INFLUENCE OF FERTILIZER LEVEL AND PLANT POPULATION ON THE PERFORMANCE OF SUMMER MUNGBEAN

BY

SYEDA SAFINA-E-SANJIDA

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Approved by:

(Prof. Dr. A.K.M. Ruhul Amin)
Supervisor

(Prof. Dr. Parimal Kanti Biswas)
Co-supervisor

(Dr. Md. Jafar Ullah)
Chairman
Examination Committee

CERTIFICATE

This is to certify that the thesis entitled, **"INFLUENCE OF FERTILIZER LEVEL AND PLANT POPULATION ON THE PERFORMANCE OF SUMMER MUNGBEAN"** 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 AGRONOMY,** embodies the result of a piece of bonafide research work carried out by **Syeda Safina-E-Sanjida**, Registration No. 00951 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 25/6/08

Dhaka, Bangladesh

(Prof. Dr. A.K.M. Ruhul Amin)
Supervisor
Department of Agronomy
Sher-e-Bangla Agricultural University
Dhaka- 1207, Bangladesh

DEDICATED TO MY ADORED PARENTS

LIST OF ABBREVIATIONS

Abbreviated form	Full Meaning
%	Percent
^0C	Degree Celsius
BARI	Bangladesh Agricultural Research Institute
BINA	Bangladesh Institute of Nuclear Agriculture
FAO	Food and Agriculture Organization
cv.	Cultivar
CV	Coefficient of variance
cm	Centimeter
DAS	Days after sowing
et al.	And others
g	Gram
ha	Hectare
HI	Harvest index
LSD	Least Significance Difference
m^2	Square meter
RH	Relative humidity
Max.	Maximum
Min.	Minimum
mm	Millimeter
No.	Number
NS	Non significant
t	Ton(s)
Temp.	Temperature

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ABSTRACT

An experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka from April 2007 to June 2007 to observe the influence of fertilizer level and plant population on the performance of mungbean. The treatments were four fertilizer levels viz. without fertilizer, half of the recommended dose of fertilizer, recommended dose of fertilizer and double of the recommended dose of fertilizer, and four plant populations viz. 15, 30, 45 and 60 plants m^{-2} of mungbean (*Vigna radiata*). The experiment was laid out in split plot design with three replications. The result revealed that yield attributes and other characters were increased significantly by the application of different fertilizer treatment over the control. The above parameters were the highest when the crop fertilized with double of the recommended dose and recommended dose of fertilizer treatment. Per plant performance was better in 15 plants m^{-2} but the yield ha^{-1} was significantly highest in 45 plants m^{-2}. Taller plant was observed in double of the recommended dose of fertilizer with 60 plants m^{-2}. Higher number of branches $plant^{-1}$, pods $plant^{-1}$, pod length, seeds pod^{-1}, weight of 1000 seeds, harvest index and dry weight $plant^{-1}$ were obtained from double of the recommended dose of fertilizer with 15 plants m^{-2}. The highest seed yield (1.22 t ha^{-1}) was obtained from double of the recommended dose of fertilizer with 45 plants m^{-2}, which was statistically similar with double and recommended dose of fertilizer with 60, 45 and 30 plants m^{-2}.

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

শেরেবাংলা কৃষি বিশ্ববিদ্যালয় গ্রন্থাগার
সংযোজন নং 56
স্বাক্ষর ... তাং 9.6.09

Pulse is a common item in the daily diet of the people of Bangladesh. Pulses have been considered poor men's meat since they are the cheapest source of protein for the underprivileged people who can not effort animal protein and it is taken mostly in the form of soup. Many of the pulse seeds are consumed as raw when they are in green stage. Generally there is no complete dish without "dhal" in Bangladesh. Moreover, adding of legume in cereal based cropping system can improve soil structure, improves nutrient exchange and maintain healthy sustainable soil system (Becker *et al.*, 1995). Grain legumes are believed to add 20-60 kg N ha^{-1} to the succeeding crop (Kumar *et al.*, 1998).

Pulse protein is rich in amino acids like isoleucine, leucine, lysine, valine etc According to FAO (1999) a minimum intake of pulse should be 80 g per head per day, whereas it is only 14.19 g in Bangladesh (BBS, 2005). Mungbean grain contains 59% CHO, 24% protein, 10% moisture, 4% mineral and 3% vitamins (Khan, 1982; Kaul, 1982).

Mungbean (*Vigna radiata* L. Wilezck) is one of the important pulse crops of Bangladesh. Among the pulse crops the largest area is covered by lentil (40.17%) where as mungbean covers only 6.34% area. Reports show that the area and production of mungbean cultivation is gradually declining (BBS, 2005). In the year 2002-2003 the area under mungbean cultivation was 109 thousand acres that declined to 60 thousand acres in the year 2004-2005 (BBS, 2005). In Bangladesh the total production of mungbean from the year 2001-2002 to 2005-2006 was 31, 30, 30, 18 and 17 thousand tones respectively. In these years the total production of mungbean in this country decreases 3% to 40% (BBS, 2006).

The possibilities of mungbean cultivation in summer are being experimented and successes have already been made in Bangladesh. A study of BARI showed that the optimum time for summer mungbean is the end of March to April. One of the biggest advantages of summer pulses is their suitability for early kharif, particularly in the area where low yielding variety aus rice is produced. Experiments conducted at BARI indicated that summer pulses are more economical than low yielding aus rice (BBS, 2001).

The average yield of mungbean is 0.69 t ha^{-1} (BBS, 2005) which is very poor in comparison to mungbean growing countries in the world. There are many reasons of lower yield of mungbean. The management of fertilizer is the important one that greatly affects the growth, development and yield of this crop. N, P, K are the three major nutrients required by the plants for growth and high yield. Pulses although fix nitrogen from the atmosphere, there is evidence that application of nitrogenous fertilizers helpful in increasing the yield (Patel *et al.*, 1984 and Ardeshana *et al.*, 1993). Nitrogen is most useful for pulse crops because it is the component of protein (BARC, 1997). Number of pod $plant^{-1}$, seed pod^{-1}, seed yield and seed protein contents were increased significantly with potassium application (Ali *et al.*, 1996). Similarly Govinda and Thirumurugan, (2000) reported that K application resulted in high yield and yield components. Phosphorus is essential for many purposes and it helps the growing plant in photosynthesis, respiration, energy storage and cell division. When the supply of phosphorous is adequate it also helps in the improvement of crop quality (Tisdale and Nelson, 1975).

For the development of appropriate management practices for mungbean, plant population plays an important role. The difference between the potential and actual yield indicates a wide space of increasing the productivity of mungbean. An optimum plant population is essential for attaining maximum yield. Plant population is one of the most important yield contributing factors, which can be manipulated to maximize yield (Babu and Mitra, 1989). The seed yield of mungbean increases with an increases in population density (Hamid *et el.*, 1991). However a high population density, lower branches and leaves overlap one another causing mutual shading; and at wider spacing, the plants develop more branches, but the contribution of secondary and tertiary branches towards seed yield in negligible in mungbean (Hamid, 1996). In lower plant population, individual plant performance is better than that of higher plant population but within tolerable limit higher plant population produces higher yield ha^{-1} (Shukla and Dixit, 1996). Therefore, optimum plant population ensures normal plant growth because of efficient utilization of moisture, light space and nutrients, thus increases the yield of crop. Considering the above facts, the present study was undertaken with the following objectives:

Objective:

1. To find out a suitable plant population for growth and yield of mungbean
2. To select an optimum fertilizer dose for better growth and yield, and
3. To determine the interaction effect of plant population and fertilizer level on the yield of mungbean.

Chapter 2

Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

Research on the effect of plant population on the yield of summer mungbean is inadequate in Bangladesh. An optimum plant population with proper spacing plays an important role in improving the yield. Obviously plant population need to be adjusted according to the plant type or varieties, location, soil fertility and cultural practices.

2.1 Effect of plant population:

2.1.1 Plant height

El-Habbasha *et al.* (1996) reported that increasing plant density increased plant height but decreased branch and leaf number plant^{-1}, dry weight of shoots, pod yield plant^{-1} and number of pods plant^{-1} of mungbean.

Brathwaite (1982) notice that increasing crop density decreased pod size and number of branches plant^{-1}, but days to flowering, maturity, plant height and pod quality remained unaffected. He recommended crop density of 148000 plant ha^{-1}.

Muesca and Oria (1981) observed that the number of days of flowering of mungbean was not affected by plant density. With a dense stand (25 plant m^{-2}) plant height was the highest (168cm) and pod set was the greatest (484 plot^{-1}). Seed yield was the highest (369 g plot^{-1}) at the lowest density of 10 plants m^{-2}.

Hoq and Hossain (1981) in an experiment observed significant effect of plant density on the height of mungbean.

Cagampang *et al.* (1977) determined the optimum plant population of mungbean in the range of 3,00,000 to 4,00,000 plant ha^{-1} in the wet season and 4,00,000 to 5,00,000 plants ha^{-1} in the dry season.

2.1.2 Number of Branch $plant^{-1}$

El-Habbasha *et al.* (1996) reported that in creasing plant density increased plant height but decreased branch and leaf number $plant^{-1}$.

Brathwaite (1982) notice that increasing crop density decreased pod size and number of branches $plant^{-1}$.

2.1.3 Number of pod $plant^{-1}$

Zahab *et al.* (1981) reported that increased plant density resulted in plants bearing less pod and seed in *Vicia faba* L.

El-Habbasha *et al.* (1996) reported that increasing plant density increased plant height but decreased the number of pods $plant^{-1}$ of mungbean.

Panwar and Sirohi (1987) reported that yield per hectare and number of seed pod^{-1} increased with increasing plant density whereas, yield per plant and number of $podplant^{-1}$ decreased with increasing plant density in mungbean.

Mackenzie *et al.* (1975) reported that the number of pods per plant of mungbean decreased as density increased unlike soybean.

In Thailand, Pookpakdi and Pataradilok (1993) investigated the response of genotypes of mungbean and blackgram to planting dates and plant population densities sown at 2,00,000, 4,00,000 and 80,000 ha^{-1}. They observed that yield of both crops generally increased with increasing plant density, while pod number plant^{-1} decreased with the increasing density.

2.1.4 Seed pod^{-1}

Parwan and Sirohi (1987) reported that yield per hectare and number of seed pod^{-1} increased with increasing plant density.

2.1.5 Harvest Index

Tsiung (1978) reported that in mungbean the harvest index declined before the maximum grain yield was attained, usually from the lowest density. He further reported that there was an increase in harvest index up to density giving the higher grain yield. All studies were consistent in showing a progressive decline in harvest index at densities above the maximum grain yield.

2.1.6 Dry matter

Working with 3 plant population densities of mungbean, Trung and Yoshida (1985) found that increasing plant density increased DM production, but it had little effect on average number or weight of seeds pod^{-1} or 1000-seed weight.

2.1.7 Weight of 1000-Seed

Singh and Singh (1988) and Rahman and Miah (1995) reported reduced 1000 seed weight in mungbean due to increased planting density.

Working with 3 plant population densities of mungbean, Trung and Yoshida (1985) found that increasing plant density increased DM production, LAI, seed yield and pod number per unit area but it had little effect of 1000-seed weight.

2.1.8 Seed yield

Tomar and Tiwani (1996) conducted a field trial in late spring season of 1983 and 1984 to study the response of green gram and black gram genotypes to plant density. They found that mean yield increased with increasing plant density up to 8,00,000 plants ha^{-1} in green gram and 10,00,000 plants ha^{-1} in black gram.

At Joydebpur, Haque (1995) carried out a field trial on *Vigna radiata* cultivar BM 7703 using population of 2,50,000, 3,33,333, 4,00,000 or 5,00,000 plants ha^{-1} and found that 3,33,333 plants ha^{-1} gave the highest seed yield.

Beech and Wood (1978) conducted several studies and reported a higher plant population up to 4,50,000 plants ha^{-1} gave higher yield in mungbean under good management condition.

