EFFECT OF PHOSPHORUS AND MOLYBDENUM ON THE GROWTH, YIELD AND CHEMICAL COMPOSITION OF MUNGBEAN (*Vigna radiata* L.)

BY

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CERTIFICATE

This is to certify that the thesis entitled "**Effect of Phosphorus and Molybdenum on the Growth, Yield and Chemical Composition of Mungbean (*Vigna radiata* L.)**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in Soil Science, embodies the result of a piece of *bonafide* research work carried out by **Muhammad Arshad Miah**, Registration number: 00964 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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Dedicated To

My Beloved Parents

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ABSTRACT

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during March to May 2008 to study the effects of phosphorus (P) and molybdenum (Mo) on growth, yield and chemical composition of mungbean. The variety, BARI Mung-6 was used in this experiment as the test crop. The experiment consists of two factors: Factor A: Phosphorus (4 levels) namely, P_0: 0 kg P_2O_5 ha^{-1} (Control), P_{40}: 40 kg P_2O_5 ha^{-1},P_{80}: 80 kg P_2O_5 ha^{-1}, P_{120}: 120 kg P_2O_5 ha^{-1}, Factor B: Molybdenum (4 levels) namely, Mo_0: 0 kg Mo ha^{-1} (Control), $Mo_{0.25}$: 0.25 kg Mo ha^{-1}, $Mo_{0.50}$: 0.50 kg Mo ha^{-1} and $Mo_{0.75}$: 0.75 kg Mo ha^{-1}. Data on different yield contributing characters, yield and nutrient content in harvested seed and plant and nutrients concentration in soil were recorded. There was a positive impact of P and Mo and their interaction on growth, yield and yield attributes of mungbean. All the plant parameters were increased with increasing level of P (up to 80 kg/ha) and Mo (up to 0.50 kg/ha). Nutrient content in plant and seed were also increased with increasing level of P and Mo up to certain level. The highest N (3.88%), P (0.565%) and K (0.66%) content in seeds was found in $P_{40}Mo_0$, $P_{80}Mo_{0.50}$ and $P_{80}Mo_{0.50}$ treatment respectively. Nutrient content and organic matter in post harvest soil was also influenced by different levels of P and Mo application. The highest seed yield (1.27t/ha) and stover yield (1.68 t/ha) were obtained from the treatment $P_{80}Mo_{0.50}$ due to combined effect of P and Mo which was 64.9% and 75.0% higher over control treatment respectively. However, from the study it can be concluded that application of P_2O_5 @ 80 kg/ha and Mo @ 0.50 kg/ha was the most suitable combination for better yield of mungbean in Deep Red Brown Terrace Soils of Tejgaon Series in Bangladesh.

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LIST OF SYMBOLS AND ABBRIVIATIONS

ABBREVIATION	FULL WORD
@	At the rate
Cm	Centimeter
i.e	That is
%	Per cent
AEZ	Agro-Ecological Zone
CEC	Cation Exchange Capacity
$CuSO_4.5H_2O$	Copper Sulphate
cv.	Cultivar(s)
CV%	Percentage of Coefficient of Variance
DMRT	Duncan's Multiple Range Test
e.g.	example
et al	and others
FYM	Farm Yard Manure
g	Gram
H_3BO_3	Boric acid
$HClO_4$	Perchloric acid
HNO_3	Nitric acid
H_2O_2	Hydrogen per oxide
H_2SO_4	Sulfuric acid
K	Potassium
kg	Kilogram
kg ha^{-1}	Kg per hectare
K_2SO_4	Potassium Sulfate
LSD	Least Significant Difference
TSP	Triple Super Phosphate
m	Meter
ml	Milliliter
mm	Millimeter
MP	Muriate of Potash
N	Nitrogen
NaOH	Sodium Hydroxide
NPK	Nitrogen, Phosphorus and Potassium
NS	No Significant
OM	Organic matter
pH	Hydrogen ion concentration
^0C	Degree Celsius
No.	Number
SAU	Sher-e-Bangla Agricultural University
RCBD	Randomized Complete Block Design

Chapter 1

Introduction

Chapter I

INTRODUCTION

Bangladesh grows various types of pulse crops namely grasspea, lentil, mungbean, blackgram, chickpea, fieldpea and cowpea which are important pulse crops because they are the cheap source of easily digestible dietary protein. Pulse protein is rich in amino acids like isoleucine, leucine, lysine, valine etc. A minimum intake of pulse by a human should be 80 g per head per day, whereas it is only 14.19 g in Bangladesh (BBS, 2005).

Mungbean (*Vigana radiata* L.) is one of the most important pulse crops in Bangladesh. It is originated in South and Southeast Asia (India, Myanmar, Thailand etc.). Now it is widely grown in India, Pakistan, Bangladesh, Burma, Thailand, Philipines, China and Indonesia. It is also grown in parts of east and central Africa, the West Indies, USA and Australia (Gowda and Kaul, 1982). It has good digestibility, flavor, and high protein content. Mungbean grain contains 59.9% carbohydrates, 24.5% protein, 10% moisture, 4% mineral and 3% vitamins (Khan, 1981; Kaul, 1982). Its residues can be used as green manure. Being a short duration crop it fits well into the intensive cropping system of Bangladesh (Ahmed *et al.*, 1978).

In Bangladesh mungbean ranks third in acreage and production but ranks second in market price. The crop is potentially useful in improving cropping pattern as it can be grown as a crop due to its rapid growth and early maturing characteristics. At present the cash area under pulse crops is 0.337 million hectares with a production of 0.279 million tones where mungbean is cultivated in the area of 0.108 million hectares (BBS, 2005). The average yield of mungbean is 0.83 t ha^{-1}(BBS, 2006) which is very poor in comparison to other mungbean growing countries in the world.

There are many reasons of low yield of mungbean. The management of fertilizer is the important one that greatly affects the growth, development and yield of this crop. Mungbean cultivation covers an area of 22,267 hectares producing about 17,000 metric tons (BBS, 2006). The average production of mungbean in the country is about 741 kg/ha, which is much lower than that of India and some other countries.

Mungbean can also fix atmospheric nitrogen through the symbiotic relationship between the host mungbean roots and soil bacteria and thus improves soil fertility. It may play an important role to supplement protein in the cereal-based low-protein diet of the people of Bangladesh, but the acreage and production of mungbean is steadily declining (BBS, 2006). However, it is one of the least cared crops. Mungbean is cultivated with minimum land preparation and without fertilizer application and insect, diseases or weed control. All these factors are responsible for low yield of mungbean.

Phosphorus (P) is also one of the important essential macro elements for the normal growth and development of plant. Phosphorus requirements vary depending upon the nutrient content of the soil (Bose and Som, 1986). Phosphorus shortage restricted the plant growth and remains immature (Hossain, 1990). Mungbean is a short duration crop, for that easily soluble forms of fertilizers should be applied in the field. On the other hand nutrient availability in a soil depends on some factors. Among them balance fertilizer is the important one. The optimum proportion of fertilizers enhance the growth and development of a crop as well as ensures the availability of other essential nutrients for the plant. Again secondary mechanism of interference was the absorption of phosphorus from the soil through luxury consumption, increasing the tissue content without enhancing smooth biomass accumulation (Santos *et al.*, 2004).

Molybdenum (Mo) plays a vital role in legume crop as Mo plays a vital role in symbiotic nitrogen fixation. Application of molybdenum in combination with phosphate increases growth and uptake of nitrogen, phosphorus, potassium, molybdenum and also effective in symbiotic nitrogen fixation (Kadwe and Badhe, 1973).

Hence, the present study was undertaken to maximize the seed yield of mungbean with optimum phosphorus and molybdenum dose. Considering the above circumstances, the present investigation has been undertaken with the following objectives:

i. To determine the optimum dose of P for attaining maximum yield contributing characters and yield of mungbean under red terrace soil.

ii. To determine the optimum dose of Mo for attaining maximum yield contributing characters and yield of mungbean.

iii. To determine the combined effect of P and Mo for achieving maximum yield of mungbean.

iv. To find out the nutrients status of plant, seed and post harvest soil for the use of P and Mo.

Chapter 2

Review of Literature

Chapter II

REVIEW OF LITERATURE

Mungbean is one of the important pulse crops in Bangladesh as well as many countries of the world. The crop has conventional less concentration by the researchers on various aspects because normally it grows without less care or management practices. For that a very few studies on the related growth, yield and development of mungbean have been carried out in our country as well as many other countries of the world. So the research work so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings related to the phosphorus and molybdenum so far been done at home and abroad on this crop and other pulses have been reviewed in this chapter under the following headings-

2.1 Effect of phosphorus

A study was conducted by Nigamananda and Elamathi (2007) in Uttar Pradesh, India during 2005-06 to evaluate the effect of N application time as basal and as DAP (diammonium phosphate) or urea spray and plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram cv. K-851. The recommended rate of N:P:K (20:50:20 kg/ha) as basal was used as a control. Treatments included: 1/2 basal N + foliar N as urea or DAP at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea or DAP and 1/2 basal N + 1/2 foliar spraying as urea or DAP + 40 ppm NAA. Results showed that 2% foliar spray as DAP and NAA, applied at 35 DAS resulted in the highest values for number of pods/plant (38.3), seeds/pod, test weight, flower number, fertility coefficient, grain yield (9.66 q/ha).

Malik *et al*. (2006) conducted a field experiment in Faisalabad, Pakistan in 2000 and 2001 to evaluate the interactive effects of irrigation and phosphorus on green gram

(*Vigna radiata* cv. NM-54). Five phosphorus doses (0, 20, 40, 60 and 80 kg P ha^{-1}) were arranged in a split plot design with four replications. Phosphorus application at 40 kg P_2O_5 ha^{-1} affected the crop positively, while below and above this rate resulted in non-significant effects. Interactive effects of two irrigations and 40 kg P_2O_5 ha^{-1} were the most effective. The rest of the combinations remained statistically non-significant to each other. It may be concluded that greengram can be successfully grown with phosphorus at 40 kg P_2O_5 ha^{-1}.

Tickoo *et al.* (2006) carried out an experiment on mungbean and cultivars Pusa 105 and Pusa Vishal which were sown at 22.5 and 30.0 m spacing and was supplied with 36-46 and 58-46 kg of N/P/ha in a field experiment conducted in New Delhi, India during the kharif season of 2000. Cultivar Pusa Vishal recorded higher biological and grain yield (3.66 and 1.63 $^{t\ ha-1}$, respectively) compared to cv. Pusa 105.Nitrogen and phosphorus rates had no significant effects on both the biological and grain yield of the crop. Row spacing at 22.5 cm resulted in higher grain yields in both the cultivars.

A field experiment was conducted by Raman and Venkataramana (2006) during February to May 2002 in Annamalainagar, Tamil Nadu, India to investigate the effect of foliar nutrition on crop nutrient uptake and yield of greengram (*V. radiata*). There were 10 foliar spray treatments, consisting of water spray, 2% diammonium phosphate (DAP) at 30 and 45 days after sowing, 0.01% Penshibao, 0.125% Zn chelate, 30 ppm NAA, DAP + NAA, DAP + Penshibao, DAP + Zn chelate, DAP + Penshibao + NAA, and DAP + NAA + Zn chelate. Crop nutrient uptake, yield and its attributes (number of pods/plant and number of seeds/pod) of greengram augmented significantly due to foliar nutrition. The foliar application of DAP + NAA + Penshibao was significantly superior to other treatments in increasing the values of N, P and K uptakes, yield attributes and yield. The highest grain yield of 1529 kg/ha was recorded with this treatment.

Bhat *et al*. (2005) conducted a study during the summer of 2004 in Uttar Pradesh, India to examine the effects of phosphorus levels on greengram. Four phosphorus rates (0, 30, 60 and 90 kg/ha) were used. All the phosphorus rates increased the seed yield significantly over the control. The highest seed yield was observed with 90 kg P/ha, which was at a with 60 kg P/ha, and both were significantly superior to 30 kg P/ha. Likewise, 60 kg P/ha significantly improved the yield attributes except test weight compared to control. For the phosphorus rates, the stover yield followed the trend observed in seed yield.

A field experiment was conducted by Vikrant (2005) on a sandy loam soil in Hisar, Haryana, India during khatif 2000-01 and 2001-02 to study the effects of P (0, 20, 40 and 60 kg P_2O_5/ha) applications to green gram cv. Asha. Application of 60 kg P, being at par with 40 kg P, was significantly superior to 0 and 20 kg P/ha in respect of grain, stover and protein yields of green gram.

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

Oad and Buriro (2005) conducted a field experiment to determine the effect of different NPK levels (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg/ha) on the growth and yield of mungbean cv. AEM 96 in Tandojam, Pakistan, during the spring season of 2004.

The different NPK levels significantly affected the crop parameters. The 10-30-30 kg NPK/ha was the best treatment, recording plant height of 56.3, germination of 90.5%, satisfactory plant population of 162.0, prolonged days taken to maturity of 55.5, long pods of 5.02 cm, seed weight $^{plant-1}$of 10.5 g, seed index of 3.5 g and the highest seed yield of 1205.2 kg/ha. There was no significant change in the crop parameters beyond this level.

A field experiment was conducted by Edwin *et al.* (2005) during 1995 and 1996 pre-kharif seasons in Imphal, Manipur, India to study the effect of sources (Single superphosphate (SSP), diammonium phosphate (DAP), Mussoorie rock phosphate (MRP), phosphate solubilizing organism (PSO) and farmyard manure) and levels (10, 15, 30 and 60 kg P_2O_5/ha) of P on the growth and yield of greengram cv. AAU-34. The highest number of branches/plant(3.23) was obtained with 30 kg MRP + 30 kg SSP/ha. Single super phosphate at 60 kg/ha gave the highest number of clusters/plant(4.36), pod length (7.34 cm), seeds/pod (10.5), 1000-seed weight (34.9 g) and seed yield (15.1 q/ha). Maximum plant height (31.2 cm), dry matter/plant(36.1 g) and number of pods/plant(17.4) was obtained with 60 kg DAP/ha.

Khan *et al.* (2004) conducted a study to determine the effect of different levels of phosphorus on the yield components of mungbean cv. NM-98 in D.I. Khan, Pakistan in 2000. Treatments comprised: 0, 20, 40, 60, 80, and 100 kg P/ha. The increase in phosphorus levels decreased the days to flowering and increased the branches/plant, number of pods/ plant, 1000-grain weight and grain yield. The highest yield of 1022 kg/ha was obtained at the phosphorus level of 100 kg/ha compared to a 774-kg/ha yield in the control. However, the most economical phosphorus level was 40 kg/ha, because it produced a grain yield statistically comparable to 100 kg P/ha.

