilizer) showed that highest number of siliquae per plant (191.3) in SAU sharisha-1 whereas the lowest number of siliquae per plant (122.0) was recorded from control (F_0) treatment in SAU sharisha-4. Similar result was also obtained by Singh *et al.* (2003); Singh (2002) and Amar and Meena (2004) in mustard.

Table 3. The effect of different vermicompost and inorganic fertilizer doses on the number of siliquae per plant of mustard varieties (SAU sharisha-1&4)

Varieties	Fertilizers	Number of siliquae per plant
V_1	F_0	145.0 bc
	F_1	183.7 ab
	F_2	184.3 ab
	F_3	191.1 a
	F_4	191.3 a
	F_5	188.3 a
V_2	F_0	122.0 c
	F_1	145.5 bc
	F_2	171.6 ab
	F_3	180.1 ab
	F_4	188.3 a
	F_5	187.25 a
	Level of significance (%)	0.05

F_0= 0 t ha^{-1}; F_1 (Low Vermicompost)=1.5 t ha^{-1}; F_2(High Vermicompost)=2.5 t ha^{-1}; F_3(Low fertilizer)= (40kgN + 15kgP+ 20kgK + 10kgS + 1.2kgZn + 1.0kgB) ha^{-1}; F_4(Medium fertilizer)= (80kgN + 30kgP+ 40kgK + 20kgS + 2.4kgZn + 2.0kgB) ha^{-1}; F_5(High fertilizer)= (120kgN + 45kgP + 60kgK + 30kgS + 3.6kgZn + 3.0kgB) ha^{-1}.

(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 Number of seeds per siliquae

4.5.1 Varietal effects on seeds per siliquae

Number of seeds per siliquae is one of the most important yield contributing characters in mustard. The varietal effects on number of seeds per siliquae of mustard are presented in appendix-II. Variety-1 (SAU sharisha-1) produced highest number of seeds per siliquae (21.75) and the lowest number (18.51) of seeds per siliquae was obtained from variety-2 (SAU sharisha-4).

4.5.2 Effect of fertilizers

The number of seeds per siliquae varied significantly with different levels of vermicompost and inorganic fertilizers. The fertilizer effects on the number of seeds per siliquae of mustard are presented in appendix-III and Figure 9. Application of high vermicompost dose (F_2) yielded the highest number of seeds per siliqua (20.545) in comparison to other application of fertilizer. On the other hand, the application of high inorganic fertilizer treatment F_5 (120 kg N + 45 kg P + 60 kg K + 30 kg S + 3.6 kg Zn + 3.0 kg B) ha^{-1} showed the lowest number of seeds per siliqua (19.27) in mustard.