In a field experiment in 1983-84 Tomar *et al.* (1993) using 4 cultivars each of mungbean and urdbean at population of 4,00,000, 6,00,00, 8,00,000 or 10,00,00 plant ha^{-1} found that a population of 10,00,000 plants ha^{-1} gave higher yield and heigher returns than any other plant populations.

A higher plant population (4,00,000 plant ha^{-1}) as compared to low plant population (2,00,000 plants ha^{-1}) produced maximum grain yield in trails of Singh and Malhotra (1983) and Maheshwari *et al.* (1974) in North India. They reported that maximum bean yield was obtained from a population of 30,00,000 to 4,00,000 plants ha^{-1}.

Mimber (1993) carried out a field trial on *Vigna radiata* cultivar walet using 400000, 600000 or 800000 plants ha^{-1} and found that yield increased with increasing plant population.

In Thailand, Pookpakdi and Pataradilok (1993) investigated the response of mungbean genotypes to plant population densities sown at 200000, 400000 and 800000 ha^{-1}. They observed that yield was generally increased with increasing plant density, while pod number $plant^{-1}$ decreased with increasing density.

Singh *et al.* (1991) carried out a field experiment to study the effect of spacing and seed rate on yield of green gram. They reported that plant population increased with increasing seed rate and highest seed yield of 0-55 t ha^{-1} was obtained from 32 kg ha^{-1} seed rates.

Singh and Singh (1988) reported that of mungbean (*Vigna radiata*) cultivars at a density of 400000, 500000 or 600000 plant ha^{-1} gave similar average seed yield of 1.13-1.15 t ha^{-1}. Rahman and Miah (1995) got the highest yield with 50 plants m^{-2}.

Mackenzie *et al.* (1975) reported that one approach of elevating the seed yield of mungbean by Asian Vegetables Research and Development Center (AVRDC) in to increase yield by increasing plant density.

Hamid (1989) found that mungbean grown at very high density failed to produce yield because of high rate of mortality. Per plant dry matter yield decreased progressively with increasing density. Grain yield $plant^{-1}$ decreased with in creasing density but the yield density function constructed based on grain yield unit $area^{-1}$ followed a quadratic relationship.

Tomar *et al.* (1993) who reported that highest yield in mungbean at the planting density of 40 plants m^{-2}.

It was observed from a large number of trials conducted on grain legumes in India that they respond favorably to increased plant population from 1,00,000 to 5,00,000 plant ha^{-1} depending upon the growth condition (Saini and Das, 1979).

2.2 Effect of fertilizer

Nutrient requirements of different pulse crops depend on fertility status of the soil as well as yield goals. In Bangladesh pulse crops are generally grown without the application of any fertilizer. Information on nutrient requirements of mungbean is meager in the scientific literature. The effects of fertilizer on mungbean have been reviewed below in respect of dry matter production, growth, yield and yield attributes and other agronomic characters.

2.2.1 Total dry matter

The total dry matter production is the integration of crop growth rate over the entire growth period. The pattern of assimilate distribution is determined by that of photosynthesis and environmental conditions (Evans, 1975). Total dry matter production of a crop is dependent on the source and its activities as well as the length of its growth period, during which photosynthesis continues. It is the actual assimilates of seed after maintaining the total cost of respiration. The process of photosynthesis, mineral uptake, respiration and senescence of leaves usually determine the dry weight of plant.

Yein (1982) carried out 2-year field experiment in Assam, India, on mungbean (*V. radiata*) and reported that combined application of nitrogen and phosphorus significantly increased the dry weight of the plants.

Agbenin *et al.* (1991) found that applied N significantly increased the dry matter yield of mungbean over the control. Leelavathi *et al.* (1991) also reported that different levels of nitrogen showed significant difference in dry matter of mungbean up to a certain level (60 kg N ha^{-1}).

Chowdhury and Rosario (1992) studied the effects of 0, 30, 60 or 90 kg N ha^{-1} on the yield and yield performance of mungbean at Lo Banos, Philippines in 1988. They observed that N at levels above 30 kg ha^{-1} reduced the dry matter yield.

Santos *et al.* (1993) carried out an experiment on mungbean cv. Berken which grown in pots in podzolic soil with 7 levels of N (0, 25, 50, 100, 200, 400 and 500 kg ha^{-1}), applied as NH_4NO_3 and noted that application of N up to 200 kg ha^{-1} increase the total dry matter but higher rates decreased it.

Reddy *et al.* (1990) set up an experiment with three cultivars of mungbean in 1987, applying 0 or 50 kg P_20_5 ha^{-1} as a basal dressing or 50 kg P_20_5 ha^{-1} in two equal split at the sowing and flowering. They found that application of phosphprus increased the dry matter accumulation in mungbean.

Masthan *et al.* (1999) conducted a field experiment during 1991 to 1993 at Andhra Pradesh, India, Kharif rice cv. Tella Hams was followed by sunflower cv. APSH-1 and summer mungbean cv. LGG 127. Dry matter of mungbean increased with increasing residual Kharif and Rabi P rates.

A field trial carried out by Mitra *et al.* (1999) during the Kharif (rainy seasons) of 1996 and 1997 to study the effect rock phosphate on the growth and yield of mungbean in acid soils of Tripura, India. Result revealed that mungbean cv. GM-9002 had greater dry matter accumulation at harvest than cv. UPM-12 or MH-309.

Maximum dry matter at the harvest was recorded with the application of Mussoorie rock phosphate (50 kg P_20_5 ha^{-1}). Raundal *et al.* (1999) also reported that application of phosphorus 60 kg ha^{-1} to mungbean grown in Kharif (monsoon) season dry increased the dry matter yield.

Sadasivam *et al.* (1990) found that mungbean (*V. radiata* L.) cv. C03 gave 50.3, 53.8, 49.7 and 61.8 g dry matter (DM) yield plant^{-1} with no K, 25 kg K_20 ha^{-1}, 1% KCl spray and 1% K_2S0_4 spray at flowering, respectively.

2.2.2 Plant height

An experiment was conducted by Sardana and Verma (1987) in New Delhi, India, in 1983-84. They stated that application of N P and K fertilizer resulted in significant increases in plant height of mungbean. Suhartatik (1991) also reported that NPK fertilizers significantly increased the plant height of mungbean.

In a field experiment, Yein *et al.* (1981) applied Nitrogen in combination with phosphorus fertilizer to mungbean, which resulted in increased plant height. Yein (1982) carried out 2-year field trails in Assam, India on mungbean and reported that application of various levels of nitrogen plaus phosphorus significantly increased the plant height.

A field experiement was carried out by Gopala Rao *et al.* (1993) to find out the response of four mungbean cultivars (Pusa Baishakhi, LGG 407, LGG 410 and MS 267) to 3 levels phosphorus (0, 25 and 50 kg P_20_5 ha^{-1}) in sandy loam soil of Bapalta. The soil was low in available P_20_5 (9 kg ha^{-1}) .A uniform dose of 20 kg N/ha was applied as a basal for all the treatments. Experimental results showed that pant height significantly increased with the increase in p levels from 0 to 50 kg P_20_5 ha^{-1}.

Trung and Yoshida (1983) conducted a field trial on mungbean in nutrient soil, containing 0-100 ppm N in the form of ammonium nitrate or 10 or 100 ppm N as urea. They observed that maximum plant height was obtained by 25 ppm N at all the stages of development.

Hamid (1988) reported that N increased the plant height of mungbean CV. Mubarik grown in a polyethylene green house.

Quah and Jaafar (1994) also found that plant height of mungbean significantly increased by nitrogen fertilizer at 50 kg ha^{-1}.

Ahmed *et al*. (1986) carried out an experiment with various levels of phosphorus on the growth and yield of mungbean. They noted that phosphorus application up to 60 kg ha^{-1} progressively and significantly enhanced the plant height.

In a field experiment, Patel and Patel (1991) observed that plant height of mungbean showed superiority at 60 kg P_20_5 ha^{-1} followed by 50 kg P_20_5 ha^{-1} application rate, grown on the soil which was sandy in texture low in total N (0-04%), higher in available P (77.33 kg ha^{-1}) and rich in available K (388.15 kg ha^{-1}) with the p^H 7.5. Thus plant height was found to be increasing levels of phosphorus from 0 to 60 kg ha^{-1}.

Bayan and Saharia (1996) carried out an experiment to study the effect of phosphorus on mungbean during the Kharif seasons of 1994-95 in Biswanath chariale, Assam, India. The results indicated that plant height was unaffected by phosphorus application.

Sharma and Singh (1997) carried out a field experiment during 1989 and 1990 to study the effect of various levels of P (0, 25, 50 and 75 kg ha^{-1}) on the growth, yield and yield attributes of mungbean. Results of their study revealed that application of P at 50 kg ha^{-1} enhanced the plant height significantly.

An experiment was conducted by Singh *et al.* (1999) on mungbean CV. NDM-1 grown at Faisalabad, Uttar Pradesh, India in summer 1996 and was given 0-26.4 kg P ha^{-1}. They reported that plant height generally increased with up to 26.4 kg P ha^{-1}.

Masud (2003) conducted an experiment at the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh and observed the highest plant with the application of 30 kg N ha^{-1}. Ghosh (2004) found the highest plant height of mungbean at 25 kg N ha^{-1}.

Agbenin *et al*. (1991) revealed that application of N significantly increased plant height, seed yield, dry weight, crop growth rate and nutrient uptake of mungbean over control.

Singh *et al*. (2001) observed that 30 mg P_2O_5 kg^{-1} soil gave the highest plant height of green gram. Sardar (2002) found in a field experiment on *vigna radiata* that application of phosphorus at the rate of 40 kg ha^{-1} enhanced the plant height.

Patel and Patel (1991) conducted a field trial where plant height of mungbean showed superiority at 60 kg P_20_5 ha^{-1} followed by 40 kg P_20_5 ha^{-1} application rate.

2.2.3 Number of pod $plant^{-1}$

Samiullah *et al*. (1987) reported that number of pods $plant^{-1}$ was highest with the application of 10 kg N+75 kg P_20_5+60 kg K_20 in summer mungbean. Suhartatik (1991) observed that NPK fertilizer significantly increased the number of pods $plant^{-1}$of mungbean.

A field trial was carried by Sardana and Verma (1987) in New Delhi, India, in 1989-84 and observed that application of nitrogen, phosphorus and potassium fertilizers resulted in significant increases in number of pods $plant^{-1}$ of mungbean.

In an experiment, Yein *et al.* (1981) applied nitrogen and phosphorus fertilizers to mungbean and reported that combined application of nitrogen and phosphorus fertilizer increased the number of pods plant^{-1}.

Manpreet *et al.* (2004) conducted an experiment in Liudhiana Punjab, India during summer 2000 to investigate the response of mungbean genotypes to P application (0, 20, 40, 60 kg ha^{-1}) under irrigated conductions. P application increase showed significant increase in the number of pod plant^{-1}, which accounted for significantly higher grain and straw yields at higher levels (40 and 60 kg ha^{-1}) composed to lower level (0 and 20 kg ha^{-1}). The economic optimum p level for all the 3 summer mungbean genotypes was found to be 46.1 kg P_20_5 ha^{-1}.

Sarkar *et al.* (2005) conducted a field experiment to study the effect of plant spacing and P on seed yield of mungbean and observed that the highest pod plant^{-1} was found in the spacing of 20cm×20cm with 40 kg P_20_5 ha^{-1}.

In trials, on clayey soils during the summer seasons of 1979-80, Patel *et al.* (1984) studied the effects of 0, 10, 20 and 30 kg N ha^{-1} and 20, 40, 60 and 180 kg P_20_5 ha^{-1} on the growth and seed yield of mungbean. Results of their studies revealed that application of 40 kg P_20_5 ha^{-1} along with up to 20 kg N ha^{-1} significantly increased the number of pods plant^{-1} of mungbean; further increase in phosphorus rates was not economical.