A field experiment was conducted by Manpreet *et al.* (2004) in Ludhiana, Punjab, India during summer 2000 to investigate the response of mungbean genotypes (SML 134, SML 357 and SML 668) to P application (0, 20, 40 and 60 kg P_2O_5/ha) under irrigated conditions. Yield attributes such as number of branches/plant and pods/plant were significantly higher in SML 357 and SML 134, whereas pod length and 100-seed weight were higher in SML 668, which accounted for higher grain yield in this cultivar compared to SML 134 but was at par with SML 357. The straw yield showed the reverse trend with significantly higher value for SML 134, thus lowering the harvest index significantly compared to SML 668 and SML 357. Phosphorus application showed a non-significant effect on number of branches/plant, number of seeds/pod, pod length and 100-seed weight. However, the increase in P level showed significant increase in the number of pods per plant, which accounted for significantly higher grain and straw yields at higher levels (40 and 60 kg/ha) compared to lower levels (0 and 20 kg/ha). Harvest index remained unaffected with P application. The economic optimum P level for all the 3 summer mungbean genotypes was found to be 46.1 kg P_2O_5/ha.

Nadeem *et al.* (2004) studied the response of mungbean cv. NM-98 to seed inoculation and different levels of fertilizer (0-0, 15-30, 30-60 and 45-90 kg N- P_2O_5 ha^{-1}) under field conditions. Application of fertilizer significantly increased the yield and the maximum seed yield was obtained when 30 kg N ha^{-1} was applied along with 60 kg P_2O_5 ha^{-1}.

Malik *et al.* (2003) conducted an experiment to determine the effect of varying levels of nitrogen (0, 25, and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98 in 2001. They observed that number of flowers/plant was found to be significantly higher by 25 kg N ha^{-1}. Number of seeds/pod was significantly affected by varying levels of nitrogen and phosphorus. Growth and yield components were significantly affected by varying levels of nitrogen and phosphorus. A fertilizer combination of 25 kg N + 75 kg P ha^{-1} resulted with maximum seed yield (1113 kg ha^{-1}).

Satish *et al*. (2003) conducted an experiment in Haryana, India in 1999 and 2000 to investigate the response of mungbean cultivars Asha, MH 97-2, MH 85-111 and K 851 to different P levels (0, 20, 40 and 60 kg P_2O_5/ha). Results revealed that the highest dry matter content in the leaves, stems and pods was obtained in Asha and MH 97-2. The total above-ground dry matter as well as the dry matter accumulation in leaves, stems and pods increased with increasing P level up to 60 kg P/ha. MH 97-2 and Asha produced significantly more number of pods and branches/plant compared to MH 85-111 and K 851. Phosphorus at 40 and 60 kg/ha increased the number of pods/plant, grain yield and grains per pod over the control and P at 20 kg/ha. The number of branches $^{plant-1}$increased with increasing P rates.

Rajender *et al*. (2002) investigated the effects of N (0, 10, 20 and 30 kg/ha) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T44. Grain yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect yield. The number of branches, number of pods/plant, number of seeds/pod, 1000-seed weight and straw yield increased with increasing rates P, whereas grain yield increased with increasing rates up to 40 kg P/ha only

Mahboob and Asghar (2002) studied the effect of seed inoculation at different nitrogen levels on mungbean at the Agronomic Research Station, Farooqabad in Pakistan. They revealed that various yield components like 1000-grain weight was affected significantly with 50-50-0 N kg ha^{-1} Pkg ha^{-1}K kg ha^{-1} application. Again they revealed that seed inoculation with 50-50-0 N kg ha^{-1}P kg ha^{-1}K kg ha^{-1} exhibited superior performance in respect of seed yield (955 kg ha^{-1}).

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

Srinivas *et al.* (2002) conducted an experiment on the performance of mungbean at different levels of nitrogen and phosphorus. Different rates of N (0, 25 and 60 kg ha^{-1}) and P (0, 25, 50 and 60 kg ha^{-1}) were tested. They observed that the number of pods/plant was increased with the increasing rates of N up to 40 kg/ha followed by a decrease with further increase in N. They also observed that 1000-seed weight was increased with increasing rates of N up to 40 kg ha^{-1} along with increasing rates of P which was was then followed by a decrease with further increase in N.

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

Two field experiments were conducted in Kalubia Governorate, Egypt, in 1999 and 2000 summer seasons by El-Metwally and Ahmed (2001) to investigate the effects of P levels (0, 15, 30 and 45 kg/feddan) on the growth, yield and yield components as well as chemical composition of mungbean cv. Kawmy-1. Growth, yield and yield components of mungbean were markedly improved with the addition of 45 kg P/feddan. Addition of 45 kg P/feddan markedly increased total carbohydrates and protein percentages compared with other treatments. Application of 45 kg P/feddan markedly increased the number of pods/plant. Addition of 30 kg P/feddan was the recommended treatments to obtain the best results for growth, yield and yield components as well as chemical composition of mungbean.

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

A field experiment was carried out by Sharma and Sharma (1999) during summer seasons at Golaghat, Assam, India. Mungbean was grown using farmers practices (no fertilizer) or using a combinations of fertilizer application (30 kg N + 35 kg P_2O_5 ha^{-1}). Seed yield was 0.40 ton ha^{-1} with farmers practices, while the highest yield was obtained by the fertilizer application (0.77 ton ha^{-1}).

Karle and Pawar (1998) examined the effect of varying levels of N and P fertilizers on summer mungbean. They reported that mungbean produced higher seed yield with the application of 15 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}.

Thakur *et al.* (1996) conducted an experiment with greengram (*Vigna radiata*) grown in kharif [monsoon] 1995 at Akola, Maharashtra,India which was given 0, 25, 50 or 75 kg P_2O_5/ha as single superphosphate or diammonium phosphate. Seed and straw yields were not significantly affected by P source, and seed yield averaged 0.91, 1.00, 1.24 and 1.13 ^{t} $^{ha-1}$ at the 4 P rates, respectively. Phosphorus uptake was also highest with 50 kg P_2O_5.

2.2 Effect of molybdenum

Rosolem and Caires (1998) reported that a high N-uptake had been observed in limed plots probably due to an increase in molybdenum availability.

Mandal *et al.* (1998) observed that dry matter yield of lentil was increased by the application of lime, P and Mo. Plant dry matter/pot was highest with 100% lime + 50 mg P + 1 mg Mo. Yield response to Mo application was highest, followed by lime and P.

Dwivedi *et al.* (1997) observed that soybean was given 0-12 kg P_2O_5 and 0-1.5 kg Mo/ha. Seed yield increased with increasing P and Mo rates.

Geetha *et al.* (1996) reported that pod yields of mungbean were significantly increased by seed treatment with 8 gm Mo/kg seed.

Sinha *et al.* (1994) observed that lentil cv. B77 was given 0.6 or 1.2 kg B/ha as borax, 4.4 kg Zn/ha as zinc sulphate or 0.5 kg Mo/ha as sodium molybdenum singly or in various combinations. Compared with the control yield, application of the trace elements increased seed yield between 14 and 55%. Application of Mo + Zn gave the highest seed yield of 2.29 t/ha, the highest net return.

Johal and Chahal (1994) noted that nodule numbers and dry weights of mungbean were greatest with 5 ppm Mo. Nodule leghaemoglobin content increased with up to 5 ppm Mo as did nodule nitrogenous activity.

Solaiman *et al.* (1991) carried out an experiment with two varieties of lentil, Utfala and Mymensingh local. They reported the 2 kg Mo/ha when applied with *Rhizobium* inoculant was found stimulating in respect of nodulation and dry matter production of the crop.

Ahmed (1988) observed that Mo application increased seed yield of green gram (*Vigna radiata)* by 28% and DM yield by 34%. All trace element treatments increased yield compared with the control.

Verma *et al.* (1988) observed that application of Mo and P increased the number and weight of nodules. Pod number and seed yield increased with Mo application up to the highest level. Similar trends were noted for seed protein content. Mo is potentially limiting factor for chickpea yields in similar alluvial soil.

Naphade and Wankhade (1987) observed that seed and straw yields of mungbean were increased significantly with 50kg S and 1.5 kg Mo/ha.

Paricha *et al.* (1983) conducted a field experiment with *Vigna radiata L.* and observed that Mo alone increased the yield by 26.4%.

Library

Chapter 3

Materials and Methods

Chapter III

MATERIALS AND METHODS

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during March to May 2008 to study the effect of phosphorus (P) and molybdenum (Mo) on the growth, yield and chemical composition of mungbean. This chapter consists of a short description of locations of the experimental site, characteristics of soil, climate, materials used for the experiments, treatment of the investigation, layout and design of the experiment, land preparation, manuring and fertilizing, intercultural operations, irrigation, harvesting, data collection procedure and statistical analysis etc. The details regarding materials and methods of this experiment are presented below under the following headings

3.1 Experimental site

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experimental site is situated between $23^0 74'$N latitude and $90^0 35'$E longitude (Anon. 1989).

3.2 Soil

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

Table 1. Physical and chemical characteristics of the initial soil

1. pH		6.0
2. Particle-size analysis of soil	Sand	29.04
	Silt	41.80
	Clay	29.16
3. Textural Class		Silty Clay Loam
4. Organic matter (%)		0.840
5. Total N (%)		0.0670
6. Phosphorous (ppm)		8.333
7. Exchangeable Potassium(me/100g soil)		25.00

3.3 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, the rabi season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Meteorological data related to the temperature, relative humidity and rainfalls during the period of the experiment was collected from the Bangladesh Meteorological Department (Climate Division), Sher-e-Bangla Nagar and presented in Appendix I.

3.4 Planting material

The variety, BARI Mung-6 was used as the test crop. The seeds were collected from the Pulse Research Centre of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. BARI Mung-6 is a recommended variety of mungbean, which was developed by the National Seed Board. It grows both in kharif and rabi season. Life cycle of this variety ranges from 55-60 days. Maximum seed yield is 1.1-1.4 t ha^{-1}.

3.5 Land preparation

The land was irrigated before ploughing. After having zoe condition the land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 4 operations of ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 20 February and 28 February 2008, respectively. Experimental land was divided into unit plots following the design of experiment. The plots were spaded one day before planting and the basal dose of fertilizers was incorporated thoroughly.

3.6 Fertilizer application

Urea, Triple Super Phosphate (TSP) and muriate of potash (MOP) were used as a source of nitrogen, phosphorous, and potassium, respectively. Total N and K_2O were applied @ 40 and 50 kg per hectare respectively following the BARI recommendation and phosphorus and molybdenum were applied as per treatment.

3.7 Treatments

The experiment consists of two factors:

Factor A: Phosphorus (4 levels)

i. P_0: 0 kg P_2O_5 ha^{-1} (Control)

ii. P_{40}: 40 kg P_2O_5 ha^{-1}

iii. P_{80}: 80 kg P_2O_5 ha^{-1}

iv. P_{120}: 120 kg P_2O_5 ha^{-1}

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Factor B: Molybdenum (4 levels)

i. Mo_0: 0 kg Mo ha^{-1} (Control)

ii. $Mo_{0.25}$: 0.25 kg Mo ha^{-1}

iii. $Mo_{0.50}$: 0.50 kg Mo ha^{-1}

iv. $Mo_{0.75}$: 0.75 kg Mo ha^{-1}

There were 16 treatment combinations such as P_0Mo_0, $P_0Mo_{0.25}$, $P_0Mo_{0.50}$, $P_0Mo_{0.75}$, $P_{40}Mo_0$, $P_{40}Mo_{0.25}$, $P_{40}Mo_{0.50}$, $P_{40}Mo_{0.75}$, $P_{80}Mo_0$, $P_{80}Mo_{0.25}$, $P_{80}Mo_{0.50}$, $P_{80}Mo_{0.75}$, $P_{120}Mo_0$, $P_{120}Mo_{0.25}$, $P_{120}Mo_{0.50}$ and $P_{120}Mo_{0.75}$.

3.8 Experimental design and layout

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. An area of 25.5 m × 9.0 m was divided into three equal blocks. Each block was divided into 16 plots where 16 treatment combinations were allotted at random. There were 48 unit plots altogether in the experiment. The size of the each unit plot was 2.0 m × 1.0 m. The distance maintained between two plots and two blocks were 0.5 m and 1.0 m, respectively. The layout of the experiment is shown in Figure 1.

3.9 Sowing of seeds in the field

The seeds of mungbean were sown on March 4, 2008. Seeds were treated with Bavistin 50WP (carbendazim) before sowing the seeds to control the seed borne diseases. The seeds were sown in rows in the furrows having a depth of 2-3 cm. Row to row distance was 50 cm.

3.10 Intercultural operations

3.10.1 Thinning

After sowing it took four days for seed germination (DAS). Thinning was done two times; first thinning was done at 8 DAS and second was done at 15 DAS to maintain proper population in each plot.

3.10.2 Irrigation and weeding

Irrigation was done as per requirements. The crop field was weeded twice; first weeding was done at 15 DAS and second weeding was done at 30 DAS.

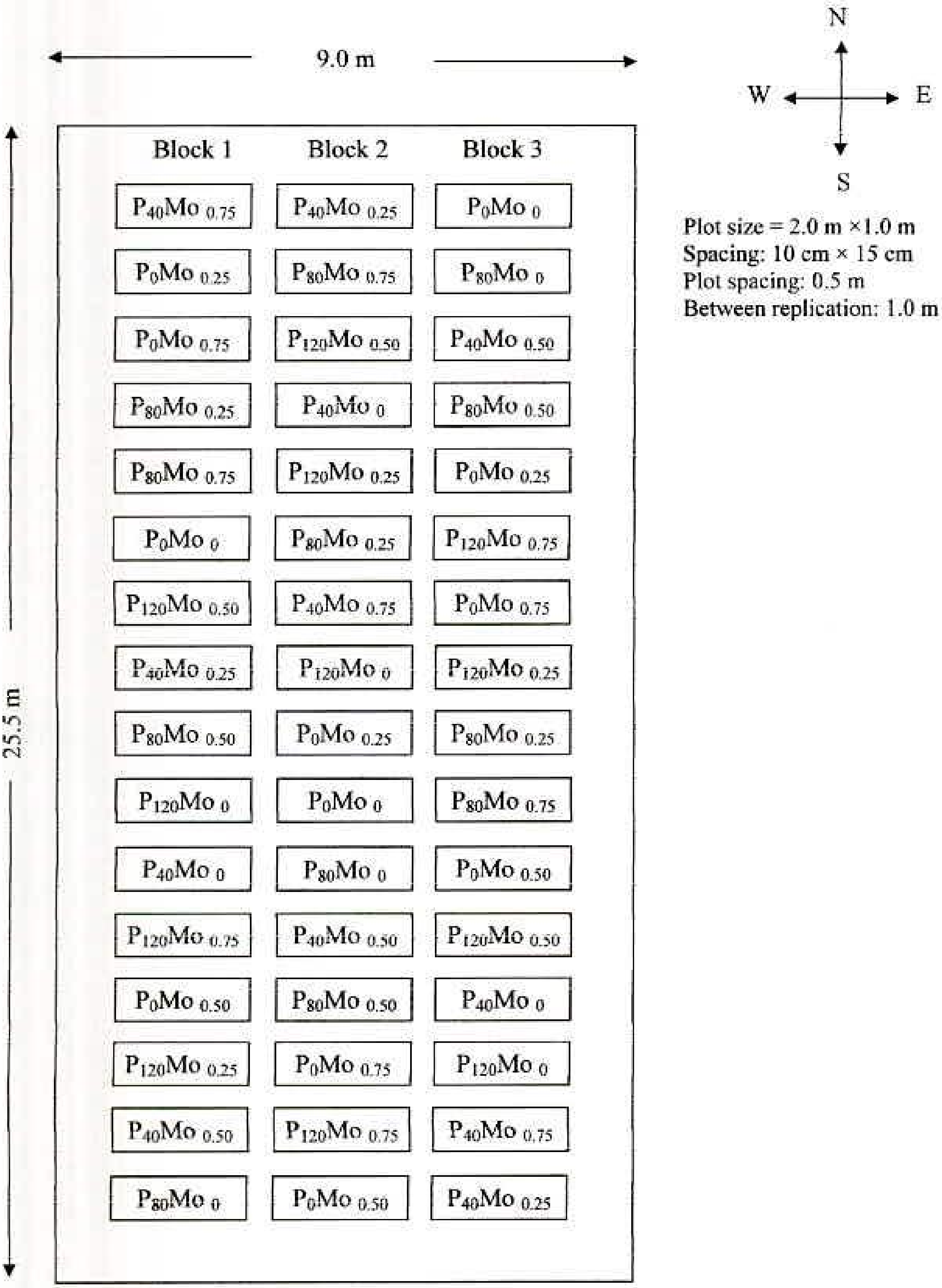

Figure 1. Field layout of two factors experiment in the Randomized Complete Block Design (RCBD)

3.10.3 Protection against insect and pest

At early stage of growth few worms (*Agrotis ipsilon*) and virus vectors (Jassid) attacked the young plants and at latter stage of growth pod borer (*Maruca testulalis*) attacked the plant. Agromethrin 10 EC was sprayed at the rate of 1 ml/L water to control the pest.