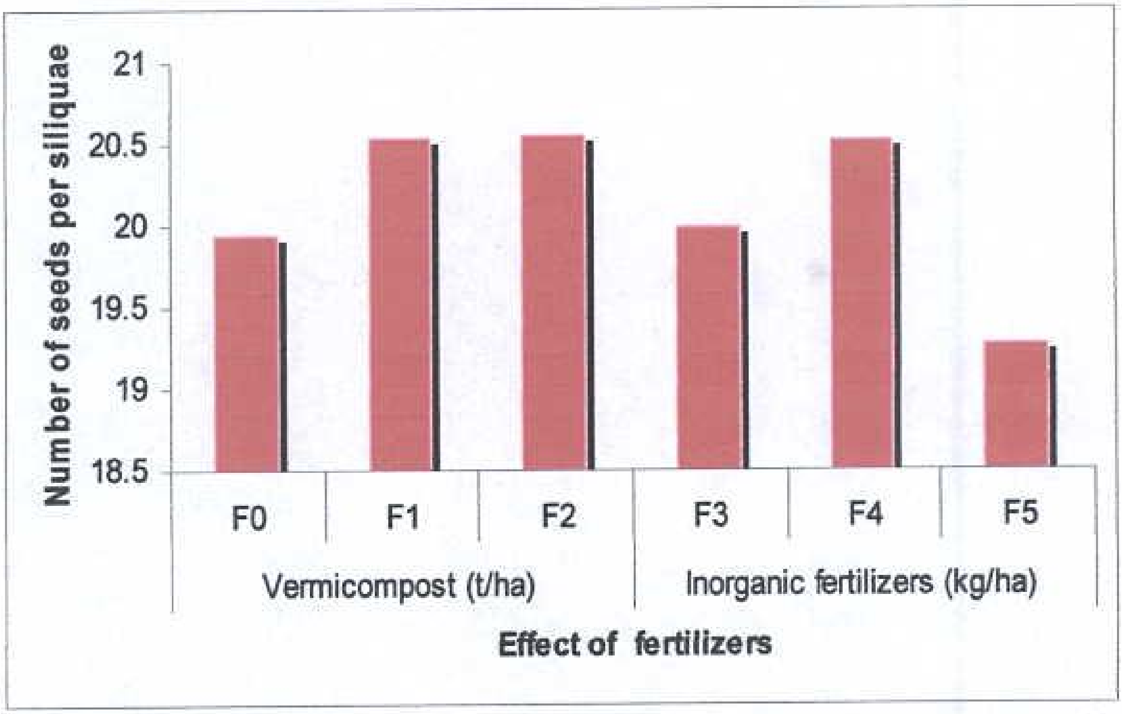

Fig. 9 Effects of different vermicompost and inorganic fertilizer doses on the number of seeds siliquae per plant of mustard

4.5.3 Effects between varieties and fertilizers

The effects of varieties and fertilizers on number of seeds per siliquae of mustard are presented in appendix-I and Table 4. In comparison with varieties and fertilizers, the application of medium fertilizer dose (F_4) (80 kg N/ha, 30 kg P_2O_5/ha, 40 kg K_20/ha, 20 kg S/ha, 2.4 kg Zn/ha and 2 kg B/ha) gave the highest number of seeds per siliqua (22.66) in SAU sharisha-4 and the control (F_0) treatment was showed the lowest number of seeds per siliqua (17.84) in SAU sharisha-1. The present result agrees well with findings of Amar and Meena (2004).

Table 4. The effect of different vermicompost and inorganic fertilizer doses on the number of seeds per siliquae of mustard varieties (SAU sharisha-1&4)

Varieties	Fertilizers	Number of seeds per siliquae
V_1	F_0	22.02 ab
	F_1	22.33 a
	F_2	22.10 ab
	F_3	21.70 ab
	F_4	22.66 a
	F_5	19.69 ab
V_2	F_0	17.84 b
	F_1	18.73 ab
	F_2	18.99 ab
	F_3	18.28 ab
	F_4	18.37 ab
	F_5	18.85 ab
Level of significance (%)		0.05

F_0= 0 t ha^{-1}; F_1 (Low Vermicompost)=1.5 t ha^{-1}; F_2(High Vermicompost)=2.5 t ha^{-1}; F_3(Low fertilizer)= (40kg N + 15kg P + 20kg K + 10k S + 1.2kg Zn + 1.0kg B) ha^{-1}; F_4(Medium fertilizer)= (80kg N + 30kg P + 40kg K + 20kg S + 2.4kg Zn + 2.0kg B) ha^{-1}; F_5(High fertilizer)= (120kg N + 45kg P + 60kg K + 30kg S + 3.6kg Zn + 3.0kg B) ha^{-1}.

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

4.6 Length of siliquae

4.6.1 Varietal effects on the length of siliquae

Length of siliquae is one of the most important yield contributing characters in mustard. The varietal effects on length of siliquae of mustard are presented in appendix-II. Variety-2 (SAU sharisha-4) produced highest siliquae length (5.8035 cm) and the lowest one (5.493333 cm) was observed from variety-1(SAU sharisha-1).

4.6.2 Effect of fertilizers

Length of siliquae of mustard was significantly influenced by different levels of vermicompost and inorganic fertilizers. The fertilizer effects on length of siliquae of mustard are presented in appendix-III and Figure 10. Application of high vermicompost (F_2) (2.5 t/ha) gave the highest siliquae length (5.915cm) and the control treatment (F_0) gave the lowest one (4.9715 cm). The present result agrees well with findings of Amar and Meena (2004).