Gopala Rao *et al.* (1993) carried out a field experiment to find out the response of four-mungbean cultivars cv. Pusa Baishakhi, LGG 407, LGG 410 and MS 267 to 3 levels of phosphorus (0, 25 and 50 kg P_20_5 ha^{-1}). They reported that number of pods plant^{-1} increased significantly with increasing phosphorus levels from 0 to 50 kg ha^{-1} where a uniform dose of 20 kg N ha^{-1} was applied as a basal for all the treatments. A field experiment conducted by Sarkar and Banik (1991), results revealed that application of 10 kg N ha^{-1} to mungbean resulted in appreciable improvement in number of pods $plant^{-1}$over no nitrogen.

Tank *et al.* (1992) showed that mungbean fertilizer with 20 kg N along with up to the level of 40 kg $P_2 0_5$ ha^{-1} could be assigned to significantly higher number of pods $plant^{-1}$ over the unfertilized control. Ahmed *et al.* (1986) studied in a field experiment to investigate the effects of various levels of phosphorus on the growth and yield of mungbean and expected that phosphorus application up to 60 kg ha^{-1} progressively and significantly increased the number of pods $plant^{-1}$.

Kalita (1989) conducted an experiment in 1986-88 applying 30 kg $P_2 0_5$ ha^{-1} to mungbean and suggested that application of phosphorus increased the number of pods $plant^{-1}$. In another trial, Reddy *et al.* (1990) found that application of phosphorus increased the number of pods $plant^{-1}$ in mungbean.

Bayan and Saharia (1996) reported that application of phosphorus to mungbean (*V. radiata* L.) unaffected the number of pods $plant^{-1}$. Results of a field experiment carried out by Shukia and Dixit (1996) revealed that application of phosphorus to mungbean significantly increased the number of pods $plant^{-1}$ up to 40 kg $P_2 0_5$ ha^{-1}.

Sharma and Singh (1997) carried out a field experiment during 1989 and 1990 to study the effects of various levels of phosphorus (0, 25, 50 and 75 kg ha^{-1}) on the growth, yield and yield attributes of mungbean. They observed that application of phosphorus at 50 kg ha^{-1} significantly enhanced the number of pods $plant^{-1}$.

Masthan *et al.* (1999) stated that number of pods $pant^{-1}$ of summer mungbean cv. LGG 127 increased with increasing P rates. Mitra *et al.* (1999) expected that mungbean grown in acid soils of Tripura, the maximum number of pods $plant^{-1}$ were recorded with application of 50 kg $P_2 0_5$ ha^{-1}. Singh *el al.* (1999) studied in a field trial that number of pods $plant^{-1}$ of mungbean cv. NDM-1 grown at

Faisalabad, Uttar Pradesh, India in summer 1996 generally increased with up to 26.4 kg P ha^{-1}.

Sangakkara (1990) carried out a field experiment on mungbean cv. M15 and Type 61 where 0-120 kg K_20 ha^{-1} were applied as basal dressings or split applications (60:40 at planting and flowering time) and followed that potassium application significantly increased the percentage of pod set in mungbean.

2.2.4 Number of branches Plant^{-1}

Gopala Rao *et al.* (1993) conducted a field trial to find out the response of loam mungbean cultivars (pusa Baishakhi LGG 407, LGG 410 and MS 267) to 3 levels of Phosphorus (0, 25, 50 Kg P_20_5 ha^{-1}) and Sandy loam soil. The soil was low in available P_20_5 (9 kg ha^{-1}). They found that number of branches plant^{-1} increased significantly with the increase in P up to 50 kg ha^{-1} along with 20 kg N ha^{-1}.

In a field experiment, Patel and Patel (1991) suggested that number of branches plant^{-1} of mungbean showed superiority at 60 kg P_20_5 ha^{-1} followed by 40 kg ha^{-1} P_20_5 application when grown in Sandy textured soil, low in total N (0.04%) higher in available P (77.33 kg ha^{-1}) and rich in available K (388.15 kg ha^{-1}) with the p^H 7.5

Hamid (1988) reported that N application increased the number of branches plant^{-1} of mungbean CV. Mubanik grown in a polyethylene green house. Abd-EL-Lateef *et al.* (1998) conducted a field experiment during 1994 and 1995 summer season at Shalakan, Kalubia Governorate, to study the effect of foliar application of nutrients on the growth and yield of mungbean CV.Kawmy-1. Experimental results revealed that application of urea increased the number of branches plant^{-1}

Sharma and Singh (1997) noted that application of 50 kg ha^{-1} to mungbean enhanced the number of branches plant^{-1}.

Singh and Ahlawat (1998) expressed that application of P to mungbean CV PS 16 increased the number of branches plant^{-1} up to 12.9 kg ha^{-1} when the grown in a sandy loam soil, low in organic carbon and N, and medium in P and K and with a p^{H} of 7.8.

Singh *et al.* (1999) carried out of field experiment on mungbean CV NDM-1 at Faisabad, Uttra Pradesh, India in summer 1996 and noted total number of branches plant^{-1} generally increased with up to 26.4 kg P ha^{-1}.

Ghosh (2004) observed in a pot experiment at Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh that different levels of nitrogen indicate that number of branches plant^{-1} was gradually increased with increasing N level @ 25 kg N ha^{-1}.

Tomar *et al.* (1996) observed that leaf number, branch number plant^{-1} of summer mungbean (*Vigna radita*) were highest with 60 kg P_20_5 ha^{-1}.

Sarker *et al.* (2005) conducted a field experiment to study the effect of plant spacing and phosphorus on seed yield of mungbean and observed that the highest number of branches plant^{-1} was found in the spacing of 20 cm×20cm with 40 kg P_20_5 ha^{-1}.

Kumar *et al.* (2003) conducted an experiment to find out the response of mungbean cultivars to different levels of phosphorus (0, 20, 40 and 60 kg P_20_5 ha^{-1}) in Haryana, India. They found that the number of branches plant^{-1} increased with increasing P rates.

2.2.5 Pod length

During field trial, carried out by Sardana and Verma (1987) in Delhi, India, in 1983-84, it was followed that application of nitrogen, phosphorus and potassium fertilizers resulted in significant increases in the pod length of mungbean. Suhartatik (1991) noted that residue of lime with NPK fertilizer significantly increased the pod length of mungbean.

Tank *et al.* (1992) reported that mungbean fertilized with 20 kg N ha^{-1} could be assigned to significantly longer pod length over the rest of the higher (40 kg N ha^{-1} and lower (unfertilized control) levels of N. They also observed that pod length significantly increased up to the levels of 40 kg P_20_5 ha^{-1} over the control. A field trial, carried out by Sarkar and Banik (1991), result showed that application of 10 kg N ha^{-1}) to mungbean resulted in appreciable improvement in pod length over the control.

Patel and Patel (1991) found that pod length of mungbean varieties showed superiority at 60 kg P_20_5 ha^{-1} followed by 40 kg P_20_5 ha^{-1} application rate. Thus pod length was found to be increased with increasing levels of phosphorus from 0 to 60 kg ha^{-1}.

2.2.6 Number of seeds pod^{-1}

Samiullah *et al.* (1987) conducted a field experiment and observed that number of seeds pod^{-1} were the highest with 10 kg N + 75 kg P_20_5 + 60 kg K_20 in summer mungbean.

A field experiment carried out by Gopala Rao *et al.* (1993) to find out the response of four mungbean cultivars (Pusa Baishakhi, LGG 407, LGG 410 and MS 267) to 3 levels of phosphorus (0, 25 and 50 kg P_20_5 ha^{-1}) in sandy loam soil, which contain low in available P_20_5 (9 kg ha^{-1}). Their study suggested that number of seeds pod^{-1} significantly increased with the increase in P levels from 0 to 50 kg P_20_5 ha^{-1} where a uniform dose of 20 kg N ha^{-1} was applied as a basal for all the treatments. In a field experiment, Sarkar and Banik (1991) observed that application of 10 kg N ha^{-1} resulted in increased number of seeds pod^{-1} of mungbean over no nitrogen.

Kalita (1989) conducted field trials during 1986 to 1988, applied 30 kg P_20_5 ha^{-1} to mungbean and noted that phosphorus application increased the number of seeds pod^{-1} over the control. Reddy *et al.* (1990) earned out an experiment with three cultivars of mungbean in 1987, applying 0 or 50 kg P_20_5 ha^{-1} as a basal dressing or 50 kg P_20_5 ha^{-1} in two equal split dressings at the sowing and flowering time. Results showed that application of phosphorus increased the number of seeds pod^{-1} in mungbean.

Bayan and Saharia (1996) reported that application of phosphorus to mungbean unaffected the number of seeds pod^{-1}. Shukla and Dixit (1996) conducted a field experiment with mungbean and reported that application of phosphorus significantly increased the number of seeds pod^{-1} up to 40 kg P_20_5 ha^{-1}.

Singh and Ahlawat (1998) reported that application of phosphorus to mungbean cv. PS 16 increased the number of seeds pod^{-1} when grown in a sandy loam soil, by organic carbon and N, and medium in P and K and with a P^H of 7.8. In a field trial, carried out by Masthan *et al.* (1999) followed that number of seeds pod^{-1} of summer mungbean cv. LGG 127 increased with increasing residual Kharif and Rabi phosphorus rates.

Mitra *et al.* (1999) stated that application of rock phosphate (50 kg P_20_5 ha^{-1}) to summer mungbean grown in acid soils of Tripura, India, during the Kharif (rainy) seasons of 1996 and 1997, maximize the number of seeds pod^{-1}.

Singh *et al.* (1999) studied a field trial on mungbean cv. NDM-1 grown at Faisabad, Uttar Pradesh, India, in summer 1996, was given 0-26.4 kg P ha^{-1}. Their study revealed that number of seeds pod^{-1} generally increased with up to 26.4 kg P ha^{-1}.

Sangakkara (I990 conducted a field trial on mungbean cv. M15 and Type 61 where 0-120 kg K_20 ha^{-1} were applied as basal dressings or split applications (60:40 at planting and flowering time) and noted that application of potassium to mungbean significantly increased the number of seeds pod^{-1} when grown on the soil contain low in potassium.

Kumar *et al.* (2003) conducted an experiment in Haryana, India to investing ate the response of mungbean cultivars to different level of P (0, 20, 40, 60 kg P_20_5 ha^{-1}). They found that P at 20, 40, 60 kg ha^{-1} increased the grain pod^{-1} over control.

2.2.7 Weight of 1000-Seed

Sardana and Verma (1987) carried out an experiment in Delhi, India, in 1983-84 and stated that application of nitrogen, phosphorus and potassium fertilizers resulted in significant increases in 1000-seed weight of mungbean.

Patel *et al.* (1984) studied the effects of 0, 10, 20 and 30 kg N ha^{-1} and 0, 20, 40, 60 and 80 kg P_20_5 ha^{-1} on the growth and seed yield of mungbean on clayey soil during, the summer seasons of 1979-80. They observed that application of 40 kg P_20_5 ha^{-1} with up to 20 kg N ha^{-1} significantly increased the 1000-seed weight of mungbean; further increase in phosphorus rates was not economical. Bali *et al.* (1991) carried out a field trial during the Kharif season on silty clay loam soil, found that 1000-seed weight of mungbean increased with up to 40 kg N and 60 kg P_20_5 ha^{-1}.

Trung and Yoshida (1983) set up an experiment on mungbean in nutrient soil, containing 0-100 ppm N in the form of ammonium nitrate or 10 or 100 ppm N as urea, sodium nitrate, ammonium nitrate or ammonium sulphate. Results showed that 1000-seed weight was highest with 100 ppm N.

A field experiment conducted by Sarkar and Banik (1991), results revealed that application of 10 kg N/ha to mungbean resulted in appreciable improvement m yield attributes like 1000 seed weight over the control (no nitrogen). Quah and Jaafar (1994) noted that 1000 seed-weight of mungbean increased significantly the application of nitrogen at 50 kg ha^{-1}.

An experiment carried out in 1980-82 by Patel *et al.* (1988) on a loamy sand soil and observed that application of 20 kg P_20_5 ha^{-1} to mungbean increased 1000 seed weight.