3.11 Crop sampling and data collection

Ten plants from each treatment were randomly sampled and marked with sampling card. The data of plant height, number of leaves, branches, pods/plant, pod length, yield were recorded from sampled plants

3.12 Harvest

The crop was harvested at maturity on 4th May 2008. The matured pods were collected by hand picking from a pre demarcated area of 1 m^2 at the center of each plot.

3.13 Data collection

The following data were recorded

i. Plant height (cm)
ii. Number of leaves $plant^{-1}$
iii. Number of branches $plant^{-1}$
iv. Number of pods $plant^{-1}$
v. Pod length (cm)
vi. Number of seeds pod^{-1}
vii. 1000- seed weight (g)
viii. Seed yield (t ha^{-1})
ix. Stover yield (t ha^{-1})

3.14 Procedure of data collection

3.14.1 Plant height (cm)

The heights were measured with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot during harvest.

3.14.2 Number of leaves/plant

The leaves (trifoliate) were counted from selected plants. The average number of leaves/was determined. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot during harvest.

3.14.3 Number of branches/plant

The branches were counted from selected plants. The average number of branches/was determined. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot during harvest.

3.14.4 Number of pods/plant

Number of total pods of selected plants from each plot was counted and the mean number was expressed on plant^{-1}basis. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot.

3.14.5 Pod length

Pod length of selected plants from each plot was counted and the mean length was expressed on per pod basis. Data were recorded as the average of 10 pods selected at random from the inner rows plant of each plot.

3.14.6 Number of seeds per pod

The number of seeds in each pod was also recorded from randomly selected pods at the harvest. Data were recorded as the average of 10 pods selected at random from the inner rows of each plot.

3.14.7 Weight of 1000-seed (g)

One thousand cleaned dried seeds were counted randomly from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g). Data were recorded as the average of 10 plants selected at random from the inner rows.

3.14.8 Seed yield (t ha^{-1})

The seeds collected from 1.0 m^2 of each plot were sun dried properly. The weight of seeds was taken and converted into the yield t ha^{-1}.

3.14.9 Stover yield (t ha^{-1})

The stover collected from1.0 m^2 of each plot was sun dried properly. The weight of stovers were taken and converted into the yield t ha^{-1}.

3.15 Chemical analysis of plant samples

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

3.15.1 Nitrogen

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

3.15.2 Phosphorous

The grounded plant samples and seeds were digested with conc. HNO_3 and $HClO_4$ mixture for the determination of P. Phosphorous in the digest was determined by ascorbic acid Blue Color Method (Murphy and Riley, 1962) with the help of a Spectrophotometer.

3.15.3 Potassium

The grounded plant samples and seeds were digested with conc. HNO_3 and $HClO_4$ mixture for the determination of K. Potassium content in plant sample was determined by flame photometer.

3.16 Soil sample analysis

3.16.1 Organic carbon

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

3.16.2 Organic matter

Soil organic carbon was determined by Wet Oxidation method as out lived by Jackson (1973). Organic mater content was calculated by multiplying the percent organic carbon with the Van Bemmelin factor of 1.723 (Piper, 1950)

3.16.3 Total nitrogen

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

3.16.4 Available Phosphorous

Available phosphorous was extracted from the soil by Bray-1 method (Bray and Kurtz, 1945). Phosphorous in the extract was determined by Ascorbic Acid Blue Color Method (Murphy and Riley, 1962) with the help of a Spectrophotometer.

3.16.5 Exchangeable potassium

Exchangeable potassium in the soil sample was extracted with 1N neutral ammonium acetate and the potassium content was determined by flame photometer as described by page *et al.* (1989).

3.17 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference at different levels of phosphorus and molybdenum on yield and yield attributes of mungbean. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

Chapter IV
RESULTS AND DISCUSSION

The study was conducted to determine the effect of phosphorus (P) and molybdenum (Mo) on the growth, yield and chemical composition of mungbean. Data on different yield contributing characters, yield and nutrient content in harvested seed and plant and nutrients concentration in soil were recorded to find out the optimum levels of phosphorus and molybdenum on mungbean. The analysis of variance (ANOVA) of the data on different yield components and yield are given in Appendix II-VI. The results have been presented and discussed, and possible interpretations have been given under the following headings:

4.1 Effect of P and Mo on growth and yield of Mungbean

4.1.1 Plant height

Plant height of mungbean varied significantly due to the application of different level of phosphorus (Appendix II). The longest plant (53.61 cm) was recorded under P_{80} treated plot which was followed (50.39 cm) by P_{120}, while the shortest plant (48.78 cm) was recorded in P_{40} treated plot which was statistically similar (50.15 cm) with P_0 (Table 2). Probably, phosphorus ensured the availability of other essential nutrients. As a result maximum growth was occurred and the ultimate results were the maximum plant height. Edwin *et al.* (2005) reported that maximum plant height (71.20 cm) was obtained in greengram with 60 kg DAP/ha. Malik *et al.* (2006) reported that phosphorus application at 40 kg P_2O_5 ha^{-1} affected the crop positively, while rates below and above this rate resulted in non-significant manner.

Application of molybdenum showed statistically significant variation in terms of plant height of mungbean (Appendix II). The longest plant (52.70 cm) was recorded in $Mo_{0.50}$

which was statistically similar (51.39) with $Mo_{0.75}$ and the shortest plant (47.85 cm) was recorded in Mo_0 which was closely followed (50.98 cm) by $Mo_{0.25}$ (Table 2).

Combined effect of phosphorus and molybdenum showed statistically significant variation for plant height under the trial (Appendix II). The longest plant (57.00 cm) was recorded in $P_{80}Mo_{0.75}$ which was statistically identical (56.23 cm) with $P_{80}Mo_{0.50}$ and the shortest plant (47.00 cm) was recorded in $P_{40}Mo_0$ (Table 3).

4.1.2 Number of leaves plant^{-1}

Number of leaves per plant of mungbean differed significantly due to the application of different level of phosphorus (Appendix II). The maximum number of leaves per plant (9.81) was recorded in P_{80} which was statistically identical (9.33) with P_{120}, while the minimum number of leaves per plant (8.04) was recorded in P_0 which was closely followed (9.05) by P_{40} (Table 2). Probably, phosphorus ensured the availability of other essential nutrients as a result maximum growth was occurred and the ultimate results is the maximum number of leaves per plant. Bhat *et al.* (2005) observed 60 kg P/ha significantly improved the yield attributes compared to the control.

Statistically significant variation in terms of number of leaves per plant of mungbean was recorded for the application of molybdenum (Appendix II). The maximum number of leaves per plant (9.52) was recorded from $Mo_{0.75}$ which was statistically similar (9.49 and 9.24) with $Mo_{0.50}$ and $Mo_{0.25}$, respectively while the minimum number of leaves per plant (7.98) was recorded from Mo_0 (Table 2).

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Combined effect of phosphorus and molybdenum showed statistically significant variation for number of leaves per plant (Appendix II). The maximum number of leaves plant^{-1} (10.83) was recorded in $P_{80}Mo_{0.75}$ which was statistically identical (10.50) with $P_{80}Mo_{0.50}$ $P_{40}Mo_{0.25}$, $P_{40}Mo_{0.50}$, $P_{40}Mo_{0.75}$, $P_{80}Mo_{0.25}$, $P_{120}Mo_{0.25}$, $P_{120}Mo_{0.50}$ and $P_{120}Mo_{0.75}$ and the minimum number of leaves per plant (7.27) was recorded in P_0Mo_0 (Table 3).

Table 2. Main effect of phosphorus and molybdenum on the yield contributing characters of mungbean

Level of Phosphorus and Molybdenum	Plant height (cm)	Number of leaves/plant	Number of branches/plant	Number of pods/plant	Pod length (cm)
Effect of Phosphorus					
P_0	50.15 bc	8.04 c	1.03 b	14.46 b	6.42 b
P_{40}	48.78 c	9.05 b	1.22 a	14.78 b	6.86 a
P_{80}	53.61 a	9.81 a	1.30 a	16.65 a	6.96 a
P_{120}	50.39 b	9.33 ab	1.21 a	15.52 ab	6.86 a
$LSD_{(0.05)}$	1.527	0.705	0.142	1.309	0.275
Significance level	0.01	0.01	0.01	0.01	0.01
Effect of Molybdenum					
Mo_0	47.85 c	7.98 b	1.12 bc	14.20 b	5.97 b
$Mo_{0.25}$	50.98 b	9.24 a	1.24 ab	15.51 ab	6.90 a
$Mo_{0.50}$	52.70 a	9.49 a	1.30 a	16.64 a	7.17 a
$Mo_{0.75}$	51.39 ab	9.52 a	1.09 c	15.07 b	7.05 a
$LSD_{(0.05)}$	1.527	0.705	0.142	1.309	0.275
Significance level	0.01	0.01	0.05	0.01	0.01
CV (%)		9.33	8.33	10.22	4.88

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 3. Combined effect of phosphorus and molybdenum on the yield contributing characters of mungbean

Phosphorus × Molybdenum	Plant height (cm)	Number of leaves/plant	Number of branches/plant	Number of pods/plant	Pod length (cm)
P_0Mo_0	48.33 cde	7.27 e	0.97 c	13.03 e	5.66 g
$P_0Mo_{0.25}$	50.20 b-e	8.77 b-e	1.10 bc	14.13 b-e	6.62 cde
$P_0Mo_{0.50}$	52.13 b	8.10 cde	1.05 bc	15.7 a-e	6.54 def
$P_0Mo_{0.75}$	49.93 b-e	8.03 de	0.99 c	14.95 a-e	6.85 bcd
$P_{40}Mo_0$	47.00 e	7.60 e	1.23 abc	13.80 cde	5.97 fg
$P_{40}Mo_{0.25}$	50.20 b-e	9.30 a-d	1.20 abc	15.43 a-e	6.92 a-d
$P_{40}Mo_{0.50}$	50.57 bcd	9.57 a-d	1.27 abc	16.60 abc	7.39 ab
$P_{40}Mo_{0.75}$	47.33 de	9.73 abc	1.16 bc	13.28 de	7.15 a-d
$P_{80}Mo_0$	48.87 b-e	8.47 b-e	1.20 abc	15.17 a-e	6.07 efg
$P_{80}Mo_{0.25}$	52.33 b	9.43 a-d	1.33 ab	17.00 ab	7.10 a-d
$P_{80}Mo_{0.50}$	56.23 a	10.50 a	1.51 a	18.00 a	7.51 a
$P_{80}Mo_{0.75}$	57.00 a	10.83 a	1.16 bc	16.45 abc	7.16 a-d
$P_{120}Mo_0$	47.20 de	8.60 b-e	1.08 bc	14.80 b-e	6.19 efg
$P_{120}Mo_{0.25}$	51.20 bc	9.47 a-d	1.33 ab	15.47 a-e	6.97 a-d
$P_{120}Mo_{0.50}$	51.87 bc	9.80 ab	1.36 ab	16.22 a-d	7.24 abc
$P_{120}Mo_{0.75}$	51.30 bc	9.47 a-d	1.05 bc	15.62 abcde	7.03 abcd
$LSD_{(0.05)}$	3.055	1.410	0.284	2.618	0.551
Significance level	0.05	0.05	0.05	0.05	0.05
CV (%)	7.61	9.33	8.33	10.22	4.88

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

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4.1.3 Number of branches plant $^{-1}$

Number of branches per plant of mungbean varied significantly due to the application of different level of phosphorus (Appendix II). The maximum number of branches per plant (1.30) was recorded in P_{80} which was statistically identical (1.22 and 1.21) with P_{40} and P_{120}, respectively. On the other hand the minimum number of branches per plant (1.03) was recorded in P_0 treated plot (Table 2). Probably, phosphorus ensured the availability of other essential nutrients as a result maximum growth was occurred and the ultimate results is the maximum number of branches per plant.

Number of branches per plant of mungbean differed significantly due to the application of molybdenum (Appendix II). The maximum number of branches per plant (1.30) was recorded in $Mo_{0.50}$ which was statistically similar (1.24) with $Mo_{0.25}$, while the minimum number of branches per plant (1.09) was recorded in $Mo_{0.75}$ (Table 2).

Combined effect of phosphorus and molybdenum showed statistically significant differences for number of branches per plant (Appendix II). The maximum number of branches per plant (1.51) was recorded in $P_{80}Mo_{0.50}$ which was statistically identical with $P_{120}Mo_{0.50}$, $P_{40}Mo_0$, $P_{40}Mo_{0.25}$, $P_{40}Mo_{0.50}$, $P_{40}Mo_{0.75}$, $P_{80}Mo_0$, $P_{80}Mo_{0.25}$, $P_{120}Mo_{0.25}$ and $P_{120}Mo_{0.50}$ and the minimum number of branches per plant (0.97) was recorded in P_0Mo_0 (Table 3).

4.1.4 Number of pods plant $^{-1}$

Application of different level of phosphorus influenced significantly on the number of pods per plant of mungbean (Appendix II). The maximum number of pods per plant (16.65) was recorded in P_{80} which was statistically identical (15.52) with P_{120}. On the other hand the minimum number of pods per plant (14.46) was recorded in P_0 (Table 2). Probably, phosphorus ensured the availability of other essential nutrients as a result maximum growth was occurred and the ultimate results is the maximum number of pods per plant.