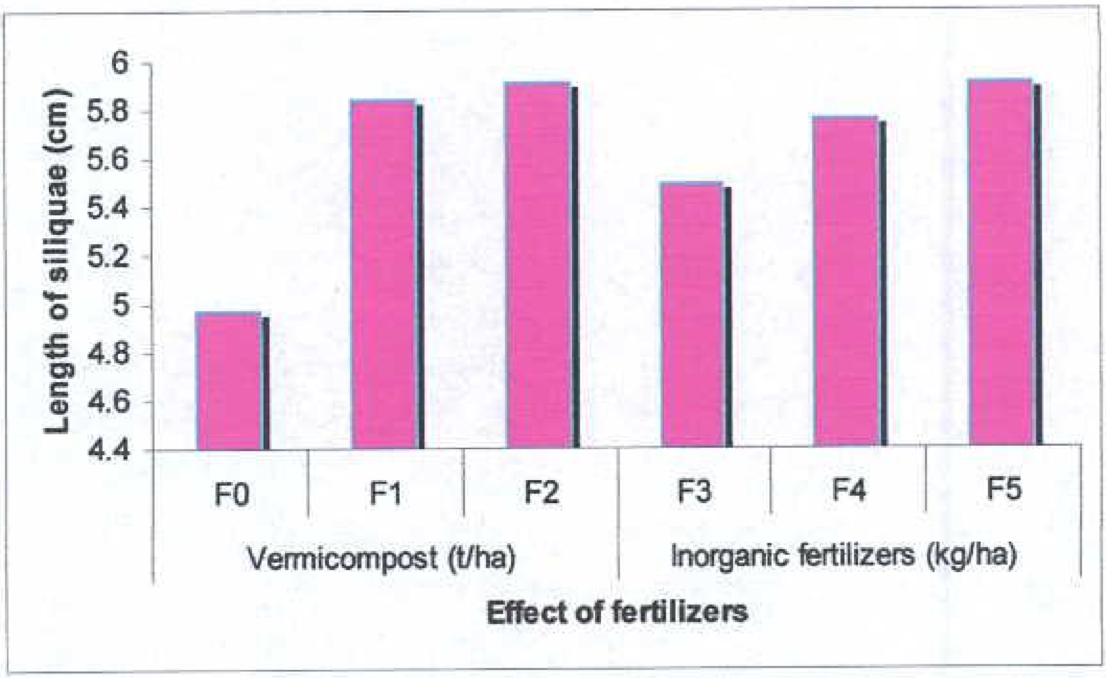

Fig. 10 Effects of different doses of vermicompost and inorganic fertilizer on the length of siliquae of mustard

4.6.3 Effects between varieties and fertilizers

The effects of varieties and fertilizers on the length of siliquae of mustard are presented in appendix-I and Table 4. In comparison with varieties and fertilizers, the highest siliquae length (6.297 cm) was observed by the application of F_5 (high fertilizer) (120 kg

N + 45 kg P + 60 kg K + 30 kg S + 3.6 kg Zn + 3.0 kg B) in SAU sharisha-4 and the control (F_0) fertilizer gave the lowest one (4.810 cm) in SAU sharisha-1.

Table 5. The effect of different doses of vermicompost and inorganic fertilizer on the length of siliquae of mustard varieties (cv. SAU sharisha-1&4)

Varieties	Fertilizers	Length of siliqua (cm)
V_1	F_0	4.810 d
	F_1	6.003 ab
	F_2	5.690 abc
	F_3	5.560 abcd
	F_4	5.377 bcd
	F_5	5.520 abcd
V_2	F_0	5.133 cd
	F_1	5.678 abc
	F_2	6.140 ab
	F_3	5.423 bcd
	F_4	6.150 ab
	F_5	6.297 a
Level of significance (%)		0.05

F_0= 0 t ha^{-1}; F_1 (Low Vermicompost)=1.5 t ha^{-1}; F_2(High Vermicompost)=2.5 t ha^{-1}; F_3(Low fertilizer)= (40kg N + 15kgP + 20kg K + 10kg S + 1.2kgZn + 1.0kg B) ha^{-1}; F_4(Medium fertilizer)= (80kg N + 30kg P + 40kg K + 20kg S + 2.4kg Zn + 2.0kg B) ha^{-1}; F_5(High fertilizer)= (120kg N + 45kg P + 60kg K + 30kg S + 3.6kg Zn + 3.0kg B) ha^{-1}.

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

4.7 Seed yield

4.7.1 Varietal effects on seed yield

The varietal effects on seed yield of mustard are presented in appendix-II. In case of variety-1 (SAU Sharisha-1) showed the highest seed yield (2.04666667 t/ha) and the lowest seed yield (1.78667 t/ha) showed in (SAU sharisha-1) variety-1.

4.7.2 Effect of fertilizers

In the present study, significant variation was found in seed yield at different levels of vermicompost and inorganic fertilizers. Figure 11 showed that the seed yield of mustard (cv. SAU sharisha-1&4) increased markedly due to the fertilizer application. The highest seed yield (2.3135 t/ha) was obtained from the plots receiving medium inorganic fertilizer (F_4) (80 kg N/ha, 30 kg P_2O_5/ha, 40 kg K_20/ha, 20 kg S/ha, 2.4 kg Zn/ha and 2 kg B/ha) (Figure 11) and the lowest yield (1.625 t/ha) was showed from the low vermicompost (F_1) treatment.