Reddy *et al.* (1990) conducted an experiment with three cultivars of mungbean in 1987, applying 0 or 50 kg P_20_5 ha^{-1} as a basal dress or 50 kg P_20_5 ha^{-1} in two equal split dressings at the time of sowing and flowering. Results revealed that application of phosphorus increased 1000-seed weight.

Singh and Ahlawat (1998) stated that application of phosphorus to mungbean PS 16 increased 1000-seed weight up to 12.9 kg ha^{-1}. Mitra *et al.* (1999) reported that 1000-seed weight of summer mungbean might be maximized with the application of rock phosphate (50 kg P_20_5 ha^{-1}) when grown in acid soils of Tripura in India.

2.2.8 Seed yield

Rudreshappa and HaliKatti (2002) conducted a field experiment in Karnataka. India during the summer season of 1999-96 to study the effect of nitorgen levels (0, 12.5 and 25 kg ha^{-1}) on growth, yield and nutrient uptake of green gram in paddy flowers. Application of 12.5 kg N ha^{-1} recorded significantly higher grain yield. Further increase in N does (25 kg N ha^{-1}) did not significantly increase the yield.

Pathak *et al.* (2001) conducted an experiment in India to study the effect of N levels (0, 10, 20 or 30 kg ha^{-1}) on growth and yield of green gram under rainfed condition during the summer of 1999 application of 20 kg N ha^{-1} yielded at poor with that of 30 kg N ha^{-1} where as it had higher yield than 10 kg N ha^{-1} and no N treatments.

Mian *et al.* (2000) conducted a field experiment to know the effect of foliar spray with Bavistin 50wp (0.05%). In dofil M 45 80 wp (0.2%) and urea (1.2%) on the control of cercospora leaf spot and is reported that foliar application of urea showed no significant effect on cercospora leaf spot but increased seed yield.

Sarkar *et al.* (2005) conducted a field experiment to study the effect of plant spacing and phosphorus on seed yield of mungbean and observed that highest seed yield was found in the 30cm×10cm with 40 kg P_20_5 ha^{-1}

Kumar *et al.* (2002) conducted an experiment in Haryana. India to investigate the response of mungbean cultivar to different levels of P (0, 20, 40 and 60 kg ha^{-1}). They found that P at 40 and 60 kg ha^{-1} increased the grain yield over control and P at 20 kg ha^{-1}.

Yadav and Jakhar (2001) found that grain and stover yield of mungbean increased up to 60 kg P_20_5 application ha^{-1}. Singh *et al.* (2001) observed that 30 mg P_20_5 kg^{-1} soil gave the highest seed yield of green gram.

Malik *et al.* (2003) conducted a study in Pakistan to determine the effect of various level of N (0, 25, 50 kg ha^{-1}) and P (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean (*vigna radiata*) cv. NM-98 in 2001. Results showed that maximum seed yield and protein were obtained by combination of 25 kg N ha^{-1} and 75 kg P ha^{-1}.

Kumar *et al.* (2003) conducted a field experiment at Hisan, Haryana, India during the summer season of 1999-2000 to find out the effect of N (0, 10, 20 and 30 kg ha-1) and P (0, 20, 40 and 60 kg ha^{-1}) on the performance of mungbean cv. MH 85-111 and T44. They found that gain yield increased with increasing N rates up to 20 kg N ha^{-1}, but further increase in N rates did not affect yield. P at 40 and 60 kg ha^{-1} significantly increased grain and stover yield. Increasing P and N rates did not affect harvest index.

Sharma *et al.* (2001) conducted an experiment to find out the effect of different levels on N (0, 10 and 20 kg ha^{-1}) and P (0, 30, and 60 kg P_20_5 ha^{-1}) on the performance of mungbean cv pusa Baisakhi under mid-hill condition in Himachal prodesh, India. Results revealed that highest level of N and P_20_5 increased biological and grain yield, harvest index and seed protein content.

Khlaimon *et al.* (1979) conducted a field experiment in the irrigated area of Banpong in Ratchaburi province and Chainat Agricultural Experiment Station, Bangkok, Thailand where 3 mungbean varieties (U-thong 1, CES 14 and Black pod) and five rates of fertilizer (3-0-0, 3-4.5-3, 3-9-6, 13.5-9 and 3-18-12 kg ha^{-1} of N P_20_5-K_20) were used. Results indicated that both the varieties and fertilzer had no effect on mungbean seed yield in both locations. The average seed yield of Ratchaburi irrigated area was 248 kg ha^{-1} while that of Chainat Agricultural Experiment Station was 158 kg ha^{-1}. There was an interaction between the varieties and fertilizers on seed yield at Chainat Agricultural Experiment Station.

Werakonphanit *et al.* (1979) stated that mungbean showed no significant differences among fertilizer grades, (0-0-0, 3-0-0 and 3-9-0) which seed yield 156, 168 and 175 kg ha^{-1} respectively. The fertilizer application for mungbean is not necessary.

An experiment, conducted by Sardana and Verma (1987) in Delhi, India, in 1983, 84, results revealed that application of nitrogen, phosphorus and postassium fertilizers resulted in significant increases in seed yield of mungbean.

Results from field experiments conducted by Mahadkar and Saraf (1988) during the spring/summer and Kharf seasons of 1984-85 showed that application of N with P and K at 20:2:5 kg ha^{-1} to mungbean as foliar spray at the pod filling stage gave seed yield than N applied as a top dressing at the same growth stage. Khanam *et al.* (1996) reported that the full NPK plus compost treatment increased the seed yield of mungbean by 83-87%.

A field trial was conducted by Dhingra *et al.* (1998) in 1992-94 at Ludhiana, Punjab, India on loamy sand soil, low in organic carbon and medium in P and K, to study the combined effects of NPK and other manipulations on the productivity of mungbean (*V. radiata*)—Indian mustard (*Brassica juncea*) cropping system under irrigated conditions. The highest productivity of mungbean grown in the system was obtained with 30 kg N, 40 kg P and 2 kg K ha^{-1} applied to the crop under the normal plant density.

Yein *et al.* (1981) applied nitrogen and phosphorus fertilizers to study their relative contributions towards increasing the seed yield of mungbean. Their studies showed that nitrogen along with phosphorus fertilizer increased the seed yield. Yein (1982) conducted 2-year field trials in Assam, India, on mungbean and find out that 10 kg nitrogen in combination with 20 kg phosphorus ha^{-1} resulted in significant increases in seed yield.

In trials on clayey soil during the summer seasons of 1979-80, Patel *et al.* (1984) studied the effects of 0, 10, 20 and 30 kg N ha^{-1} and 0, 20, 40, 60 and 80 kg P_20_5 ha^{-1} on the growth and seed yield of mungbean. A significant increase in seed yield was observed with the application of nitrogen up to 20 kg ha^{-1} and 40 kg P_20_5 ha^{-1}; further increase in phosphorus rates was not economical.

Arya and Kalra (1988) reported that applied phosphorus (50 kg ha^{-1}) and nitrogen (50 kg ha^{-1}) increased the soil N content and mungbean yield. Bali *et al.* (1991) conducted a field trial in the Kharif seasons on silty clay loam soil and found that seed yield of mungbean increased with up to 40 kg N and 60 kg P_20_5 ha^{-1}.

A field experiment was carried out by Sarkar and Banik (1991), results showed that application of N and P improved plant productivity and significantly enhanced the seed yield of mungbean. Response to N and P_20_5 was recorded up to 10 and 60 kg ha^{-1}, respectively. The maximum seed yield was obtained with the combination of 20 kg N and 60 kg P_20_5 ha^{-1} which was statistically at par with 10 kg N supplied along with 60 kg P_20_5 ha^{-1}. Both 10 and 20 kg N ha^{-1} gave significantly higher seed yield over the control at each P level.

Gopala Rao *et al.* (1993) conducted a field trial to find out the response of four mungbean cultivars cv. Pusa Baishakhi, LGG 407, LGG 410 and MS 267 to 3 levels of phosphorus (0, 25 and 50 kg P_20_5 ha^{-1}) during the Kharif season of 1988-89 in sandy loam soil of Bapalta, India. The soil was low in available P_20_5 (9 kg ha^{-1}). A uniform dose of 20 kg N ha^{-1} was applied as a basal for all the treatments. Irrespective of varieties tested, the seed yield of mungbean increased significantly with the increase in phosphorus levels from 0 to 50 kg P_20_5 ha^{-1}. Phosphorus application increased the seed yield by 18 and 51.2% at 25 and 50 kg P_20_5 ha^{-1} over no phosphorus. However, Pusa Baishakhi out-yielded all the other varieties at 50 kg P_20_5 ha^{-1}.

In a field experiment on a clay soil during the Kharif season of 1990, Badole and Umale (1994) observed that seed yield of mungbean cv. TAP increased by N and P application. In the fertilizer treatments, application of 50% of the recommended N and P rate gave the highest yield of 1.17 t ha^{-1}.

Patel and Patel (1994) carried out a field experiment during the summer seasons of 1990-1991 at Navasari, Gujarat, India, mungbean cv. K 51 given 20 kg N + 40 kg P_2O_5 ha^{-1} (recommended rate) gave the highest seed yield (1.74 t ha^{-1}) which was not significantly different (1.67 t ha^{-1}) from the foliar application of urea (1.5%) + diammonium phosphate (0.5%) at 30 and 40 DAS. Applying only 25 or 50% of the recommended N plus P rates, with or without foliar N and P, significantly decreased the seed yield.

Yadav *et al.* (1994) conducted a field trial on sandy loam soil during the Kharif (monsoon) season of 1986 at Hisar, Haryana, India, with mungbean cv. K 851 and were given 0, 50 or 100% of the recommended N and P fertilizers (20 kg N as urea and 40 kg P_20_5 ha^{-1} as single super phosphate). They found that mungbean receiving the recommended fertilizer rate gave the highest seed yield.

Karle and Panwar (1998) conducted a field trial at Badnapur, Maharashtra, India, in 1992-95. Mungbean was grown in the Kharif (monsoon) seasons. Different N and P fertilizer rates were applied in both the seasons. There were not treatment effects on the seed yield of mungbean.

In a field experiment, carried out by Sarma and Sarma (1999) in summer 1996-1997 and 1997-98 at Golaghat, Assam, India, mungbean was grown using farmers practices or different combinations of fertilizer application (10 kg N + 35 kg P_20_5 ha^{-1}). Seed yield was 0.40 t ha^{-1} with farmers' practices, while among the individual improved practices; the highest yield was given by the fertilizer application (0.77 t ha^{-1}).

Hamid (1988) reported that N application increased the seed yield of mungbean cv. Mubarik grown in a polyethylene green house. Mahmoud *et al.* (1988) also observed that applied nitrogen increased the seed yield up to a certain level with different row spacing in mungbean. Patel *et al.* (1988) conducted a field experiment on a loamy sand soil in 1980-82 and noted that application of 0 - 20 kg N ha^{-1} to mungbean had no significant effect on the seed yield.

Pongkao and Inthong (1988) reported that application of 15 kg N ha^{-1} to mungbean was superior to nil in the entire characteristics measured, especially produced seed yield 23 per cent higher and statistically significant. Though the four rates of N applied at the flowering did not cause the difference in yield to be statistically significant, however 60 kg N ha^{-1} tended to produce the highest yield.

Hamid (1991) found that a concentration of 10 mg N was most beneficial to pod and seed development of mungbean than the higher or lower concentrations. Spraying N at flowering time caused significant increase in yield but application at flowering and late reproductive phase gave significantly greater seed yield than any single application. He also reported that foliar application of N at 10 mg applied twice in the reproductive phase gave higher yield advantage.

Leelavathi *et al.* (1991) reported that different levels of nitrogen showed significant difference in seed yield of mungbean up to a certain level (60 kg N ha^{-1}). Sarkar and Banik (1991) reported that seed yield of mungbean increased significantly up to 10 kg N ha^{-1}. On an average, seed yield increased by 24 per cent due to 10 kg N ha^{-1} over no nitrogen.