Application of molybdenum showed statistically significant variation in terms of number of pods per plant of mungbean (Appendix II). The maximum number of pods per plant (16.64) was recorded in $Mo_{0.50}$ which was statistically similar (15.51) with $Mo_{0.25}$, while the minimum number of pods per plant (14.20) was recorded in Mo_0 (Table 2). Verma *et al.* (1988) reported that pod number and seed yield increased with Mo application up to the highest level

Combined effect of phosphorus and molybdenum showed statistically significant variation for number of pods per plant (Appendix II). The maximum number of pods per plant (18.00) was recorded from $P_{80}Mo_{0.50}$ which was statistically identical with $P_{80}Mo_{0.25}$, $P_0Mo_{0.50}$, $P_0Mo_{0.75}$, $P_{40}Mo_{0.25}$, $P_{40}Mo_{0.50}$, $P_{80}Mo_0$, $P_{80}Mo_{0.25}$, $P_{80}Mo_{0.75}$, $P_{120}Mo_{0.25}$, $P_{120}Mo_{0.50}$ and $P_{120}Mo_{0.75}$ and the minimum number of pods per plant (13.03) was recorded from P_0M_0 (Table 3).

4.1.5 Pod length

Pod length of mungbean varied significantly due to the application of different levels of phosphorus (Appendix II). The maximum pod length (6.96 cm) was recorded in P_{80} treated plot which was statistically identical with P_{40} and P_{120}, respectively. On the other hand the minimum pod length (6.42 cm) was recorded under P_0 treatment (Table 2). Bhat *et al.* (2005) observed 60 kg P/ha significantly improved the yield attributes compared to the control.

Application of molybdenum showed statistically significant variation in terms of pod length of mungbean (Appendix II). The maximum pod length (7.17 cm) was recorded in

$Mo_{0.50}$ which was statistically similar (7.05 cm and 6.90 cm) with $Mo_{0.75}$ and $Mo_{0.25}$, while the minimum pod length (5.97 cm) was recorded under Mo_0 treatment (Table 2).

Combined effect of phosphorus and molybdenum showed statistically significant variation for pod length (Appendix II). The maximum pod length (7.51 cm) was recorded in $P_{80}Mo_{0.50}$ treatment plot which was statistically identical with $P_{120}Mo_{0.50}$, $P_{40}Mo_{0.25}$, $P_{40}Mo_{0.50}$, $P_{40}Mo_{0.75}$, $P_{80}Mo_{0.25}$, $P_{80}Mo_{0.75}$, $P_{120}Mo_{0.25}$, $P_{120}Mo_{0.50}$ and $P_{120}Mo_{0.75}$ and the minimum pod length (5.66 cm) was recorded in P_0Mo_0 treatment plot (Table 3).

4.1.6 Number of seeds pod^{-1}

Number of seeds per pod of mungbean varied significantly due to the application of different level of phosphorus (Appendix III). The maximum number of seeds per pod (10.28) was recorded in P_{80} which was statistically identical (10.05 and 9.89) with P_{120} and P_{40} and the minimum number of seeds per pod (9.47) was recorded in P_0 (Table 4) Application of molybdenum showed statistically significant variation in terms of number of seeds per pod of mungbean (Appendix III). The maximum number of seeds per pod (10.69) was recorded in $M_{0.50}$ which was significantly higer over $M_{0.25}$ and $M_{0.75}$ and the minimum number of seeds per pod (8.99) was recorded in M_0 (Table 4).

Combined effect of phosphorus and molybdenum showed statistically significant variation for number of seeds per pod (Appendix III). The maximum number of seeds per pod (11.03) was recorded in $P_{80}Mo_{0.75}$ treated plot which was statistically identical (10.90) with $P_{80}Mo_{0.50}$, $P_{80}Mo_{0.25}$, $P_{120}Mo_{0.25}$ and $P_{120}Mo_{0.50}$ and the minimum number of seeds per pod (8.73) was recorded in P_0Mo_0 treated plot (Table 5)

4.1.7 Weight of 1000 seeds

Weight of 1000 seeds of mungbean varied significantly due to the application of different level of phosphorus (Appendix III). The maximum weight of 1000 seeds (46.75 g) was recorded in P_{80} which was higher over P_{120} and P_{40} and the minimum weight of 1000 seeds (43.25 g) was recorded in P_0 (Table 4). Srinivas *et al.* (2002) observed that 1000-seed weight was increased with increasing rates of N up to 40 kg ha^{-1}.

Table 4. Main effect of phosphorus and molybdenum on the yield and yield attributes of mungbean

Level of Phosphorus and Molybdenum	Number of seeds/pod	Weight of 1000 seeds (g)	Seed yield (t/ha)	Stover yield (t/ha)
Effect of Phosphorus				
P_0	9.47 b	43.25 c	0.88 b	1.22 b
P_{40}	9.89 a	44.42 bc	0.99 ab	1.30 a
P_{80}	10.28 a	46.75 a	1.12 a	1.33 a
P_{120}	10.05 a	45.00 b	0.98 ab	1.32 a
$LSD_{(0.05)}$	0.41	1.58	0.13	0.07
Significance level	0.01	0.01	0.01	0.01
Effect of Molybdenum				
Mo_0	8.99 c	43.83	0.82 c	1.03 c
$Mo_{0.25}$	9.94 b	45.00	0.94 bc	1.24 b
$Mo_{0.50}$	10.69 a	45.33	1.18 a	1.62 a
$Mo_{0.75}$	10.06 b	45.25	1.03 b	1.29 b
$LSD_{(0.05)}$	0.41	--	0.13	0.07
Significance level	0.01	NS	0.01	0.01
CV (%)	8.92	4.23	9.22	6.07

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 5. Combined effect of phosphorus and molybdenum on the yield and yield attributes of mungbean

Phosphorus × Molybdenum	Number of seeds/pod	Weight of 1000 seeds (g)	Seed yield (t/ha)	Stover yield (t/ha)
P_0Mo_0	8.73 f	43.00 cd	0.77 e	0.96 e
$P_0Mo_{0.25}$	9.20 ef	43.33 bcd	0.86 e	1.20 cd
$P_0Mo_{0.50}$	10.50 abc	44.33 a-d	1.03 a-e	1.46 b
$P_0Mo_{0.75}$	9.43 def	42.33 d	0.86 e	1.25 c
$P_{40}Mo_0$	9.07 ef	42.33 d	0.81 e	1.03 e
$P_{40}Mo_{0.25}$	9.70 cde	44.00 bcd	0.90 de	1.23 c
$P_{40}Mo_{0.50}$	10.93 a	44.67 a-d	1.18 a-d	1.67 a
$P_{40}Mo_{0.75}$	9.87 b-e	46.67 abc	1.08 a-e	1.28 c
$P_{80}Mo_0$	9.00 ef	45.67 a-d	0.92 cde	1.06 e
$P_{80}Mo_{0.25}$	10.20 a-d	48.00 a	1.04 a-e	1.28 c
$P_{80}Mo_{0.50}$	10.90 a	47.00 ab	1.27 a	1.68 a
$P_{80}Mo_{0.75}$	11.03 a	46.33 abc	1.25 ab	1.30 c
$P_{120}Mo_0$	9.17 ef	44.33 a-d	0.79 e	1.07 de
$P_{120}Mo_{0.25}$	10.67 ab	44.67 a-d	0.96 a-e	1.25 c
$P_{120}Mo_{0.50}$	10.43 abc	45.33 a-d	1.23 abc	1.65 a
$P_{120}Mo_{0.75}$	9.92 b-e	45.67 a-d	0.95 b-e	1.31 c
$LSD_{(0.05)}$	0.82	3.17	0.27	0.13
Significance level	0.05	0.05	0.05	0.05
CV (%)	8.92	4.23	9.22	6.07

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Application of different rates of molybdenum differed with significant variation in terms of weight of 1000 seeds of mungbean (Appendix III). The maximum weight of 1000 seeds (45.33 g) was recorded in $Mo_{0.50}$ treated plot and the minimum weight of 1000 seeds (43.83 g) was recorded in Mo_0 treatment (Table 4).

Combined effect of phosphorus and molybdenum showed statistically significant variation for weight of 1000 seeds (Appendix III). The maximum weight of 1000 seeds (48.00 g) was recorded in $P_{80}Mo_{0.25}$ and the minimum weight of 1000 seeds (42.33 g) was recorded in $P_{40}Mo_0$ treated plot (Table 5).

4.1.8 Seed yield

Statistically significant variation was recorded in terms of seed yield of mungbean due to application of phosphorus at different level (Appendix III). The maximum seed yield (1.12 t/ha) was recorded in P_{80} treated plot which was statistically identical with P_{40} and P_{120} and the minimum seed yield (0.88 t/ha) was recorded in P_0 (Table 4). Malik *et al.* (2006) reported that phosphorus application at 40 kg P_2O_5 ha^{-1} affected the crop positively, while rates below and above this rate resulted in non-significant effects. Bhat *et al.* (2005) observed the highest seed yield with 90 kg P/ha, which was at par with 60 kg P/ha, and both were significantly superior to 30 kg P/ha. Likewise, 60 kg P/ha significantly improved the yield attributes except test weight compared to the control condition.

Application of different rates of molybdenum showed significant variation in terms of seed yield of mungbean (Appendix III).Seed yield of mungbean increased with increasing level of Mo up to certain level. The maximum seed yield (1.18 t/ha) was recorded in $Mo_{0.50}$ treated plot that differ from $Mo_{0.25}$ and $Mo_{0.75}$ and the minimum seed yield (0.82 t/ha) was recorded in Mo_0 treated plot (Table 4).

Application of phosphorus along with molybdenum showed statistically significant variation for seed yield (Appendix III). The maximum seed yield (1.27 t/ha) was recorded in $P_{80}Mo_{0.50}$ which was statistically identical (1.25 t/ha) with $P_{80}Mo_{0.75,}$ $P_0Mo_{0.50}$, $P_{40}Mo_{0.50}$, $P_{40}Mo_{0.75}$, $P_{80}Mo_{0.25}$, $P_{80}Mo_{0.75}$, $P_{120}Mo_{0.25}$ and $P_{120}Mo_{0.50}$ and the minimum seed yield (0.77 t/ha) was recorded in P_0Mo_0 treated plot (Table 5).Application of P_2O_5 @ 80 kg/ha and Mo @ 0.50 kg/ha produced 64.9% higher seed yield as compared to control treatment. Dwivedi *et al.* (1997) observed that soybean was given 0-12 kg P_2O_5 and 0-1.5 kg Mo/ha. Seed yield increased with increasing P and Mo rates.

4.1.9 Stover yield

Stover yield of mungbean varied significantly due to the application of different level of phosphorus (Appendix III). The maximum stover yield (1.33 t/ha) was recorded in P_{80} which was statistically identical (1.32 t/ha and 1.30 t/ha) with P_{120} and P_{40} and the minimum stover yield (1.22 t/ha) was recorded in P_0 treated plot (Table 4).

Application of molybdenum showed statistically significant variation in terms of stover yield of mungbean (Appendix III). The maximum stover yield (1.62 t/ha) was recorded in $Mo_{0.50}$ and the minimum stover yield (1.03 t/ha) was recorded in Mo_0 (Table 4). Naphade and Wankhade (1987) observed that seed and straw yields of mungbean were increased significantly with 1.5 kg Mo/ha.

Combined effect of phosphorus and molybdenum showed statistically significant variation for stover yield (Appendix III). The maximum stover yield (1.68 t/ha) was recorded in $P_{80}Mo_{0.50}$ which was statistically identical with $P_{40}Mo_{0.50}$ and $P_{120}Mo_{0.50}$ and the minimum stover yield (0.96 t/ha) was recorded in P_0Mo_0 treated plot (Table 5).

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4.2 Effect of P and Mo on chemical composition of mungbean

4.2.1 Concentration of N, P and K in mungbean plant

4.2.1.1 Concentration of N in plant

Concentration of N in plant of mungbean varied significantly due to the application of different level of phosphorus (Appendix IV). The highest concentration of N in plant (2.77%) was recorded in P_{120} treated plot which was statistically identical (2.72%) with P_{80} and the lowest concentration of N in plant (2.29%) was recorded in P_{40} (Table 6).

Application of molybdenum showed statistically significant variation in terms of concentration of N in plant of mungbean (Appendix IV). The highest concentration of N in plant (2.73%) was recorded from Mo_0 and the lowest concentration of N in plant (2.49%) was recorded in $Mo_{0.50}$ treated plot (Table 6). Rosolem and Caires (1998) reported that a high N-uptake had been observed in limed plots probably due to an increase in molybdenum availability.

Combined effect of P and Mo showed statistically significant variation for concentration of N in plant (Appendix IV). The highest concentration of N in plant (3.06%) was recorded from $P_{80}Mo_{0.25}$ which was statistically identical with $P_0Mo_{0.25}$ and $P_{120}Mo_{0.25}$ and the lowest concentration of N in plant (2.07%) was recorded from P_0Mo_0 (Table 7).

4.2.1.2 Concentration of P in plant

Concentration of P in plant of mungbean varied significantly due to the application of different level of phosphorus (Appendix IV). The highest concentration of P in plant (0.536%) was recorded in P_{120} treated plot which was statistically identical (0.514%) with P_{40} and the lowest concentration of P in plant (0.335%) was recorded in P_0 (Table 6).

Table 6. Main effect of phosphorus and molybdenum on N, P and K content in plant of mungbean

Level of Phosphorus and Molybdenum	Nutrient concentration in plant (%)		
	N	P	K
Effect of Phosphorus			
P_0	2.53 b	0.335 c	0.469 c
P_{40}	2.29 c	0.514 ab	0.615 a
P_{80}	2.72 a	0.465 b	0.557 b
P_{120}	2.77 a	0.536 a	0.540 b
$LSD_{(0.05)}$	0.124	0.059	0.046
Significance level	0.01	0.01	0.01
Effect of Molybdenum			
Mo_0	2.73 a	0.304 c	0.487 b
$Mo_{0.25}$	2.52 b	0.511 b	0.588 a
$Mo_{0.50}$	2.49 b	0.673 a	0.612 a
$Mo_{0.75}$	2.56 b	0.362 c	0.495 b
$LSD_{(0.05)}$	0.124	0.059	0.046
Significance level	0.01	0.01	0.01
CV (%)	5.73	8.94	9.55

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 7. Combined effect of phosphorus and molybdenum on the N, P and K content in plant of mungbean

Phosphorus × Molybdenum	Concentration in plant (%)		
	N	P	K
P_0Mo_0	2.07 f	0.326 e	0.157 g
$P_0Mo_{0.25}$	2.98 ab	0.584 cd	0.717 a
$P_0Mo_{0.50}$	2.49 e	0.145 f	0.662 ab
$P_0Mo_{0.75}$	2.49 e	0.287 e	0.342 f
$P_{40}Mo_0$	2.47 e	0.125 f	0.708 a
$P_{40}Mo_{0.25}$	2.14 f	0.722 b	0.551 cde
$P_{40}Mo_{0.50}$	2.07 f	0.925 a	0.638 abc
$P_{40}Mo_{0.75}$	2.49 e	0.283 e	0.564 b-e
$P_{80}Mo_0$	2.73 b-e	0.500 cd	0.463 e
$P_{80}Mo_{0.25}$	3.06 a	0.458 d	0.542 cde
$P_{80}Mo_{0.50}$	2.64 cde	0.604 c	0.630 abc
$P_{80}Mo_{0.75}$	2.52 de	0.297 e	0.594 bcd
$P_{120}Mo_0$	2.64 cde	0.266 e	0.621 abc
$P_{120}Mo_{0.25}$	2.91 abc	0.278 e	0.542 cde
$P_{120}Mo_{0.50}$	2.78 bcd	1.018 a	0.516 de
$P_{120}Mo_{0.75}$	2.75 b-e	0.582 cd	0.481 e
$LSD_{(0.05)}$	0.247	0.118	0.091
Significance level	0.01	0.01	0.01
CV (%)	5.73	8.94	9.55

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Application of molybdenum showed statistically significant variation in terms of concentration of P in plant of mungbean (Appendix IV). The highest concentration of P in plant (0.673%) was recorded in $Mo_{0.50}$ and the lowest concentration of P in plant (0.3049%) was recorded in Mo_0 treated plot which was statistically identical (0.362%) with $Mo_{0.75}$ (Table 6).