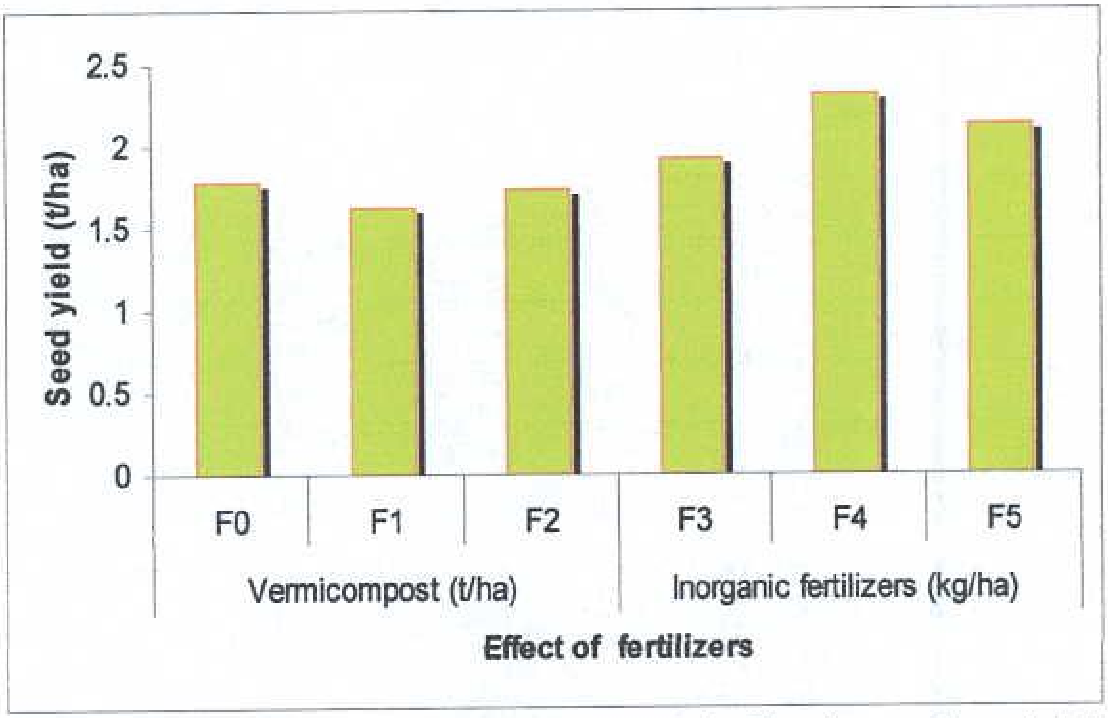

Fig. 11 Effects of different vermicompost and inorganic fertilizer doses on the seed yield (t/ha) of mustard varieties

4.7.3 Effects between varieties and fertilizers

The effects of varieties and fertilizers on the seed yield of mustard are presented in appendix-I and Table 6. In comparison with varieties and fertilizers, the rate of inorganic medium fertilizer (F_4) produced highest seed yield (2.740t/ha) in SAU sharisha-1 and the control treatment (F_0) gave the lowest seed yield per hectare (1.127 t/ha) in SAU sharisha-4. The present result agrees well with findings of Raju *et al.* (2006), Dinesh *et al.* (2005), Bhartendu and Gagendra (2004) and Kamta *et al.* (2003).

Table 6. Seed yield (t/ha) of mustard varieties (cv. SAU sharisha-1&4) as affected by vermicomposts and inorganic fertilizers

Varieties	Fertilizers	Seed yield (t/ha)
V_1	F_0	1.540 cd
	F_1	2.123 abc
	F_2	2.070 abc
	F_3	1.873bc
	F_4	2.740 a
	F_5	1.970 bc
V_2	F_0	1.970 bc
	F_1	1.127 d
	F_2	1.410 cd
	F_3	2.003 bc
	F_4	1.887 bc
	F_5	2.293 ab
Level of significance (%)		0.05

F_0= 0 t ha^{-1}; F_1 (Low Vermicompost)=1.5 t ha^{-1}; F_2(High Vermicompost)=2.5 t ha^{-1}; F_3(Low fertilizer)= (40kg N + 15kg P + 20kg K + 10kg S + 1.2kg Zn + 1.0kg B) ha^{-1}; F_4(Medium fertilizer)= (80kg N + 30kg P + 40kg K + 20kg S + 2.4kg Zn + 2.0kg B) ha^{-1}; F_5(High fertilizer)= (120kg N + 45kg P + 60kg K + 30kg S + 3.6kg Zn + 3.0kg B) ha^{-1}.
(In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT).