Chowdhury and Rosario (1992) had undertaken a study to point out the effects of 0, 30, 60 or 90 kg N ha^{-1} on the growth and yield performance of mungbean at Los Banos, Philippines in 1988. They noted that applied N at the levels above 30 kg ha^{-1} reduced the seed yield.

Phimsirkul (1992) conducted a field trial, results revealed that no effects of nitrogen fertilizer were observed, when mungbean was cultivated in Mab Bon soil. Seed yield of mungbean varieties, U-Thong 1 when received nitrogen at 3 kg ha^{-1}, trend to be relatively higher seed yield than the other treatments.

Tank *et al.* (1992) observed that mungbean fertilized with 20 kg N ha^{-1} out yielded rest of the higher (40 kg N ha^{-1}) and lower (unfertilized control) levels of N by recording significantly higher seed yield. Ardeshna *et al.* (1993) stated that application of nitrogen @ 20 kg ha^{-1} to mungbean out-yielded (7.5 q ha^{-1}), but significantly higher than 10 kg ha^{-1}.

In an experiment, carried out by Santos *et al.* (1993) on mungbean cv. Berken, grown in pots in podzolic soil where 7 levels of N (0, 25, 50, 100, 200, 400 and 500 kg ha^{-1}) were applied in the form of NH_4NO_3. They reported that seed yield per plant increased with the first increment of N (25 kg N ha^{-1}) only and were decreased at N application rates 200 kg ha^{-1} or above. Plants grown at 400 and 500 kg ha^{-1} showed reduced growth and seed yield at these high rates. It is concluded that lower rates of N can improve the seed yield of well-nodulated mungbean plants but no advantage is gained by using the rates less than 25 kg ha^{-1}.

Quah and Jaafar (1994) noted that seed yield of mungbean increased significantly by the application of nitrogen fertilizer at 50 kg ha^{-1}. Kaneria and Patel (1995) conducted a field experiment on a Vertisol in 1989-91 in Gujarat, India, mungbean cv. K 581 was sown and given 0 or 20 kg N ha^{-1}. The application of 20 kg N ha^{-1}

to mungbean significantly increased the seed yield from 1.08 (no nitrogen) to 1.14 t ha^{-1}.

In a field experiment conducted by Satyanarayanamma *et al.* (1996) in 1992-93 at Lam, Guntur, Andhra Pradesh, India, 5 mungbean cultivars were sprayed with 2% urea at pre-flowering, flowering, pod development or at all the combinations or two to three growth stages. They followed that spraying urea at flowering and pod development stages produced the highest seed yield of 1.59 t ha^{-1}.

In a field trial, Vasimalai and Subramanian (1980) reported that seed yield of mungbean was significantly increased with 50 kg P_20_5 ha^{-1} and decreased with further increases in P rates. Abdulsalam and Nair (1983) grown mungbean on a sandy clay loam acidic soil (P^H 5), applied 0, 30 and 60 kg P_20_5 ha^{-1} and/or 0, 0.5 and 1 t calcium hydroxide ha^{-1} (corresponding to 0, 25 and 50% of lime requirement up to 15 cm depth). Results revealed that seed yield was significantly increased by phosphorus, lime and especially lime + phosphorus.

Ahmed *et al.* (1986) conducted a field experiment to investigate the effect of various levels of phosphorus on the growth and yield performance of mungbean. They found that phosphorus application up to 60 kg ha^{-1} progressively and significantly enhanced the seed yield.

Patel *et al.* (1988) reported that application of 20 kg P_20_5 ha^{-1} to mungbean gave average seed yield of 0.75 t ha^{-1} compared with 0.57 t ha^{-1} without phosphorus. Yield was not further increased with 40-60 kg P_20_5 ha^{-1}. In 1986-88, Kalita (1989) applied 30 kg P_20_5 ha^{-1} to mungbean that produced the seed yields of 0.90 - 0.96 t ha^{-1} compared with 0.59 - 0.68 t ha^{-1} without phosphorus. Further increase in yield with 45 kg P_20_5 ha^{-1} was not significant.

In an experiment, carried out by Reddy *et al.* (1990) with three cultivars of mungbean in 1987, applying 0 or 50 kg P_2O_5 ha^{-1} as a basal dressing or 50 kg P_2O_5 ha^{-1} in two equal split dressings at the time of sowing and flowering, gave the average seed yield of 65.09, 99.56 and 108.61 g m^{-2}, respectively.

Thakuria and Saharia (1990) noted that Phosphorus levels significantly influence the seed yield. The highest seed yield of 7.20 q ha^{-1} was recorded with the application of 20 kg P_2O_5 ha^{-1}, which was at par with 40 and 60 kg P_2O_5 ha^{-1}. In a field trial, Sarkar and Banik (1991) studied that increase in levels of P_2O_5 up to 60 kg ha^{-1} resulted into correspondingly higher seed yield. They also found that increase in seed yield mungbean due to 30 and 60 kg P_2O_5 ha^{-1} was 51 and 93 per cent over the control, respectively.

In a field experiment, during the summer seasons in 1987-88 at Baruipur Farm Calcutta University, Sarkar (1992) studied that seed yield of mungbean response phosphorus application (0, 40 or 80 kg P_2O_5 ha^{-1}) was linear.

Tank *el al.* (1992) carried out a field experiment and reported that seed yield increased significantly up to the level of 40 kg P_2O_5 ha^{-1} over the control. This was evidently resulted from higher number of pods $plant^{-1}$, pod length and test weight. Relative consistency in seed yield with an increase in P level from 40 to 80 kg ha^{-1} indicates that P level greater than 40 kg P_2O_5 ha^{-1} may not be helpful for harvesting potential yield of summer mungbean.

Ardeshna *et al.* (1993) observed that significantly higher seed yields of mungbean (7.7 and 7.71 q ha^{-1}) were recorded at 40 and 60 kg P_2O_5 ha^{-1}, respectively compared with 20 kg P_2O_5 ha^{-1} (6.46 q ha^{-1}). Chovati *et al.* (1993) followed that application of 40 kg P_2O_5 ha^{-1} being on a par with 60 kg P_2O_5 ha^{-1} resulted in significantly higher growth and seed yield of summer mungbean than 0 and 20 kg

P_2O_5 ha^{-1}. The response to Phosphorus fertilization could be described to low P status of these soils.

In a field trial conducted by Borah (1994) at Shillongani, Assam, India, in the 1990- 91 rainy seasons and applied 0 or 50 kg diainmonium phosphate ha^{-1} on mungbean cv. ML- 131. Results revealed that applied phosphorus did not affect the crop yield.

Kalita *et al*. (1995) conducted an experiment during the winter season, of 1988-89 in India. Results reported that application of phosphorus significantly increased the seed yield of mungbean. Bayan and Saharia (1996) carried out an experiment to study the effect of phosphours on mungbean during the Kharif seasons of seasons of 1994-95 in Biswanath Chariali, Assam, India. The results indicated that seed yield was unaffected by phosphorus application.

Sharma *et al*. (1997) conducted a field experiment in 1989 and 1990 in Uttar Pradesh, India, mungbean cv. Pant Moong 2 was given 0, 25, 50 or 75 kg P_2O_5 ha^{-1}. It was found that seed yield increased with up to 50 kg P_2O_5 (1.22 t ha^{-1}).

Sharma and Singh (1997) carried out a field experiment during 1989 and 1990 to study the effects of various levels of phosphorus (0, 25, 50 and 75 kg ha^{-1}) on the growth, yield attributes and yield of mungbean. They found that application of phosphorus @ 50 kg ha^{-1} enhanced the seed yield significantly during both the years.

Karam Husain *et al*. (1998) performed a field trial in 1986-88 at Kanpur, Uttar Pradesh, India, mungbean cv. T 44 was intercropped with pigeonpea (*Cajanus cajan*) cv. T 21 with application of 0, 30, 60, or 90 kg P ha^{-1}. The best-combined yield was obtained by the application of 60 kg P ha^{-1}.

Singh and Ahlawat (1998) carried out 2-years experiment at the Indian Agricultural Research Institute, New Delhi, India, during 1986-87 on a sandy loam soil, low in organic carbon and N, and medium in P and K and with a pH of 7.8. Results of their study indicated that P application to mungbean cv. PS 16 increased the seed yield up to 12.9 kg ha^{-1}. Masthan *et al.* (1999) conducted a field experiment in 1991- 93 at Hyderabad, Andhra Pradesh, India, and reported that yield of summer mungbean cv. LGG 127 increased with the increasing phosphorus rates.

Mitra *et al.* (1999) conducted a field experiment during the Kharif (rainy) seasons of 1996 and 1997 to study the effect of rock phosphate on the growth and yield of mungbean in acid soils of Tripura, India. Results of their study revealed that seed yield of mungbean should be maximized with the combined application of Mussoorie rock phosphate (50 kg P_20_5 ha^{-1}). Application of Mussoorie rock phosphate increased the seed yield by 39.9%.

Rashid *et al.* (1999) carried out a field experiment for determining P deficiency diagnostic criteria in mungbean. In a pot culture experiment using a P-deficient typic Ustochrept, maximum increased in seed yield by P application was 686% over the control and fertilizer requirement for near-maximum (95%) seed yield was 30 mg P kg^{-1} soil In a field experiment on a P-deficient typic Camborthid, however maximum increased in seed yield was 262% over the control.

Raundal *et al.* (1999) carried out a field trial in Kharif (monsoon) season at Pune, Maharashtra, India, in 1997-98 and the results of their experiment suggested that application of 60 kg P_20_5 ha^{-1} to mungbean significantly increased the seed yield (18.23 q ha^{-1}).

An experiment was conducted by Singh *et al.* (1999) on mungbean cv. NDM at Faisabad, Uttar Pradesh, India in summer 1996 and was given 0-26.4 kg P ha^{-1}.

Results of their study showed that seed yield of mungbean generally increased with up to 26.4 kg P ha^{-1}.

Ram and Dixit (2000) conducted a field experiment during summer 1987 at Faisabad, Uttar Pradesh, India, mungbean cv. K-851 was sown on 20 or 30 March or 9 April and given 0, 20, 40 or 60 kg P ha^{-1}. They reported that seed yield of mungbean was increased with increasing P rate.

Sadasivam *et al.* (1990) reported that mungbean cv. C03 gave 809, 833, 870 and 890 kg seed ha^{-1} with no K, 25 kg K_20 ha^{-1}, 1% KC1 spray and 1% K_2S0_4 spray at the flowering, respectively. The greatest responses came from the application as foliar sprays.

In a field trial, conducted by Sangakkara (1990), 0-120 kg K_20 ha^{-1} was applied as basal dressings or split applications (60:40 at the planting and flowering time) and the growth and yield parameters of mungbean cv. MI 5 and Type 61 were studied. Potassium application did not affect the germination of seeds and seedlings establishment but it increased the seed yield $plant^{-1}$.

Dinata *et al.* (1992) studied the response of mungbean varieties cv. MLG 944 and MLG 648 to potassium fertilizer from April to June 1989 in Kuta, Badung (Bali). The potassium content in the soil was low. The potassium doses were 0, 12.5, 25, 37.5, 50 and 75 kg K_20 ha^{-1}, respectively. There was no significant effect of potassium on the seed yield of MLG 944 and MLG 648 (1.9 and 1.5 t ha^{-1}, respectively).

2.2.9 Straw yield

Sarkar and Banik (1991) noted that the interaction effect between N and P on straw yield of mungbean was significant. With higher rates of both N and P, there were correspondingly higher straw yield. The straw yield was appreciably higher at higher N levels at all the levels of P. Both the 10 and 20 kg N ha^{-1} gave significantly higher straw yield over the control at each P level. The response to higher rate of N proved more beneficial with higher rate of P only.

Mahmoud *et al.* (1988) observed that nitrogen application increased the straw production up to a certain level with different row spacing in mungbean.

Banik (1991) conducted a field experiment, results showed that straw yield of mungbean increased significantly up to 10 kg N ha^{-1}. On an average straw yield increased by 24 per cent due to 10 kg N ha^{-1} over no nitrogen.