Combined effect of phosphorus and molybdenum showed statistically significant variation for concentration of P in plant (Appendix IV). The highest concentration of P in plant (1.018%) was recorded in $P_{120}Mo_{0.50}$ treated plot which was statistically identical (0.925%) with $P_{40}Mo_{0.50}$ and the lowest concentration of P in plant (0.125%) was recorded in $P_{40}Mo_0$ (Table 7).

4.2.1.3 Concentration of K in plant

Concentration of K in plant of mungbean varied significantly due to the application of different level of phosphorus (Appendix IV). The highest concentration of K in plant (0.615%) was recorded in P_{40} and the lowest concentration of K in plant (0.469%) was recorded in P_0 treated plot (Table 6).

Application of molybdenum showed statistically significant variation in terms of concentration of K in plant of mungbean (Appendix IV). The highest concentration of K in plant (0.612%) was recorded in $Mo_{0.50}$ which was statistically similar (0.588%) with $Mo_{0.25}$ and the lowest concentration (0.487%) was recorded in Mo_0 treated plot (Table 6).

Combined effect of phosphorus and molybdenum showed statistically significant variation for concentration of K in plant (Appendix IV). The highest concentration of K in plant (0.717%) was recorded in $P_0Mo_{0.25}$ which was statistically similar with $P_{40}Mo_0$, $PoMo_{0.25}$, $PoMo_{0.50}$, $P_{40}Mo_{0.50}$, $P_{80}Mo_{0.50}$ and $P_{120}Mo_0$ and the lowest concentration of K in plant (0.157%) was recorded in P_0Mo_0 (Table 7).

4.2.2 Concentration of N, P and K in seed

4.2.2.1 Concentration of N in seed

Concentration of N in seed of mungbean varied significantly due to the application of different level of phosphorus (Appendix V). The highest concentration of N in seed (3.50%) was recorded in P_{80} which was statistically identical (3.46%) with P_{40} and the lowest concentration of N in seed (3.24%) was recorded in P_{120} treated plot (Table 8).

Application of molybdenum showed statistically non significant variation in terms of concentration of N in seed of mungbean (Appendix V). Though, the highest concentration of N in seed (3.45%) was recorded in $Mo_{0.50}$ and the lowest (3.35%) was recorded in $Mo_{0.75}$ and $Mo_{0.25}$, respectively (Table 8).

Combined effect of phosphorus and molybdenum showed statistically significant variation for concentration of N in seed (Appendix V). The highest concentration of N in seed (3.88%) was recorded in $P_{40}Mo_0$ and the lowest concentration of N in seed (2.93%) was recorded in P_0Mo_0 treated plot (Table 9).

4.2.2.2 Concentration of P in seed

Concentration of P in seed of mungbean varied significantly due to the application of different levels of phosphorus (Appendix V). The highest concentration of P in seed (0.378%) was recorded in P_{80} which was statistically identical with P_{120} and P_{40}, respectively, and the lowest (0.299%) was recorded in P_0 (Table 8).

Application of molybdenum showed statistically significant variation in terms of concentration of P in seed of mungbean (Appendix V). The highest concentration of P in seed (0.496%) was recorded in $Mo_{0.50}$ and the lowest concentration of P in seed (0.208%) was recorded in Mo_0 (Table 8).

Table 8. Main effect of phosphorus and molybdenum on N, P and K content in seed of mungbean

Level of Phosphorus and Molybdenum	Nutrient content in seed (%)		
	N	P	K
Effect of Phosphorus			
P_0	3.33 b	0.299 b	0.363 c
P_{40}	3.46 a	0.357 a	0.403 b
P_{80}	3.50a	0.378 a	0.474 a
P_{120}	3.24 b	0.370 a	0.414 b
$LSD_{(0.05)}$	0.206	0.037	0.037
Significance level	0.01	0.01	0.01
Effect of Molybdenum			
Mo_0	3.39	0.208 c	0.368 c
$Mo_{0.25}$	3.35	0.349 b	0.426 b
$Mo_{0.50}$	3.45	0.496 a	0.464 a
$Mo_{0.75}$	3.35	0.351 b	0.396 bc
$LSD_{(0.05)}$	--	0.037	0.037
Significance level	NS	0.01	0.01
CV (%)	6.66	11.28	10.64

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

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Table 9. Combined effect of phosphorus and molybdenum on the N, P and K content in seed of mungbean

Phosphorus × Molybdenum	Nutrient content in seed (%)		
	N	P	K
P_0Mo_0	2.93 h	0.087 g	0.278 gh
$P_0Mo_{0.25}$	3.49 bcd	0.477 bc	0.485 b
$P_0Mo_{0.50}$	3.66 b	0.451 bcd	0.354 d-g
$P_0Mo_{0.75}$	3.24 efg	0.182 f	0.336 e-h
$P_{40}Mo_0$	3.88 a	0.200 f	0.464 b
$P_{40}Mo_{0.25}$	3.05 gh	0.342 e	0.289 fgh
$P_{40}Mo_{0.50}$	3.60 bc	0.508 ab	0.433 bcd
$P_{40}Mo_{0.75}$	3.33 def	0.380 de	0.428 bcd
$P_{80}Mo_0$	3.68 b	0.041 g	0.268 h
$P_{80}Mo_{0.25}$	3.40 cde	0.475 bc	0.602 a
$P_{80}Mo_{0.50}$	3.40 cde	0.575 a	0.657 a
$P_{80}Mo_{0.75}$	3.53 bcd	0.423 bcd	0.369 c-f
$P_{120}Mo_0$	3.07 gh	0.504 abc	0.464 b
$P_{120}Mo_{0.25}$	3.46 b-e	0.103 g	0.330 fgh
$P_{120}Mo_{0.50}$	3.12 fgh	0.451 bcd	0.413 b-e
$P_{120}Mo_{0.75}$	3.32 def	0.420 cde	0.451 bc
$LSD_{(0.05)}$	0.412	0.075	0.075
Significance level	0.01	0.01	0.01
CV (%)	6.66	11.28	10.64

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Combined effect of phosphorus and molybdenum showed statistically significant variation for concentration of P in seed (Appendix V). The highest concentration of P in seed (0.575%) was recorded from $P_{80}Mo_{0.50}$ which was statistically identical (0.504%) with $P_{120}Mo_0$ and the lowest concentration of P in seed (0.087%) was recorded in P_0Mo_0 (Table 9).

4.2.2.3 Concentration of K in seed

Concentration of K in seed of mungbean varied significantly due to the application of different level of phosphorus (Appendix V). The highest concentration of K in seed (0.474%) was recorded in P_{80} and P_{40} and the lowest concentration of K in seed (0.363%) was recorded in P_0 (Table 8).

Application of molybdenum showed statistically significant variation in terms of concentration of K in seed of mungbean (Appendix V). The highest concentration of K in seed (0.464%) was recorded in $Mo_{0.50}$ and the lowest concentration of K in seed (0.368%) was recorded in Mo_0 (Table 8).

Combined effect of phosphorus and molybdenum showed statistically significant variation for concentration of K in seed (Appendix V). The highest concentration of K in seed (0.657%) was recorded from $P_{80}Mo_{050}$ which was statistically similar with $P_{80}Mo_{0.25}$ and the lowest concentration of K in seed (0.268%) was recorded in $P_{80}Mo_0$ (Table 9).

4.3 Physical and chemical properties of post harvest soil

4.3.1 Soil pH

Application of different level of phosphorus varied significantly in terms of soil pH of mungbean land (Appendix VI). The maximum pH (5.10) was recorded from P_{120} which was statistically identical (5.04 and 5.03) with P_{80} and P_{40}, respectively and the minimum pH (4.86) was recorded from P_0 (Table 10).

Application of molybdenum showed statistically significant variation in terms of pH of mungbean (Appendix VI). The maximum pH (5.21) was recorded from $Mo_{0.75}$ which was statistically similar (5.14) with $Mo_{0.50}$ and the minimum pH (4.82) was recorded from Mo_0 (Table 10).

Interaction effect of phosphorus and molybdenum showed statistically significant variation for pH (Appendix VI). The maximum pH (5.28) was recorded from $P_{80}Mo_{0.75}$ which was statistically identical (5.24) with $P_{120}Mo_{0.75}$ and the minimum pH (4.66) was recorded from $P_{80}Mo_0$ (Table 11).

4.3.2 Organic matter content in post harvest soil

Organic matter in soil varied significantly due to the application of different level of phosphorus (Appendix VI). The highest organic matter in soil (1.05%) was recorded from P_{120} which was statistically identical (1.01%) with P_{40} and the lowest organic matter in soil (0.96%) was recorded from P_{80} Table 10).

Application of molybdenum showed statistically significant variation in terms of organic matter in soil of mungbean (Appendix VI). The highest organic matter in soil (1.04%) was recorded from $Mo_{0.75}$ which was statistically similar with $Mo_{0.25}$ and $Mo_{0.50}$ and the lowest organic matter in soil (0.94%) was recorded from Mo_0 (Table 10).

Table 10. Main effect of phosphorus and molybdenum on physical and chemical properties of post harvest soil

Level of Phosphorus and Molybdenum	Nutrient content%				
	pH	OM (%)	Nitrogen	Phosphorus	Potassium
Effect of Phosphorus					
P_0	4.86 b	0.97 bc	0.08 a	0.001602 d	0.0014b
P_{40}	5.03 a	1.01 ab	0.07 ab	0.002056 c	0.0014b
P_{80}	5.04 a	0.96 c	0.06 a	0.003119 b	0.0015a
P_{120}	5.10 a	1.05 a	0.07 ab	0.003378 a	0.0014b
$LSD_{(0.05)}$	0.079	0.046	0.008	2.404	--
Significance level	0.01	0.01	0.01	0.01	NS
Effect of Molybdenum					
Mo_0	4.82 b	0.94 b	0.05 c	0.002551 b	0.0014 b
$Mo_{0.25}$	4.86 b	1.02 a	0.08 a	0.002226 c	0.0013 b
$Mo_{0.50}$	5.14 a	1.00 a	0.08 a	0.002467 b	0.0014 b
$Mo_{0.75}$	5.21 a	1.04 a	0.07 b	0.002911 a	0.0016 a
$LSD_{(0.05)}$	0.079	0.046	0.008	2.404	0.008
Significance level	0.01	0.01	0.01	0.01	0.01
CV (%)	4.88	5.90	10.85	11.36	7.59

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

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Table 11. Combined effect of phosphorus and molybdenum on physical and chemical properties of post harvest soil

Phosphorus × Molybdenum	Nutrient content%				
	pH	OM (%)	Nitrogen	Phosphorus	Potassium
P_0Mo_0	4.68	0.94	0.07 bc	0.00149 jk	0.0014 bc
$P_0Mo_{0.25}$	4.53	0.94	0.06 cd	0.00161 ijk	0.0011 d
$P_0Mo_{0.50}$	5.09	0.94	0.09 a	0.00136 k	0.0015 ab
$P_0Mo_{0.75}$	5.13	1.06	0.08 ab	0.00193 hij	0.0016 a
$P_{40}Mo_0$	5.02	0.94	0.05 d	0.00187 h-k	0.0013 c
$P_{40}Mo_{0.25}$	4.83	1.06	0.08 ab	0.00200 hij	0.0015 ab
$P_{40}Mo_{0.50}$	5.08	1.06	0.09 a	0.00213 ghi	0.0014 bc
$P_{40}Mo_{0.75}$	5.19	1.00	0.07 bc	0.00222 fgh	0.0016 a
$P_{80}Mo_0$	4.66	0.87	0.05 d	0.00371 b	0.0016 a
$P_{80}Mo_{0.25}$	5.03	1.06	0.08 ab	0.00260 efg	0.0014 bc
$P_{80}Mo_{0.50}$	5.19	0.94	0.07 bc	0.00298cde	0.0013 c
$P_{80}Mo_{0.75}$	5.28	0.96	0.06 cd	0.00317 cd	0.0016 a
$P_{120}Mo_0$	4.94	1.01	0.05 d	0.00312 cd	0.0013 c
$P_{120}Mo_{0.25}$	5.05	1.01	0.08 ab	0.00268 def	0.0013 c
$P_{120}Mo_{0.50}$	5.18	1.06	0.08 ab	0.00338 bc	0.0013 c
$P_{120}Mo_{0.75}$	5.24	1.14	0.07 bc	0.00432 a	0.0016 a
$LSD_{(0.05)}$	--	--	0.017	4.808	0.017
Significance level	NS	NS	0.01	0.01	0.01
CV (%)	4.88	5.90	10.85	11.36	7.59

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 11. Combined effect of phosphorus and molybdenum on physical and chemical properties of post harvest soil

Phosphorus × Molybdenum	Nutrient content%				
	pH	OM (%)	Nitrogen	Phosphorus	Potassium
P_0Mo_0	4.68	0.94	0.07 bc	0.00149 jk	0.0014 bc
$P_0Mo_{0.25}$	4.53	0.94	0.06 cd	0.00161 ijk	0.0011 d
$P_0Mo_{0.50}$	5.09	0.94	0.09 a	0.00136 k	0.0015 ab
$P_0Mo_{0.75}$	5.13	1.06	0.08 ab	0.00193 hij	0.0016 a
$P_{40}Mo_0$	5.02	0.94	0.05 d	0.00187 h-k	0.0013 c
$P_{40}Mo_{0.25}$	4.83	1.06	0.08 ab	0.00200 hij	0.0015 ab
$P_{40}Mo_{0.50}$	5.08	1.06	0.09 a	0.00213 ghi	0.0014 bc
$P_{40}Mo_{0.75}$	5.19	1.00	0.07 bc	0.00222 fgh	0.0016 a
$P_{80}Mo_0$	4.66	0.87	0.05 d	0.00371 b	0.0016 a
$P_{80}Mo_{0.25}$	5.03	1.06	0.08 ab	0.00260 efg	0.0014 bc
$P_{80}Mo_{0.50}$	5.19	0.94	0.07 bc	0.00298cde	0.0013 c
$P_{80}Mo_{0.75}$	5.28	0.96	0.06 cd	0.00317 cd	0.0016 a
$P_{120}Mo_0$	4.94	1.01	0.05 d	0.00312 cd	0.0013 c
$P_{120}Mo_{0.25}$	5.05	1.01	0.08 ab	0.00268 def	0.0013 c
$P_{120}Mo_{0.50}$	5.18	1.06	0.08 ab	0.00338 bc	0.0013 c
$P_{120}Mo_{0.75}$	5.24	1.14	0.07 bc	0.00432 a	0.0016 a
$LSD_{(0.05)}$	--	--	0.017	4.808	0.017
Significance level	NS	NS	0.01	0.01	0.01
CV (%)	4.88	5.90	10.85	11.36	7.59

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Combined effect of phosphorus and molybdenum showed non significant variation for organic matter in soil (Appendix VI). The highest organic matter in soil (1.14%) was recorded from $P_{120}Mo_{0.75}$ and the lowest organic matter in soil (0.87%) was recorded from $P_{80}Mo_0$ (Table 11).