4.8 Oil content

4.8.1 Varietal effects on oil content of mustard seed

The varietals effects on oil content of mustard are presented in appendix-II. In case of variety-2 (SAU sharisha-4) showed the highest oil percentage (44.1167%) was found and the lowest oil percentage (43.1%) was found from variety-1 (SAU sharisha-1).

4.8.2 Effect of fertilizers

There was no significant effect of vermicompost and inorganic fertilizers on oil content of mustard applied alone. The oil contents were the lowest in control treatments and it increased with increasing rates of fertilizers, when applied alone. In the present study, significant variation was found in oil content at different levels of fertilizers. Application of medium inorganic fertilizer (F_4) gave highest oil percentage (44.4%) and the lowest oil percentage (43.05%) by the application of control treatment (F_0) which is showed in appendix III and Figure 12.

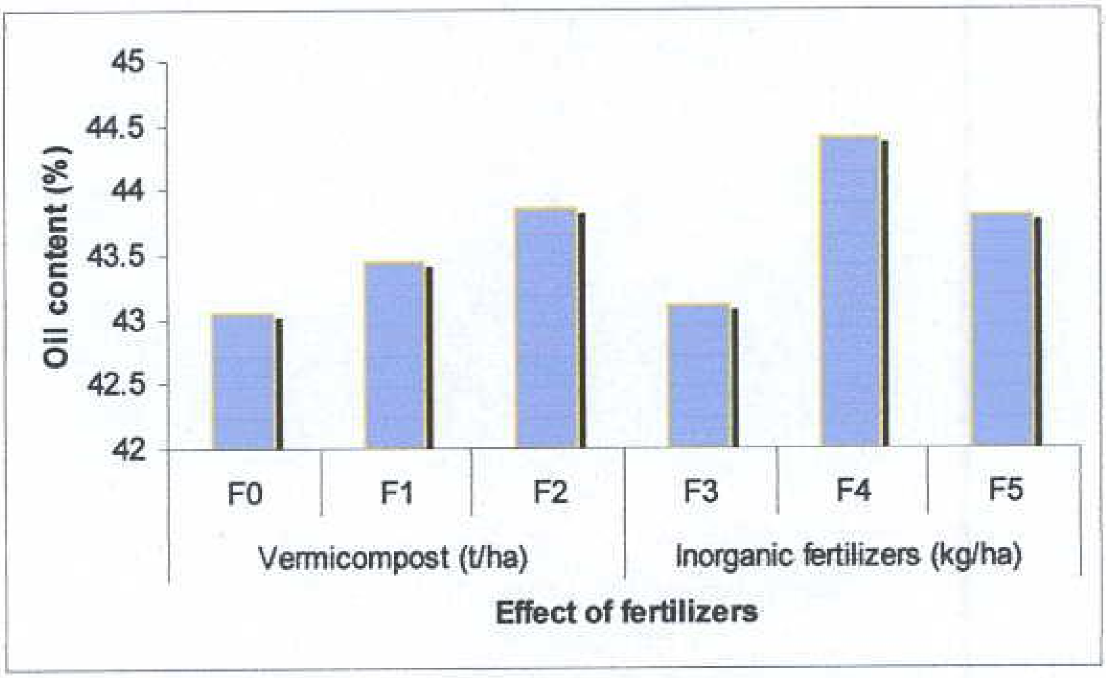

Fig. 12 Effects of different doses of vermicompost and inorganic fertilizer on the oil content of mustard seed

4.8.3 Effects between varieties and fertilizers

The effects of varieties and fertilizers on oil content of mustard are presented in appendix-I and Table 7. In comparison with varieties and fertilizers, application of medium fertilizer (F_4) showed the highest oil percentage (45.2%) in variety-2 (SAU sharisha-4) and the lowest oil percentage (42.5%) were found by the application of control treatment (F_0) in variety-1 (SAU sharisha-1). The result agrees well with the findings of Kumar *et al.* (2005); Amar and Meena (2003) and Jagvir *et al.* (2004).