Sarkar and Banik (1991) reported that increasing levels of P_20_5 up to 60 kg ha^{-1} resulted in correspondingly higher straw yield of mungbean. Increased straw yield might be due to higher synthesis of carbohydrates and protein. Sharma and Singh (1997) stated that applications of phosphorus @ 50 kg ha^{-1} enhanced the straw yield of mungbean significantly.

2.2.10 Harvest index (HI)

In a field experiment, carried out by Mozumder (1998) at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from March 1994 to June 1994, studied with five nitrogen levels (0, 20, 40, 60 and 80 kg N ha^{-1}) and two varieties of summer mungbean viz., Binamoog-2 and Kanti, results revealed that nitrogen produced negative effect on harvest index. Harvest index (%) was decreased by higher nitrogen levels.

Singh and Ahlawat (1998) conducted a 2-year study at the Indian Agricultural Research Institute, New Delhi, India during 1986-87 on a sandy loam soil that low in organic carbon and N, and medium in P and K and with a pH of 7.8. Results indicated that P application to mungbean cv. PS 16 increased the harvest index up to 12.9 kg ha^{-1}.

Chapter 3

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted to study the effect of fertilizer level and plant population on the performance of summer mungbean. The materials used and methodology followed in the investigation have been presented in this chapter.

3.1 Experimental Site

The experiment was conducted at the Agronomy farm of Sher-e-Bangla Agricultural University, Dhaka during the period from first week of April to mid June 2007. The area was situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

3.2 Soil

The experimental land was medium high belonging to the "The Modhupur Tract", AEZ-28 (Anon., 1988). The experimental site was shown in the map of AEZ of Bangladesh in Appendix-I. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH 7.1 and had organic matter 1.08%. The experimental area was flat having available irrigation and drainage system and above flood level. The physio-chemical properties of the experimental plot during the period of the study have been presented in the Appendix- II.

3.3 Climate

The climate of the locality was sub-tropical. The climate was characterized by high temperature and heavy rainfall during kharif-1 season (March- September) and scanty rainfall during rabi season (October-March) associated with moderately low temperature. The prevailing weather conditions during the study period have been presented in Appendix-III.

3.4 Planting materials

The seeds of BARI mung 5, a modern mungbean variety was used as experimental material. BARI mung 5 was developed by Pulse Research Center of Bangladesh Agricultural Research Institute in 1997. Plant height of this variety ranges from 40-45 cm and seeds are dark green in colour. Life cycle lasts for 55-60 days and synchronous type. The plants are erect, stiff and less branched. Thousand seed weight is about 41-42 g. It is resistant to the cercospora leaf spot and tolerant to yellow mosaic virus. Each plant contains 15-20 pods. Each pod is around 10 cm. long and contains 8-10 seeds. The average seed yield of this cultivar is 1200 kg (BARI).

3.5 Treatments

The aim of this experiment was to increase the yield of summer mungbean by using appropriate planting density and optimum fertilizer level of the crop. As such, two sets of treatments were included in the experiment which was as follows:

A. Fertilizer level : 4 (Main Plot)

1. Without fertilizer/Control (F_0)
2. Half of the recommended dose of fertilizer (F_1)
3. Recommended dose of fertilizer (F_2)
4. Double of the recommended dose of fertilizer (F_3)

Recommended dose of Urea, TSP, MP and Boric acid were 45, 100, 58 and 1 kg ha^{-1} respectively (BARI).

B. Plant population : 4 (Sub Plot)

1. 60 plants m^{-2} (D_1)
2. 45 plants m^{-2} (D_2)
3. 30 plants m^{-2} (D_3)
4. 15 plants m^{-2} (D_4)

3.6 Experimental design

The experiment was laid out in split-plot design with three replications where fertilizer level was assigned in the main plot and planting density in the sub plot. The unit plot size was 4m x 2.5m. The blocks and unit plots were separated by 1.5m and 1m spacing, respectively. Laying out of the experiment was done on 2 April, 2007. A layout of the experiment has been shown in the Appendix- IV.

3.7 Land preparation

At first the land was prepared by pre-sowing irrigation on March 27, 2007 and then ploughed with power drown tractor followed by laddering to achieved a good tilth that required for the crop under consideration.

3.8 Fertilizer application

The recommended dose of fertilizer of 45, 100, 58 and 1 kg ha^{-1} were applied in the form of Urea, Triple super phosphate, Murate of potash and boric acid, respectively. All the fertilizer was applied at the final land preparation as per treatment.

3.9 Seed sowing

The seeds (BARI mung 5) were sown by hand in 30 cm apart lines continuously at about 3 cm depth on April 3, 2007.

3.10 Intercultural operations

3.10.1 Weeding and thinning

The plots were weeded twice on 15 and 30 days after sowing and thinning was done as per recommended planting density.

3.10.2 Irrigation and drainage

Two irrigations were given as plants required. First irrigation was given immediate after sowing and second irrigation were applied 10 days latter. During experimental period, there was heavy rainfall for several times. So it was essential to remove the excess water from the field.

3.10.3 Plant protection measures

The fungicide Cupravit 50 WP (Cupper oxychloride) was sprayed @ 80g/5 decimal during the growth stage of crop to control foot and root rot diseases.

3.11 Determination of maturity

When about 80% of the pods were turned brown colour, the crop was assessed to attain maturity.

3.12 Harvesting and post harvesting operation

The crop was harvested on 6 and 9 June, 2007. Harvesting was done on ten pre selected plants from which plant parameters data were collected and three square meter area from the central portion of each plot for taking yield data. Harvested plants were bundled and properly tagged and then brought to the threshing floor. The pods were separated, dried and threshed. Plants were also dried.

3.13 Data collection

Harvested ten sample plants were used for taking plant characters data and plants of three square meter area were used for taking grain and stover yield. The following data were recorded from this experiment: -

A. Growth data-

1. Plant height at 15 days interval starting from 15 DAS
2. Dry weight plants^{-1} at 15 days interval starting from 15 DAS

B. Yield and other crop characters data-

1. Branches plants^{-1} (no.)
2. Pods plants^{-1} (no.)
3. Length of pod (cm)
4. Seeds pod^{-1} (no.)
5. Weight of 1000 seeds (g)
6. Seed yield (t ha^{-1})
7. Stover yield (t ha^{-1})
8. Biological yield (t ha^{-1})
9. Harvest index (%)

The detailed outline of data collection procedure is given below:

3.11.1 Plant height (cm)

The height of ten randomly pre-selected plants from each plot was measured from the ground level to the tip of the leaf of the main shoot at 15 days interval till harvest

3.11.2 Dry weight plant^{-1} (g)

Five plants were randomly selected at 15 DAS to harvest and different plant parts were separated. After that the separated plant parts were oven dried and weighed.

3.11.3 Branches plant^{-1} (no.)

Total number of branches from ten plants of each plot were counted and the mean values were determined.

3.11.4 Pods plant^{-1} (no.)

The total number of pods of ten selected plants per plot at harvest were counted and the average values were recorded.

3.11.5 Length of pod (cm)

Ten pods were randomly selected from the ten plants and the average length of pod were calculated.

3.11.6 Seeds pod^{-1} (no.)

Pods from each of ten plants were separated at harvest from which ten pods were selected randomly. The seeds were separated from the selected ten pods. Then the number of seeds per pod was counted and average number of seeds pod^{-1} was determined.

3.11.7 Weight of 1000-seeds (g)

A sub sample of seeds were taken from each plot from which 1000 seeds were counted manually. One thousand seeds thus counted were weighed in a digital balance at 12% moisture level to obtain 1000-seed weight (g).

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

The pods of harvested area were harvested as per experimental treatments and threshed. Seeds were cleaned and properly dried under sun. Then seed yield plot^{-1} was recorded and adjusted at 12% moisture level and converted into t ha^{-1}.

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

The plants of the harvested area were collected and dried in the sun and weighted. The weight was converted into t ha^{-1}.

3.11.10 Biological yield (t ha^{-1})

Biological yield was calculated using the following formula:

Biological yield = Grain yield + Stover yield

3.11.11 Harvest index

The harvest index was determined by the following formula (Donald, 1963; Gardner *et al*., 1985)

$$\text{Harvest index (\%)} = \frac{\text{Seed yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

3.13 Statistical analysis

The collected data were statistically analyzed following the IRRISTAT software and the mean values were adjudged by least significant difference (LSD) test at 5% level of significance.

Chapter 4

Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Crop growth characters

4.1.1 Plant height at different days after sowing

4.1.1.1 Effect of fertilizer level

Plant height of mungbean was significantly influenced by fertilizer level at 15, 30, and 45 days after sowing (DAS) and at harvest (Appendix V and Table 1). At 15 DAS was that the tallest plant (17.94 cm) was found in the double of the recommended dose of fertilizer and the height reduced gradually with the decreasing rate of fertilizers dose up to without fertilizer. Similar trend of plant height was observed at 30 and 45 DAS, and at harvest. However, the shortest plant (15.30cm) was found in the without fertilizer treatment which was statistically similar with half of the recommended dose of fertilizer treatment. Similar trend of plant height was observed at harvest. At 30 and 45 DAS the shortest plant was observed in the without fertilizer treatment. The pattern of plant height increment due to fertilizer treatment revealed that the rate of increase in plant height was much higher from 15 DAS to 30 DAS than other dates. Plant height at double of the recommended dose increased over without fertilizer were 17.25%, 22.29%, 18.61% and 17.70% at 15, 30, 45 DAS and at harvest, respectively. These results were in agreement with the findings of Sardana and Verma (1987), and Suhartatik (1991) who reported that NPK fertilizers significantly increased the plant height of mungbean.

Table 1. Influence of fertilizer level on plant height (cm) of mungbean at different growth stages

Fertilizer level	Days after sowing			At harvest
	15	30	45	
F_0	15.30	38.54	44.54	46.94
F_1	15.84	41.19	47.05	48.35
F_2	16.45	44.60	49.15	52.66
F_3	17.94	47.13	52.83	55.25
$LSD_{(0.05)}$	1.14	1.29	2.52	2.09
CV (%)	8.07	3.49	6.03	4.77

Here,
F_0 = Without fertilizer/Control
F_1 = Half of the recommended dose of fertilizer
F_2 = Recommended dose of fertilizer
F_3 = Double of the recommended dose of fertilizer

4.1.1.2 Effect of plant population

Plant height of mungbean was significantly influenced by plant population at 30 and 45 DAS, and at harvest (Appendix V and Table 2) but plant population had no significant effect on plant height at 15 DAS. At 30 DAS the highest plant population (60 plants m^{-2}) showed the tallest plant (46.08 cm), which was statistically similar with 45 plants m^{-2} (44.03 cm) and after that the plant height decreased gradually with decreasing plant population and the lowest height (40.32 cm) was obtained from 15 plants m^{-2}. Plant height obtained from 15 and 30 plants m^{-2} were statistically similar at 30 DAS. Similar trend of plant height was observed at 45 DAS and at harvest. The plants in higher population density became taller might be due to competition for sunlight and other related factors. The results in respect of plant height due to population densities corroborates with the findings of El-Habbasha *et al.* (1996) and Hoq and Hossain (1981).