4.3.3 N, P and K content in post harvest soil

4.3.3.1 Nitrogen content

Nitrogen (N) in soil varied significantly due to the application of different level of phosphorus (Appendix VI). The highest N in soil (0.08 ppm) was recorded from P_0 which was statistically identical (0.07 ppm) with P_{40} and P_{120}, respectively and the lowest N in soil (0.06 ppm) was recorded from P_{80} (Table 10).

Application of molybdenum showed statistically significant variation in terms of N in soil of mungbean (Appendix VI). The highest N in soil (0.08 ppm) was recorded from $Mo_{0.25}$ and $Mo_{0.50}$ and the lowest N in soil (0.05 ppm) was recorded from Mo_0 (Table 10).

Combined effect of phosphorus and molybdenum showed statistically significant variation for N in soil (Appendix VI). The highest N in soil (0.09 ppm) was recorded from $P_0Mo_{0.50}$ and $P_{40}Mo_{0.50}$, while the lowest N in soil (0.05 ppm) was recorded from $P_{40}Mo_0$ (Table 11).

4.3.3.2 Phosphorus content

Phosphorus (P) in soil varied significantly due to the application of different level of phosphorus (Appendix VI). The highest available P in soil (0.003378 ppm) was recorded from P_{120} and the lowest available P in soil (0.001602 ppm) was recorded from P_0 (Table 10).

Application of molybdenum showed statistically significant variation in terms of available P in soil of mungbean (Appendix VI). The highest available P in soil (0.002911 ppm) was recorded from $Mo_{0.75}$ and the lowest P in soil (0.002226 ppm) was recorded from $Mo_{0.25}$ (Table 10).

Combined effect of phosphorus and molybdenum showed statistically significant variation for available P in soil (Appendix VI). The highest available P in soil (0.004321 ppm) was recorded from $P_{120}Mo_{0.75}$ and the lowest P in soil (0.001369 ppm) was recorded from $P_0Mo_{0.50}$ (Table 11).

4.3.3.3 Potassium content

Potassium (K) in soil did not vary due to the application of different level of phosphorus (Appendix VI). The highest K in soil (0.0015 meq/100 g soil) was recorded from P_{80} and the lowest K in soil (0.0014 meq/100 g soil) was recorded from P_0, P_{40} and P_{120} (Table 10).

Application of molybdenum showed statistically significant variation in terms of K in soil of mungbean (Appendix VI). The highest K in soil (0.0016 meq/100 g soil) was recorded from $Mo_{0.75}$ and the lowest K in soil (0.0013 meq/100 g soil) was recorded from $Mo_{0.25}$ (Table 10).

Combined effect of phosphorus and molybdenum showed statistically significant variation for K in soil (Appendix VI). The highest K in soil (0.0016 meq/100 g soil) was recorded from $P_{120}Mo_{0.75}$ and the lowest K in soil (0.0011 meq/100 g soil) was recorded from $P_0Mo_{0.25}$ (Table 11).

Chapter 5

Summary and Conclusion

Chapter V

SUMMARY AND CONCLUSION

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during March to May 2008 to study the effect of phosphorus and molybdenum on the growth, yield and chemical composition of mungbean. The variety, BARI Mung-6 was used in this experiment as the test crop. The experiment consists of two factors: Factor A: Phosphorus (4 levels) P_0: 0 kg P_2O_5 ha^{-1} (Control), P_{40}: 40 kg P_2O_5 ha^{-1},P_{80}: 80 kg P_2O_5 ha^{-1}, P_{120}: 120 kg P_2O_5 ha^{-1}, Factor B: Molybdenum (4 levels) Mo_0: 0 kg Mo ha^{-1} (Control), $Mo_{0.25}$: 0.25 kg Mo ha^{-1}, $Mo_{0.50}$: 0.50 kg Mo ha^{-1} and $Mo_{0.75}$: 0.75 kg Mo ha^{-1}. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different yield contributing characters, yield, nutrient content in harvested seed & plant and nutrients concentration in soil were recorded to find out the optimum levels of P and Mo for higher yield of mungbean.

Different plant and yield parameters were significantly influenced by different levels of phosphorus. The highest plant height(53.61cm), number of leaves/plant(9.81), number of branches/plant(1.30), number of pods/plant(16.65), pod lenth(6.96cm), number of seeds/pod(10.28), weight of 1000-seeds(46.75g), seed yield(1.12t/ha) and stover yied(1.33t/ha) produced by P_{80} treatment. The lowest plant height(48.78cm), number of leaves/plant(8.04), number of branches/plant(1.03), number of pods/plant(14.46), pod lenth(6.42cm), number of seeds/pod(9.47), weight of 1000-seeds(43.25g), seed yield(0.88t/ha) and stover yield(1.22t/ha) produced by control(Po) treatment.

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Different plant and yield parameters were significantly influenced by different levels of phosphorus except number of leaves/plant. The highest plant height(52.70cm), number of branches/plant(1.30), number of pods/plant(16.64), pod lenth(7.17cm), number of seeds/pod(10.69), weight of 1000-seeds(45.33g), seed yield(1.18t/ha) and stover yied(1.62t/ha) produced by $Mo_{0.50}$ treatment. The lowest plant height(47.85cm), number of leaves/plant(7.98), number of pods/plant(14.20), pod lenth(5.97cm), number of seeds/pod(8.99), weight of 1000-seeds(43.83g), seed yield(0.82t/ha) and stover yield(1.03t/ha) produced by control(Mo_0) treatment.

Seed yield of mungbean responded significantly to the combined application of phosphorus and molybdenum. The highest seed yield(1.27t/ha) was recorded in $P_{80}Mo_{0.50}$ treatment. The lowest seed yield (0.77t/ha) was recorded in the control viz.$PoMo_0$ treatment which received neither phosphorus nor molybdenum. Like seed yield the highest stover yield(1.68t/ha) was recorded in $P_{80}Mo_{0.50}$ treatment and the lowest stover yield (0.96t/ha) was recorded in the control viz.$PoMo_0$ treatment. Tallest plant(57.00cm) and shortest plant(47.00cm) were produced in $P_{80}Mo_{0.75}$ and $P_{40}Mo_0$ treatments, respectively. The treatment combination $P_{80}Mo_{0.50}$ produced highest number of branches/plant(1.51), number of pods/plant(18.00), pod lenth(7.51cm), number of seeds/pod(11.03), weight of 1000-seeds(48.00g) and stover yied(1.68t/ha). The control treatment P_0Mo_0 produced lowest number of leaves/plant(7.27), number of branches/plant(0.97), number of pods/plant(13.03), pod lenth(5.66cm), number of seeds/pod(8.73) and stover yield(1.03t/ha).

The N,P and K content in mungbean plant and seed yield were influenced significantly by the combined application of phosphorus and molybdenum. The highest N,P and K contents in plants(3.06%, 1.018% and 0.717%, respectively) were recorded in $P_{80}Mo_{0.25}$,$P_{120}Mo_{0.50}$ and $PoMo_{0.25}$ treatment. The lowest N,P and K contents(2.07%, 0.125% and 0.157% respectively) was recorded in $PoMo_0$, $P_{40}Mo_0$ and $PoMo_0$. In seed yield, the highest N,P and K content(3.88%, 0.575% and 0.657% respectively) were recorded in $P_{40}Mo_0$, $P_{80}Mo_0$ and $P_{80}Mo_{0.50}$ treatment. And the lowest , N, P and K content in seed (5.86%, 0.087% and 0.268% respectively) were recorded in $PoMo_0$ and $P_{80}Mo_0$ treatment. Again in soil after harvest the highest organic matter, N, P and K concentrations(1.14%, 0.09%, 0.004321% and 0.0016% respectively) were recorded in $P_{120}Mo_{0.75}$,$P_{40}Mo_{0.50}$, $P_{40}Mo_{0.50}$ and $P_{120}Mo_{0.75}$ treatment. The lowest organic matter, N, P and K concentrations in post harvest soil (0.87%, 0.05%, 0.001369% and 0.0011% respectively) were recorded in $P_{80}Mo_0$, $P_{40}Mo_0$, $PoMo_{0.50}$ and Po $Mo_{0.25}$ treatment.

The results in this study indicated that the plants performed better in respect of seed yield in $P_{80}Mo_{0.50}$ treatment than the control treatment (P_0Mo_0) showed the least performance.

It can be therefore, concluded from the above study that the treatment $P_{80}Mo_{0.50}$ (application of phosphorus P_2O_5 @ 80 kg / ha and molybdenum $Mo_{0.50}$ @ 0.50kg/ha) was found to the most suitable combination for the highest yield of mungbean in Deep Red Brown Terrace Soils of Bangladesh.

From the present study the following conclusions may be drawn:

1. The individual and combined effects of P and Mo on yield and yield attributes of mungbean was found positive and significant.
2. Nutrient content in seed were positively affected due to P and Mo fertilization
3. Application of P_2O_5 @ 80 kg/ha and $Mo_{0.50}$ @ 0.50 kg/ha was the most suitable combination for higher yield of mungbean in Deep Red Brown Terrace Soils of Bangladesh.

This experiment was an individual one conducted in this soil type. For proper fertilizer recommendation, further regional trials should be conducted.

Chapter 6
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Appendices

APPENDICES

Appendix I. Monthly record of air temperature, rainfall, relative humidity, soil temperature and Sunshine of the experimental site during March to May 2008

Year	Month	*Air temperature (°c)		*Relative humidity (%)	*Rain fall (mm) (total)	*Sunshine (hr)
		Maximum	Minimum			
2008	March	31.4	19.6	54	11	8.2
	April	33.6	23.6	69	163	6.4
	May	34.7	25.9	70	185	7.8

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate and weather division) Agargoan, Dhaka - 1212

Appendix II. Analysis of variance of the data on the yield contributing characters of mungbean as influenced by phosphorus and molybdenum

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm)	Number of leaves/plant	Number of branches/ plant	Number of pods/plant	Pod length (cm)
Replication	2	6.182	0.791	0.050	13.816	0.322
Phosphorus (A)	3	50.231**	6.684**	0.159**	11.379**	0.706**
Molybdenum (B)	3	50.709**	6.348**	0.115**	12.323**	3.557**
Interaction (A×B)	9	7.796*	0.647*	0.018*	1.274*	0.068*
Error	30	3.356	0.715	0.029	2.464	0.109

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix III. Analysis of variance of the data on the yield and yield attributes of mungbean as influenced by phosphorus and molybdenum

Source of variation	Degrees of freedom	Mean square			
		Number of seeds/pod	Weight of 1000 seeds (g)	Seed yield (t/ha)	Stover yield (t/ha)
Replication	2	0.040	0.896	0.072	0.011
Phosphorus (A)	3	1.417**	25.521**	0.117**	0.033**
Molybdenum (B)	3	5.912**	5.799	0.267**	0.711**
Interaction (A×B)	9	0.497**	3.336*	0.012**	0.005*
Error	30	.0.239	3.607	0.026	0.006

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on the N, P and K content in plant of mungbean as influenced by phosphorus and molybdenum

Source of variation	Degrees of freedom	Mean square		
		Content in plant (%)		
		N	P	K
Replication	2	0.0001	0.006	0.003
Phosphorus (A)	3	0.561**	0.682**	0.097**
Molybdenum (B)	3	0.127**	0.096	0.327**
Interaction (A×B)	9	0.221**	1.081	0.204**
Error	30	0.022	0.061	0.005

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on the N, P and K content in seed of mungbean as influenced by phosphorus and molybdenum

Source of variation	Degrees of freedom	Mean square		
		Nutrient Content in seed (%)		
		N	P	K
Replication	2	0.002	0.002	0.001
Phosphorus (A)	3	0.015**	0.043**	0.025**
Molybdenum (B)	3	0.166**	0.048**	0.020**
Interaction (A×B)	9	0.086**	0.069**	0.045**
Error	30	0.002	0.003	0.002

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on the N, P and K amount of post harvest soil of mungbean as influenced by phosphorus and molybdenum

Source of variation	Degrees of freedom	Mean square				
		pH	OM (%)	N (ppm)	P(ppm)	K (meq/100 g soil)
Replication	2	0.007	0.004	0.0001	0.0001	29.174
Phosphorus (A)	3	0.132**	0.024**	0.0001	0.0001**	860.516**
Molybdenum (B)	3	0.452**	0.021**	0.002**	0.002**	96.683**
Interaction (A×B)	9	0.055	0.010	0.001*	0.0001**	44.952**
Error	30	0.009	0.003	0.000	0.0001	8.313