Table 7. The effect of different doses of vermicompost and inorganic fertilizer on the oil content of mustard varieties (SAU sharisha-1&4)

Varieties	Fertilizers	Oil content (%)
V_1	F_0	42.5
	F_1	42.9
	F_2	43.6
	F_3	42.8
	F_4	43.6
	F_5	43.2
V_2	F_0	43.6
	F_1	44.0
	F_2	44.1
	F_3	43.4
	F_4	45.2
	F_5	44.4
Level of Significance (%)		NS

F_0= 0 t ha^{-1}; F_1 (Low Vermicompost)=1.5 t ha^{-1}; F_2(High Vermicompost)=2.5 t ha^{-1}; F_3(Low fertilizer)= (40kg N + 15kg P + 20kg K + 10kg S + 1.2kg Zn + 1.0kg B) ha^{-1}; F_4(Medium fertilizer)= (80kg N + 30kg P + 40kg K + 20kg S + 2.4kg Zn + 2.0kg B) ha^{-1}; F_5(High fertilizer)= (120kg N + 45kg P + 60kg K + 30kg S + 3.6kg Zn + 3.0kg B) ha^{-1}.

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

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the Sher-e-Bangla Agricultural University Farm (SAU Farm), Dhaka 1207 (Tejgaon series under AEZ No. 28). During the rabi season of 2009-2010 to study the performance of vermicompost and inorganic fertilizers on growth, yield, chemical composition and oil content of mustard. Randomized complete block design was followed with twelve treatments having unit plot size 3m × 2m ($6m^2$) replicated thrice. In the experiment, vermicompost and inorganic fertilizers (N, P, K, S, Zn, and B) were used. The treatments were control T_1 (V_1F_0)=(SAU sharisha-1 with no vermicompost, T_2 (V_1F_1)= (SAU sharisha-1 with medium vermicompost), T_3(V_1F_2)=(SAU sharisha-1 with high vermicompost), T_4 (V_1F_3)= (SAU sharisha-1 with low fertilizer), T_5 (V_1F_4)= (SAU sharisha-1 with medium fertilizer), T_6 (V_1F_5)= (SAU sharisha-1 with high fertilizer), T_7 (V_2F_0)= (SAU sharisha-4 with no vermicompost), T_8 (V_2F_1)= (SAU sharisha-4 with medium vermicompost), T_9 (V_2F_2)= (SAU sharisha-4 with high vermicompost), T_{10} (V_2F_3)= (SAU sharisha-4 with low fertilizer), T_{11} (V_2F_4)= (SAU sharisha-4 with medium fertilizer), T_{12} (V_2F_5)= (SAU sharisha-4 with high fertilizer). Nitrogen from urea, phosphorus from TSP, potassium from muriate of potash (MP), sulphur from gypsum, zinc from zinc sulphate ($ZnSO_4$) and boron from boric acid were applied. Half of the urea and whole amount of inorganic fertilizers were used as basal dose and the whole required amounts of vermicompost was applied in line during sowing and the rest of urea was top dressed after irrigation.

Mustard seeds (cv. SAU sharisha-1&4) were sown on 8th November, 2010 and the crop was harvested on 17th February 2011. Intercultural operations were done when required. The data was collected plot wise for plant height, number of primary and secondary branches per plant, number of siliqua per plant, number of seeds per siliquae, number of seeds per plant and yield. All the data were statistically analyzed following F-test and the mean comparison was made by Duncan's Multiple Range Test (DMRT) at 5% level of significance. The results of the experiment are stated below.

Seed yield of mustard responded significantly to the inorganic fertilizer treatments. The highest seed yield (2.740 t ha^{-1}) was obtained from SAU sharisha-1 in T_5 (V_1F_{54}) (medium fertilizer) treatment. The lowest seed yield (1.127 t ha^{-1}) was observed from SAU sharisha-1 in the control viz. T_7 (V_2F_0), which received neither vermicompost nor fertilizer. The results revealed that when inorganic fertilizers were applied that the effect showed better performance on yield rather than applying vermicompost alone. The highest plant height (118.8 cm) was recorded from SAU sharisha-4 in T_{12} (V_2F_5) (high fertilizer) treatment and the lowest (94.53 cm) was observed from SAU sharisha-1 in T_1 (V_1F_0) control (no vermicompost).

Oil content of mustard seed was not influenced significantly by the application of vermicompost and inorganic fertilizers. The highest oil content in seed (45.2%) was recorded from SAU sharisha-4 in T_5 (V_2F_4) (medium fertilizer) and the lowest oil content (42.5%) was obtained from SAU sharisha-1 by the application of T_1 (V_1F_0) treatment (no vermicompost).

The seed yield of mustard (cv. SAU sharisha-1&4) increased markedly due to inorganic fertilizer application in soil. Higher dose of fertilizer did not exert any negative effect on the crop. So, the rate (80 kg N/ha, 30 kg P_2O_5/ha, 40 kg K_20/ha, 20 kg S/ha, 2.4 kg Zn/ha and 2 kg B/ha) was found optimum for higher seed yield of mustard.