Table 2. Influence of plant population on plant height (cm) of mungbean at different growth stages

Plant population	Days after sowing			At harvest
	15	30	45	
D_1	17.19	46.08	51.05	53.72
D_2	16.53	44.03	49.86	52.33
D_3	16.10	40.99	46.96	49.25
D_4	15.73	40.32	45.69	47.95
$LSD_{(0.05)}$	NS	2.19	1.46	1.46
CV (%)	12.9	6.98	4.14	3.95

Here,
D_1 = 60 plants m^{-2}, D_2 = 45 plants m^{-2}, D_3 = 30 plants m^{-2}, D_4 = 15 plants m^{-2}
NS = Not significant

4.1.1.3 Interaction effect of fertilizer level and plant population

There observed a significant variation in plant height due to interaction between fertilizer level and plant population at 30 and 45 DAS, and at harvest (Appendix V and Table 3). At 30 DAS, the longest plant (50.86 cm) was obtained from interaction treatment of F_3D_1 followed by interaction treatments of F_2D_1, F_3D_2, F_2D_2 and F_1D_1. The values of plant height in these treatments were statistically similar. The shortest plant (37.13 cm) was recorded in the interaction treatment of F_0D_4, which was statistically similar with the interactions of F_0D_3, F_0D_2, F_0D_1, F_1D_3, F_1D_4 and F_2D_4. The trend of plant height at 45 DAS and at harvest was similar as observed in 30 DAS. From the findings of the experimental results it appeared that double of the recommended dose and 60 plants m^{-2} gave the tallest plant and without fertilizer with 15 plants m^{-2} produced the shortest plant height.

Table 3. Interaction effect of fertilizer level and plant population on plant height (cm) of mungbean at different growth stages

Interaction	Days after sowing			At harvest
	15	30	45	
F_0D_1	16.00	39.51	47.06	49.11
F_0D_2	15.40	39.37	45.46	48.08
F_0D_3	15.03	37.98	43.53	45.73
F_0D_4	14.80	37.13	42.11	44.84
F_1D_1	16.80	45.87	50.81	51.97
F_1D_2	15.76	43.08	49.10	49.86
F_1D_3	15.60	38.57	44.72	46.66
F_1D_4	15.20	37.25	43.53	44.93
F_2D_1	17.50	48.10	51.14	55.07
F_2D_2	17.00	46.14	50.02	54.23
F_2D_3	15.90	42.23	48.13	51.30
F_2D_4	15.40	41.94	47.33	50.15
F_3D_1	18.76	50.86	55.20	58.71
F_3D_2	17.95	47.53	54.87	57.13
F_3D3	17.85	45.17	51.47	53.32
F_3D_4	17.51	44.96	49.80	51.86
$LSD_{(0.05)}$	NS	4.99	3.38	3.38
CV (%)	12.90	6.92	4.14	3.95

Here,
F_0 = Without fertilizer/Control
F_1 = Half of the recommended dose of fertilizer
F_2 = Recommended dose of fertilizer
F_3 = Double of the recommended dose of fertilizer

D_1 = 60 plants m^{-2}, D_2 = 45 plants m^{-2}
D_3 = 30 plants m^{-2}, D_4 = 15 plants m^{-2}
NS = Not significant

4.1.2 Dry matter production

4.1.2.1 Effect of fertilizer level

The total dry weight of plant was significantly influenced by fertilizer level from 15 DAS to at harvest (Appendix VI and Table 4). The result revealed that maximum dry weight (0.46 g plant^{-1}) was recorded in double of the recommended dose and minimum dry weight (0.31 g plant^{-1}) was recorded in without fertilizer at 15 DAS (Table 4). The maximum dry weight (2.95 g plant^{-1}) was recorded at 30 DAS from double of the recommended dose (F_3) followed by recommended dose of fertilizer. These two treatments showed statistically similar dry weight. The minimum dry weight (1.79 g plant^{-1}) was recorded in without fertilizer treatment. Similar trend of dry matter production was observed at 45 DAS and at harvest. These results are in agreement with the findings of Yein (1982), Agbenin *et al.* (1991) and Leelavathi *et al.* (1991) who reported that application of NP significantly increased the dry weight of the plants.

Table 4. Influence of fertilizer level on dry weight (g plant^{-1}) of mungbean at different growth stages

Fertilizer level	Days after sowing			At harvest
	15	30	45	
F0	0.31	1.79	4.99	7.35
F1	0.34	2.15	6.05	8.08
F2	0.42	2.73	7.11	9.08
F3	0.46	2.95	7.25	9.18
$LSD_{(0.05)}$	0.018	0.311	0.52	0.62
CV (%)	5.69	14.96	9.61	8.56

Here,
F_0 = Without fertilizer/Control,
F_1 = Half of the recommended dose of fertilizer,
F_2 = Recommended dose of fertilizer,
F_3 = Double of the recommended dose of fertilizer.

4.1.2.2 Effect of plant population

Dry weight of mungbean plant was significantly influenced by plant population at 15, 30 and 45 DAS and at harvest (Appendix VI and Table 5). The maximum dry weight (0.45 g $plant^{-1}$) was obtained from 15 plants m^{-2}, which was statistically similar with 30 plants m^{-2} and the minimum dry weight was obtained from 60 plants m^{-2} (0.32 g $plant^{-1}$), which was statistically similar with 30 plants m^{-2} at 15 DAS. At 30 DAS the lowest plant population (15 plants m^{-2}) showed the maximum dry weight (3.05 g $plant^{-1}$) after that dry weight decreased gradually with the increasing plant population and the minimum dry weight (1.76 g $plant^{-1}$) was obtained from 60 plants m^{-2}. Similar trend of dry weight was observed at 45 DAS and at harvest. Plants dry matter weight (plants m^{-2}) significantly increased with the decrease of plant population. This finding is conformity with the results of Trung and Yoshida (1985) who reported that increasing plant density increased dry matter productuon.

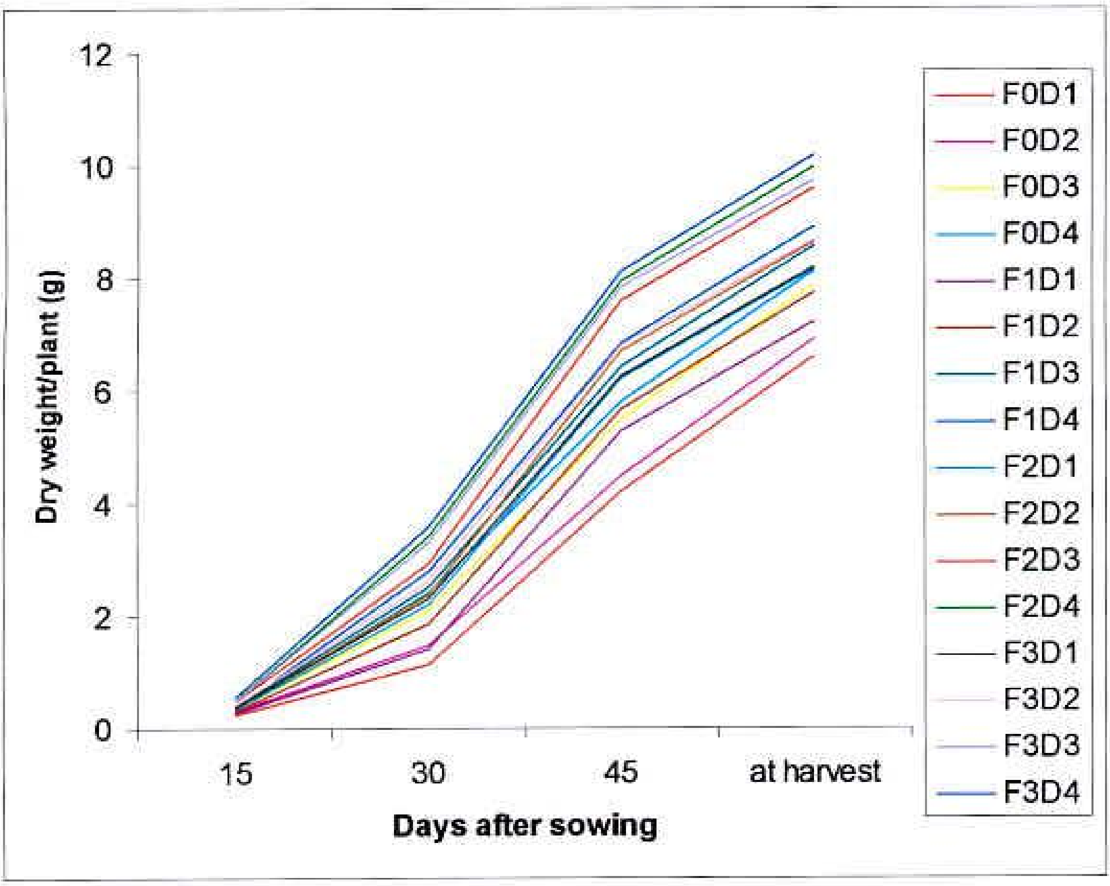
Table 5. Influence of plant population on dry weight (g $plant^{-1}$) of mungbean at different days after sowing

Plant population	Days after sowing			At harvest
	15	30	45	
D_1	0.32	1.76	5.48	7.52
D_2	0.35	2.07	5.91	7.97
D_3	0.42	2.74	6.83	8.93
D_4	0.45	3.05	7.17	9.28
$LSD_{(0.05)}$	0.025	0.172	0.64	0.61
CV (%)	9.12	9.81	13.91	10.01

Here,
D1 = 60 plants m^{-2}, D2 = 45 plants m^{-2}, D3 = 30 plants m^{-2}, D4 = 15 plants m^{-2}.

4.1.2.3 Interaction effect of fertilizer level and plant population

There was significant variation in dry weight due to interaction between fertilizer level and plant population at 15, 30 and 45 DAS and at harvest (Appendix VI and Fig 1). The figure showed that dry weight plant^{-1} increased progressively with the advances of growth stages for all interactions. The rate of increase was much higher from 30 to 45 DAS, than early and latter stages. However, the interaction F_3D_4 (double of the recommended dose with 15 plants m^{-2}) showed the highest dry weight plant^{-1} for all the growth stages followed by the interaction of F_2D_4, F_1D_2, F_3D_3 and F_2D_3. The lowest value of dry weight plant^{-1} was found to produce in the interaction of F_0D_1 (without fertilizer with 60 plants m^{-2}) for all the growth stages.



Here,

F_0 = Without fertilizer/Control

F_1 = Half of the recommended dose of fertilizer

F_2 = Recommended dose of fertilizer

F_3 = Double of the recommended dose of fertilizer

D_1 = 60 plants m^{-2}, D_2 = 45 plants m^{-2}

D_3 = 30 plants m^{-2}, D_4 = 15 plants m^{-2}

Figure 1. Interaction effect of fertilizer level and plant population on dry weight (g plant^{-1}) of mungbean at different growth stages ($LSD_{(0.05)}$ at 15 DAS = 0.058, 30 DAS = 0.398, 45 DAS = 1.488 and at harvest = 1.420)

4.2 Plant and yield characters

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

4.2.1.1 Effect of fertilizer level

Number of branches plant^{-1} responded significantly to various levels of fertilizer treatments (Appendix VII and Table 6). The result revealed that number of branches plant^{-1} showed an increasing trend with the increment of fertilizers doses. The highest number of branches plant^{-1} (2.62) was observed from double of the recommended dose of fertilizer (F_3) and that of second highest (2.54) was observed in recommended dose of fertilizer treatment. These two treatments showed statistically similar number of branches plant^{-1}. The lowest number of branches plant^{-1} (1.55) was observed in control treatment (F_0). These result was in agreement with the findings of Singh and Ahlawat (1998) who observed higher number of branches plant^{-1} with the higher fertilizer doses.

Table 6. Influence of fertilizer level on yield characters of mungbean

Fertilizer Level	Branches plant^{-1} (no.)	Pod length (cm)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	Wt. of 1000 Seed (g)
F_0	1.55	6.33	6.25	6.37	38.56
F_1	1.71	6.53	7.59	6.96	39.47
F_2	2.54	7.81	9.62	7.81	40.26
F_3	2.62	8.08	10.19	7.92	40.45
$LSD_{(0.05)}$	0.116	0.418	0.239	0.28	0.675
CV (%)	6.39	5.90	3.97	4.43	1.97

Here,
F_0 = Without fertilizer/Control
F_1 = Half of the recommended dose of fertilizer
F_2 = Recommended dose of fertilizer
F_3 = Double of the recommended dose of fertilizer

4.2.1.2 Effect of plant population

The number of branches plant^{-1} was significantly influenced by plant population (Table 7, Appendix VII). The result showed that the highest population (60 plants m^{-2}) showed lowest number of branches plant^{-1} (1.50) after that the number of branches plant^{-1} increased steadily with the decreases of plant population. However, the highest number of branches plant^{-1} (2.56) was found in 15 plants m^{-2}, which was statistically similar with the 30 plants m^{-2} (2.41). In general, number of branches plant^{-1} increased at lower plant population m^{-2} and it was probably due to availability of more space, nutrition, air, water and light to the plant in wider spacing. The present result was confirmatory with El-Habbasha *et al.* (1996) and Brathwaite (1982) who stated that increasing crop density decreased number of branches plant^{-1}.