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

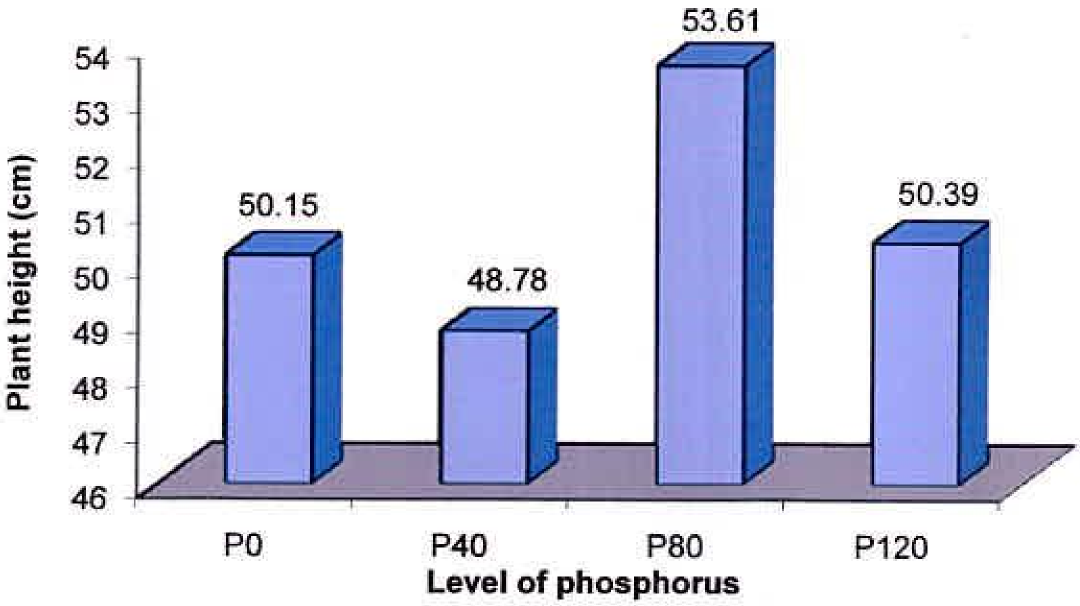

Fig. a. Effect of phosphorus on plant height of mungbean

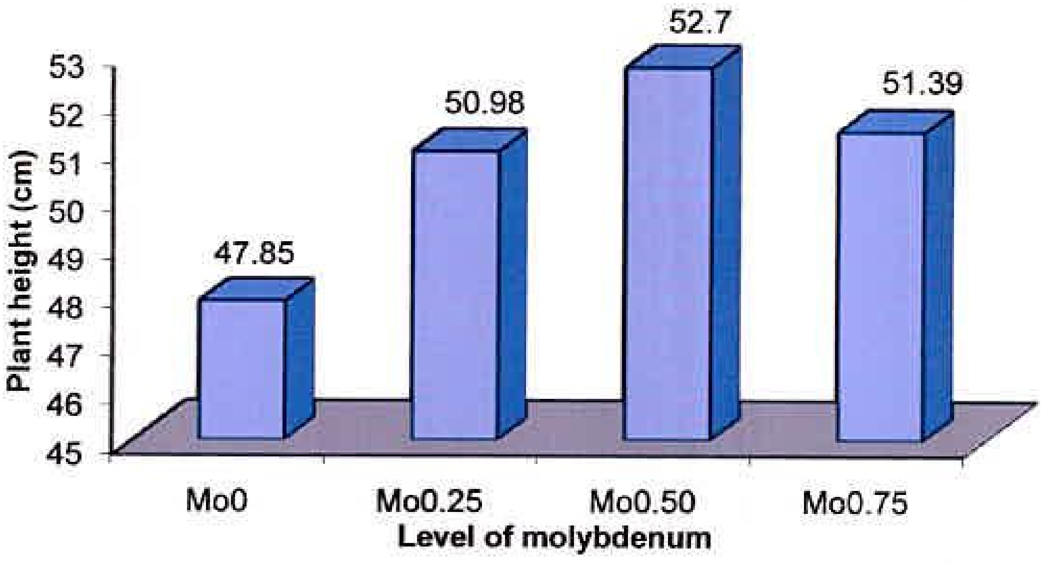

Fig. b. Effect of molybdenum on plant height of mungbean

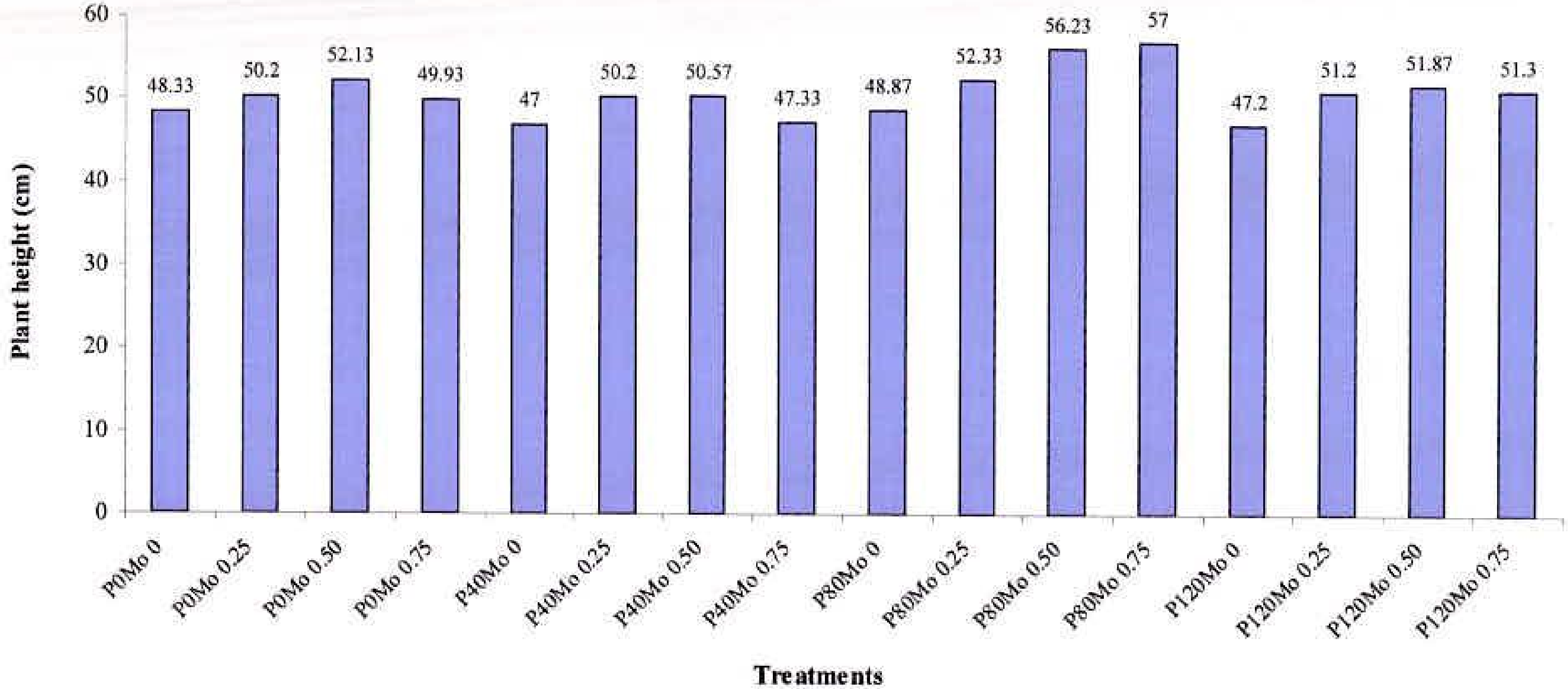

Fig. c. Combined effect of phosphorus and molybdenum on plant height of mungbean

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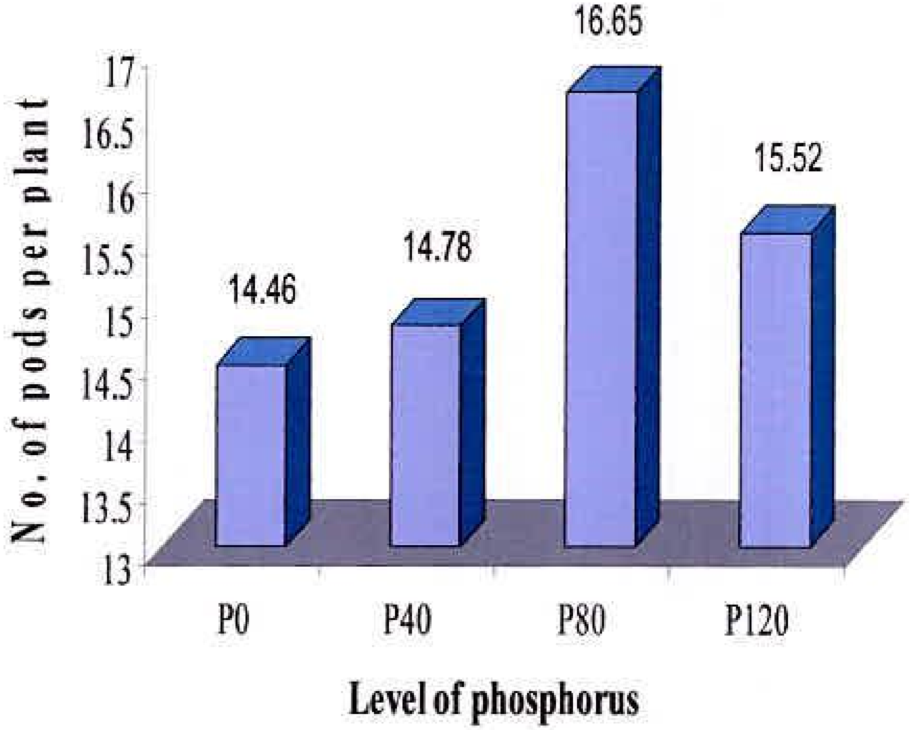

Fig. d. Effect of phosphorus on No. of pods per plants of mungbean

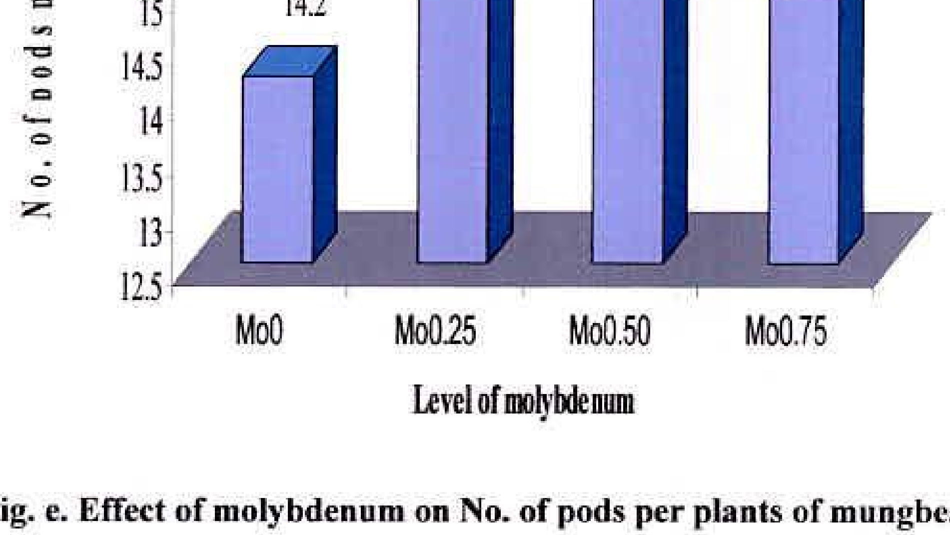

Fig. e. Effect of molybdenum on No. of pods per plants of mungbean

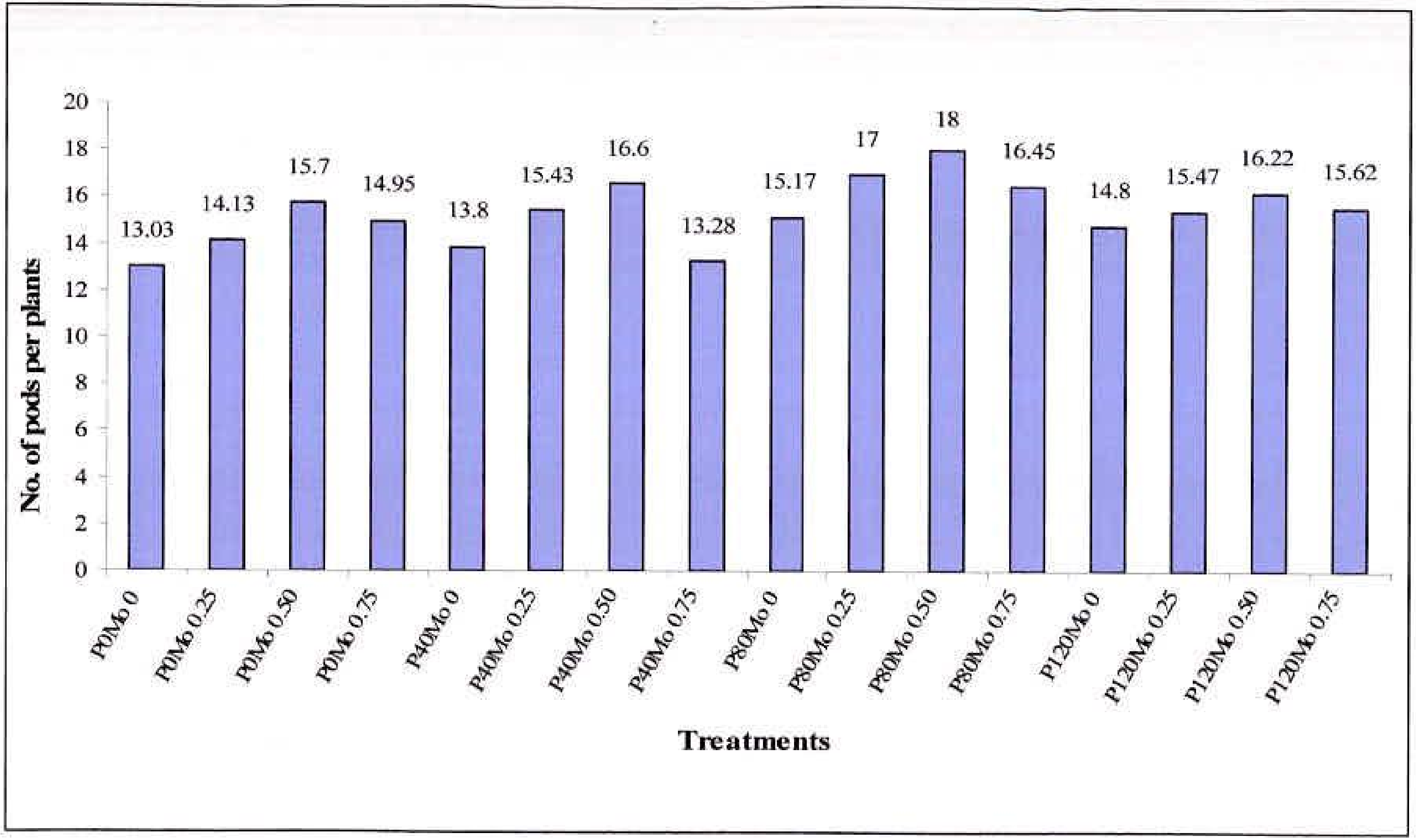

Fig. f. Combined effect of phosphorus and molybdenum on No. of pods per plants of mungbean