Considering the situation of the present experiment, further studies in the following areas may be recommended:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability;
2. Other organic and inorganic fertilizer may be included in the future study.
3. Chemical composition can be included in the further study.

Chapter VI
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CHAPTER VI
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Appendix 1: Effects on plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, number of seeds per siliquae, length of siliquae (cm), seed yield (t/ha) and oil content(%) of mustard

Varieties	Fertilizers	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of siliquae per plant	Number of seeds per siliquae	Length of siliquae (cm)	Seed yield (t/ha)	Oil content (%)
V_1	F_0	94.53 e	5.767 ab	1.233 c	145.0 bc	22.02 ab	4.810 d	1.540 cd	42.5
	F_1	96.7 de	6.867 a	2.433 bc	183.7 ab	22.33 a	6.003 ab	2.123 abc	42.9
	F_2	100.5 cde	6.433 ab	2.200 bc	184.3 ab	22.10 ab	5.690 abc	2.070 abc	43.6
	F_3	98.03 de	4.833 b	1.667 bc	191.1 a	21.70 ab	5.560 abcd	1.873 bc	42.8
	F_4	101.3 cde	5.867 ab	1.000 c	191.3 a	22.66 a	5.377 bcd	2.740 a	43.6
	F_5	107.1 bc	7.000 a	2.633 bc	188.3 a	19.69 ab	5.520 abcd	1.970 bc	43.2
V_2	F_0	97.10 de	6.000 ab	5.933 a	122.0 c	17.84 b	5.133 cd	1.127 d	43.4
	F_1	107.0 bc	6.867 a	6.633 a	145.5 bc	18.73 ab	5.678 abc	1.410 cd	44.0
	F_2	113.3 ab	6.800 a	7.100 a	171.6 ab	18.99 ab	6.140 ab	2.003 bc	44.1
	F_3	101.4 cd	6.833 a	6.600 a	180.1 ab	18.28 ab	5.423 bcd	1.887 bc	43.4
	F_4	108.3 b	7.367 a	6.400 a	188.3 a	18.37 ab	6.150 ab	2.293 ab	45.2
	F_5	118.8 a	6.167 ab	4.667 ab	187.25 a	18.85 ab	6.297 a	1.880 bc	44.4
Level of significance (%)		**	**	**	**	**	**	**	NS
LSD(0.05)		5.906	1.460	2.771	38.18	3.797	0.7263	0.6935	
CV (%)		18.82	13.47	25.05	13.78	11.13	7.44	33.74	

In a column, means followed by a common letter are not significantly differed at 5% level by DMRT
NS= Not significant, **= 5% level of significance.

Appendix 2: Varietal effects on plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, number of seeds per siliquae, length of siliquae (cm), seed yield (t/ha) and oil content of mustard

Varieties	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of siliquae per plant	Number of seeds per siliquae	Length of siliquae (cm)	Seed yield (t/ha)	Oil content (%)
V_1	99.69333	6.12783333	1.861	180.6167	21.75	5.493333	2.04666667	43.1
V_2	107.65	6.672333	6.222167	165.7917	18.51	5.8035	1.781667	44.11667

V_1= Variety-1 (SAU sharisha-1)
V_2= Variety-2 (SAU sharisha-4)

Appendix 3: Fertilizers effect on plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, number of seeds per siliquae, length of siliquae (cm), seed yield (t/ha) and oil content of mustard

Fertilizers		Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of siliquae per plant	Number of seeds per siliquae	Length of siliquae (cm)	Seed yield (t/ha)	Oil content (%)
Control	F_0	95.815	5.8835	3.583	133.5	19.93	4.9715	1.755	43.05
Vermicompost (t/ha)	F_1	101.85	6.867	4.533	164.6	20.53	5.8405	1.625	43.45
	F_2	106.9	6.6165	4.65	177.95	20.545	5.915	1.74	43.85
Inorganic (kg/ha)	F_3	99.715	5.833	4.1335	185.6	19.99	5.4915	1.92	43.1
	F_4	104.8	6.617	3.7	189.8	20.515	5.7635	2.3135	44.4
	F_5	112.95	6.5835	3.65	187.775	19.27	5.9085	2.1315	43.8

F_0(control)= 0 t ha^{-1}; F_1 (low vermicompost)=1.5 t ha^{-1}; F_2(high vermicompost)=2.5 t ha^{-1}; F_3(low fertilizer)= (40kg N + 15kg P + 20kg K + 10kg S + 1.2kg Zn + 1.0kg B) ha^{-1}; F_4(medium fertilizer)= (80kg N + 30kg P + 40kg K + 20kg S + 2.4kg Zn + 2.0kg B) ha^{-1}; F_5(high fertilizer)= (120kg N + 45kg P + 60kg K + 30kg S + 3.6kg Zn + 3.0kg B) ha^{-1}.

Appendix IV: Agro-ecological zone of Bangladesh

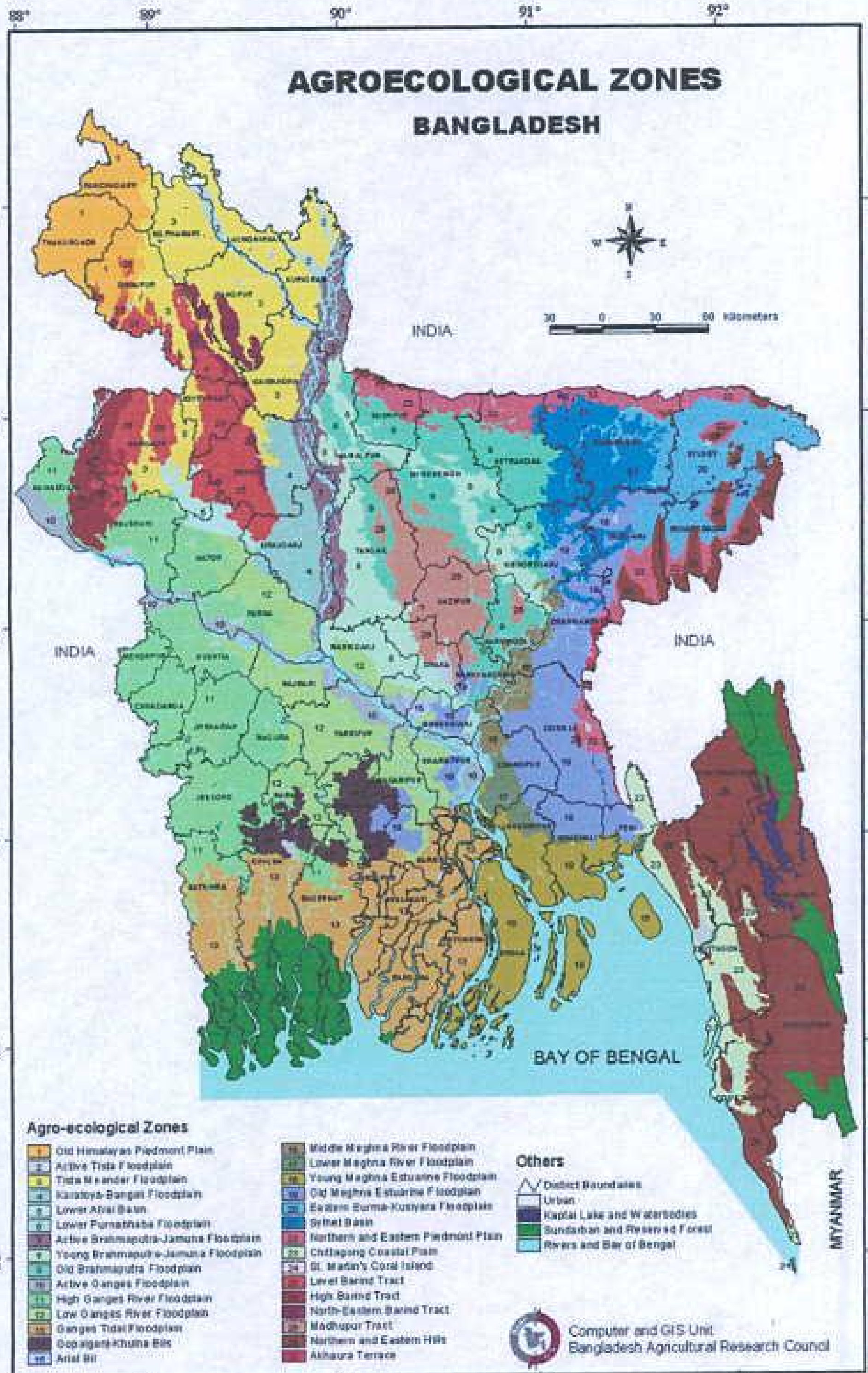

Plate 1: Agro-ecological zone of Bangladesh