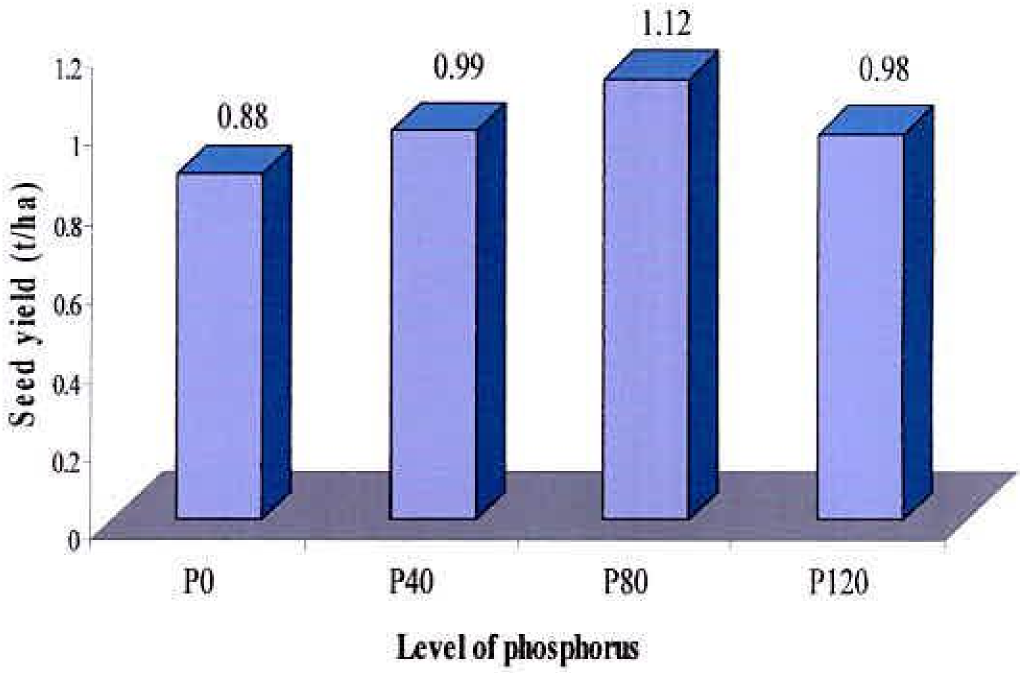

Fig. g. Effect of phosphorus on seed yield of mungbean

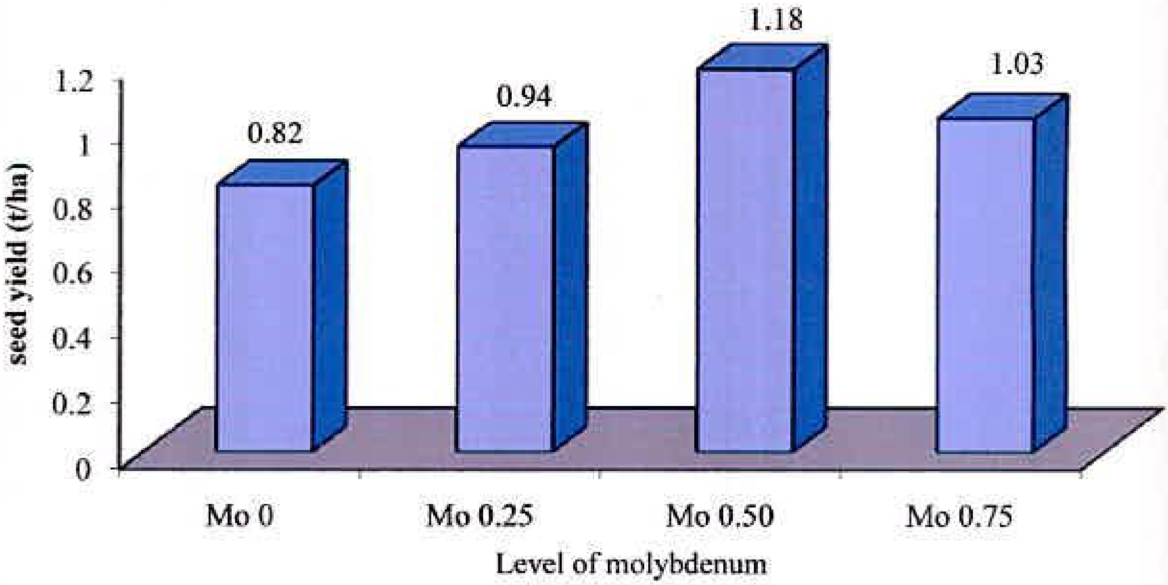

Fig. h. Effect of molybdenum on seed yield of mungbean

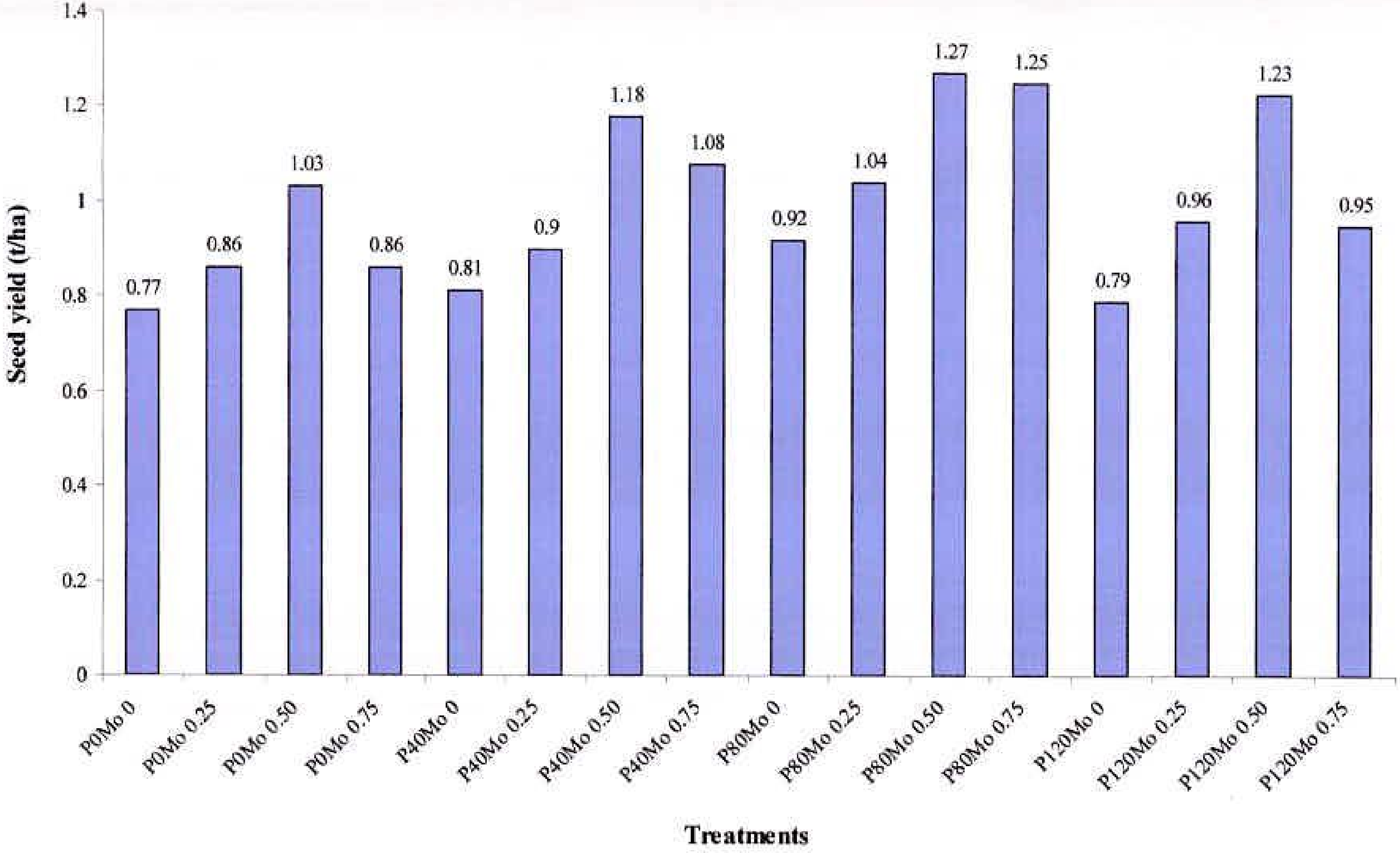

Fig. i. Cobined effect of phosphorus and molybdenum on seed yield of mungbean

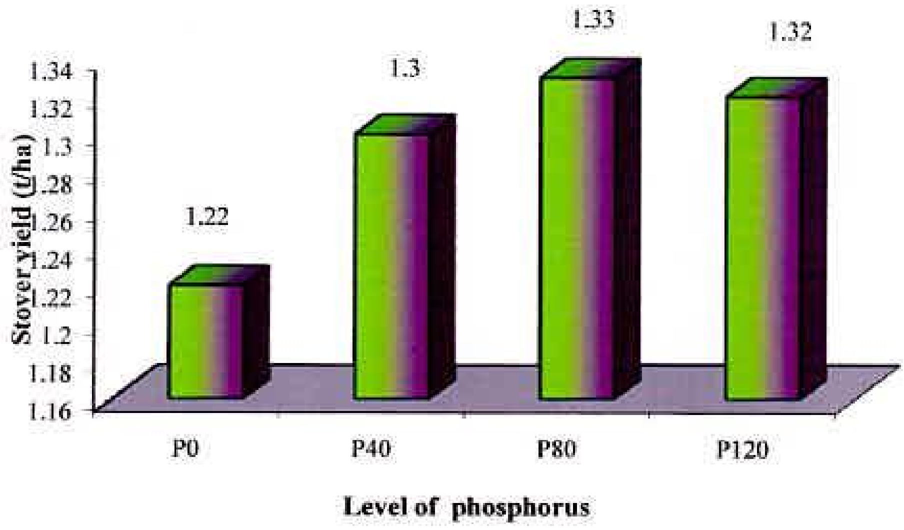

Fig. j. Effect of phosphorus on stover yield of mungbean

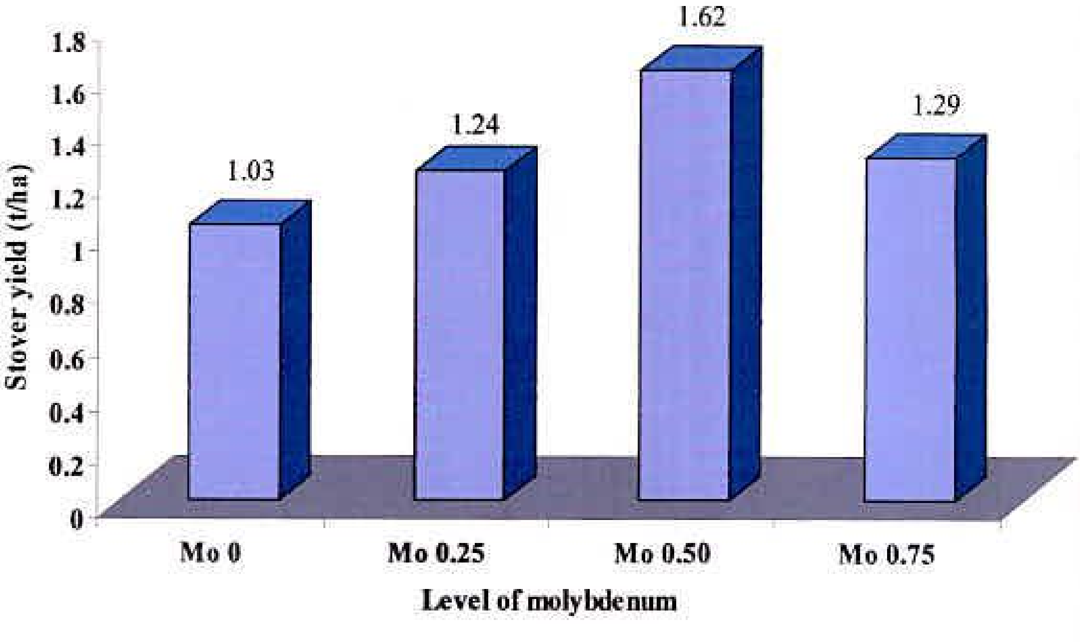

Fig. k. Effect of molybdenum on stover yield of mungbean

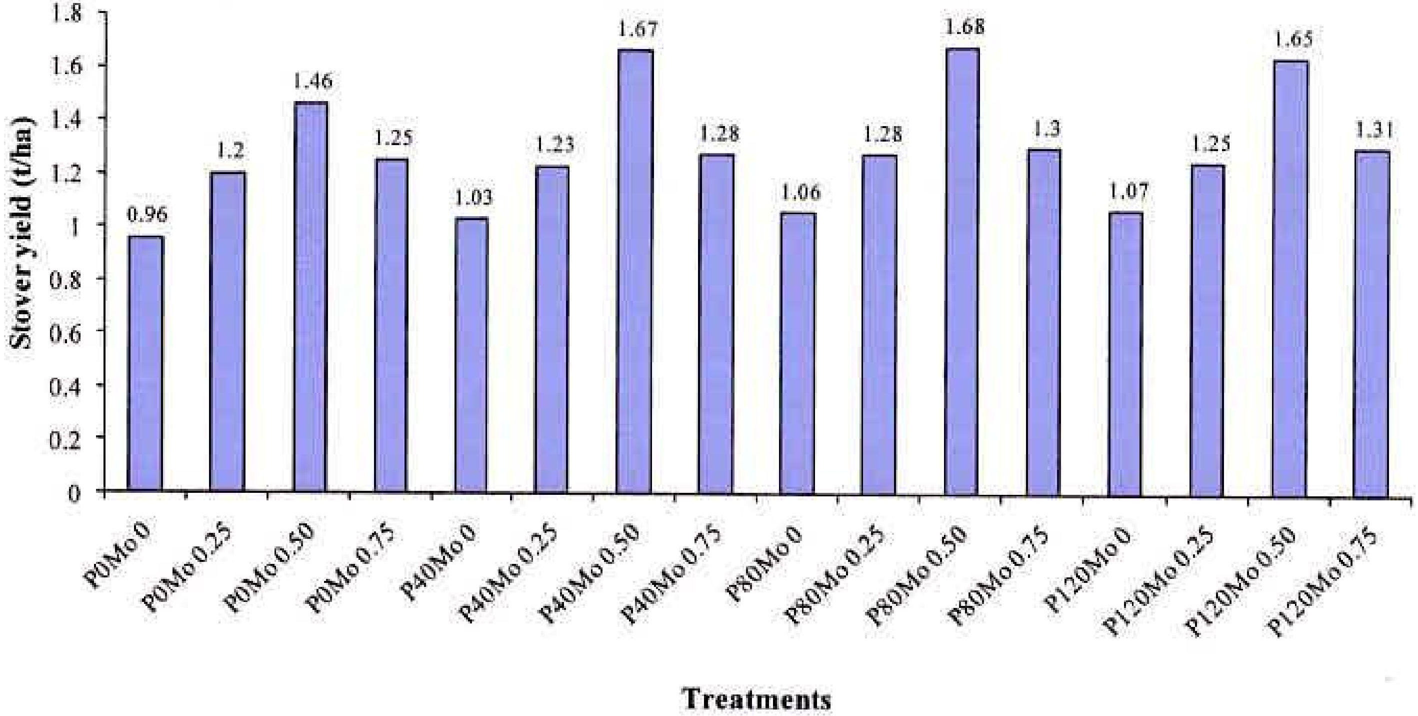

Fig I. Combined effect of phosphorus and molybdenum on stover yield of mungbean