Table 7. Influence of plant population on yield characters of mungbean

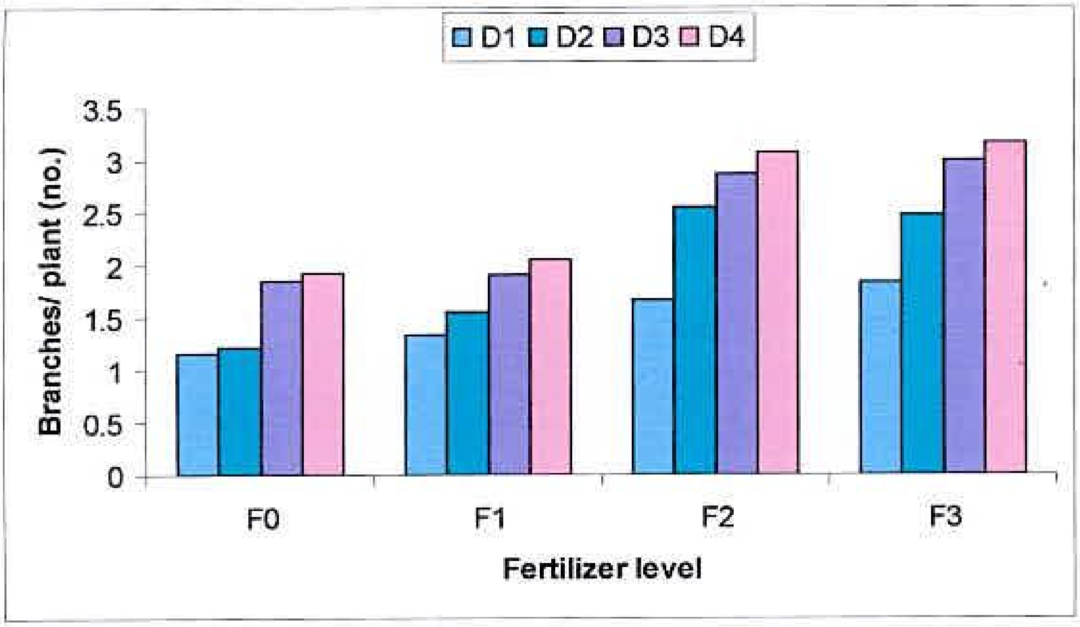
Number of plants m^{-2}	Branches plant^{-1} (no.)	Pod length (cm.)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	Wt. of 1000 Seed (g)
D_1	1.50	6.66	6.80	6.12	38.31
D_2	1.96	6.96	7.94	7.15	39.42
D_3	2.41	7.45	9.04	7.73	40.28
D_4	2.56	7.68	9.88	8.04	40.75
$LSD_{(0.05)}$	0.539	0.432	0.49	0.33	0.93
CV (%)	15.19	7.24	7.95	6.27	3.22

Here,
D_1 = 60 plants m^{-2}, D_2 = 45 plants m^{-2}, D_3 = 30 plants m^{-2}, D_4 = 15 plants m^{-2}.

4.2.1.3 Interaction effect of fertilizer level and plant population

The number of branches plant^{-1} was influenced significantly by the interaction of fertilizer level and plant population (Appendix VII). Number of branches plant^{-1} increased steadily with the increasing fertilizer dose and reducing plant population

(Fig.2). The highest number of branches plant^{-1} (3.17) was observed in the interaction of F_3D_4, which was statistically similar with the interactions of F_2D_4 (3.07), F_3D_3 (3.00) and F_2D_3 (2.87). The lowest number of branches plant^{-1} (1.17) was recorded in the interaction of F_0D_1.



Here,
F_0 = Without fertilizer/Control
F_1 = Half of the recommended dose of fertilizer
F_2 = Recommended dose of fertilizer
F_3 = Double of the recommended dose of fertilizer
D_1 = 60 plants m^{-2}, D_2 = 45 plants m^{-2}, D_3 = 30 plants m^{-2}, D_4 = 15 plants m^{-2}

Figure 2. Number of branches plant^{-1} influences by the interaction effect of fertilizer level and plant population ($LSD_{(0.05)}$ = 0.539)

4.2.2 Pod length

4.2.2.1 Effect of fertilizer level

The pod length varied significantly due to fertilizer levels (Appendix VII and Table 6). The maximum pod length (8.08 cm) was observed in double of the recommended dose of fertilizer treatment. Recommended dose of fertilizer gave the second highest result (7.81cm), which was statistically similar with double of the recommended dose. Without fertilizer gave the minimum pod length (6.33 cm). Pod length obtained from half of the recommended dose of fertilizer and without fertilizer was statistically similar. This result agreed with the findings of Sardana and Verma (1987), and Suhartatik (1991) who observed significant increased pod length of mungbean with the application of NPK fertilizers.

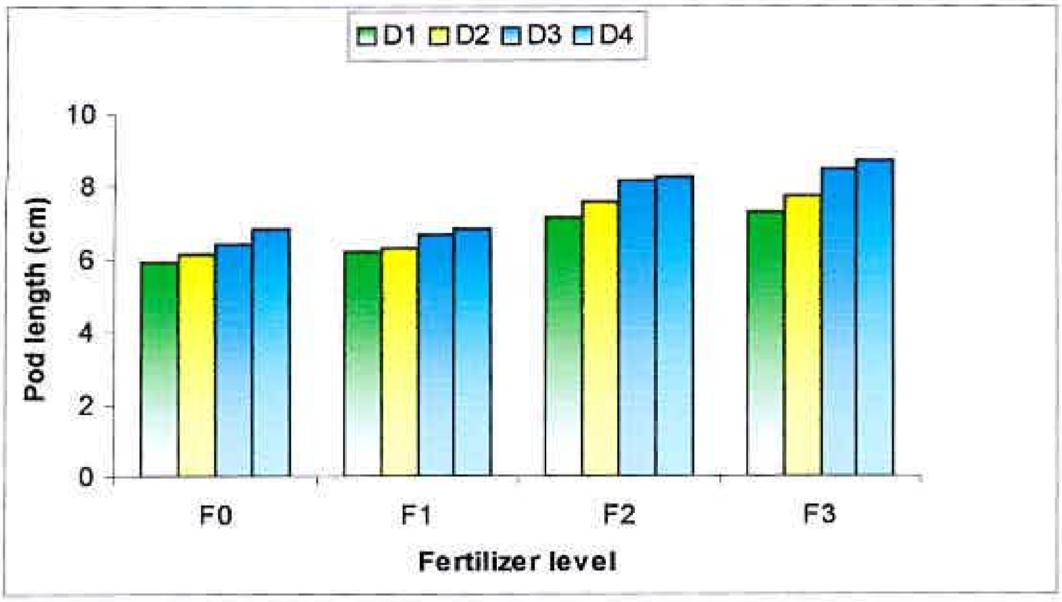
4.2.2.2 Effect of plant population

Pod length was significantly affected by the plant population (Appendix VII). The longest pod length (7.68 cm) was recorded from 15 plant m^{-2} treatment (Table 7) after that the pod length decreased gradually with increasing plant population and the shortest pod (6.66 cm) was recorded when plant population per m^{-2} were 60. Pod length obtained from 30, 45 and 60 plants m^{-2} were statistically similar. This result was in agreement with the findings of Brathwaite (1982) who reported decreased pod size with the increasing crop density.

4.2.2.3 Interaction effect of fertilizer level and plant population

Pod length was significantly affected by interaction effect of fertilizer level and plant population (Appendix VII and Figure 3). The figure showed that the longest pod (8.70 cm) was obtained from the interaction of F_3D_4 (double of the recommended dose of fertilizer with 15 plants m^{-2}) followed by interaction F_3D_3 (8.51 cm), F_2D_4 (8.31 cm), F_2D_3 (8.16 cm) and F_3D_2 (7.76 cm). The shortest pod (5.93 cm) was recorded in the interaction of F_0D_1 (no fertilizer with 60 plants m^{-2}), which was statistically similar with F_1D_4 (6.87 cm), F_0D_4 (6.84 cm), F_1D_3 (6.71

cm), F_0D_3 (6.42 cm), F_1D_2 (6.33 cm), F_1D_1 (6.22 cm) and F_0D_2 (6.14 cm) interactions. The other interaction treatment produced intermediate pod length.



Here,
F_0 = Without fertilizer/Control
F_1 = Half of the recommended dose of fertilizer
F_2 = Recommended dose of fertilizer
F_3 = Double of the recommended dose of fertilizer
D_1 = 60 plants m^{-2}, D_2 = 45 plants m^{-2}, D_3 = 30 plants m^{-2}, D_4 = 15 plants m^{-2}

Figure 3. Pod length (cm) of mungbean influenced by the interaction effect of fertilizer level and plant population ($LSD_{(0.05)}$ = 0.999)

4.2.3 Number of pods plant^{-1}

4.2.3.1 Effect of fertilizer level

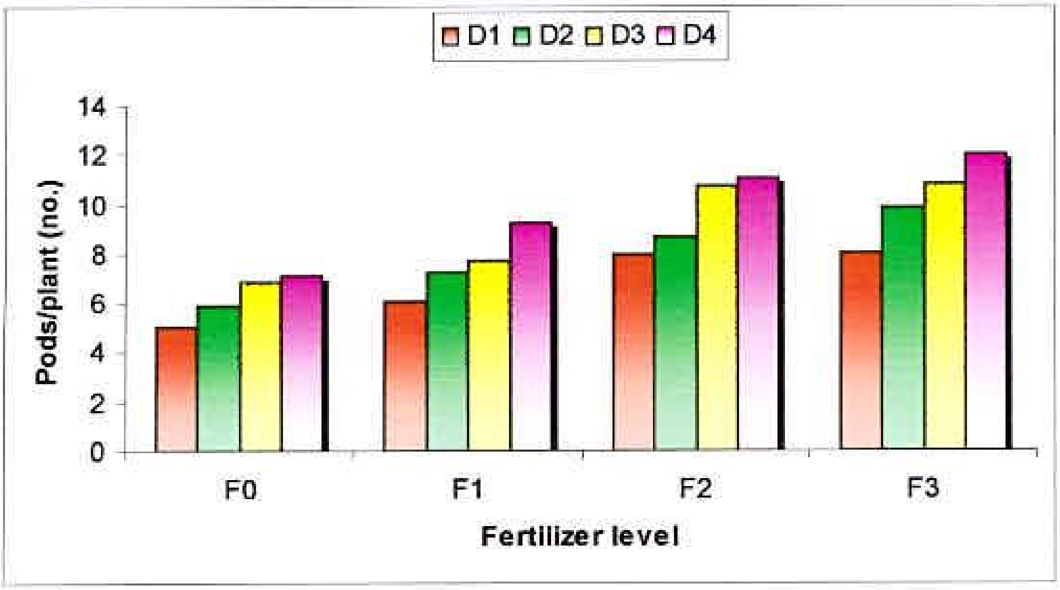
The number of pods plant^{-1} differed significantly due to fertilizer levels (Table 6 and Appendix VII). The maximum number of pods plant^{-1} (10.19) was recorded in F_3 (double of the recommended dose of fertilizer) and the minimum number of pods plant^{-1} (6.25) was recorded in F_0 (without fertilizer). It can be inferred from the table that recommended and double of the recommended dose of fertilizer treatment produced 53.92 % and 63.04 % higher pods plant^{-1} over control. The result agreed with the findings of Suhartatik (1991) and Sardana and Verma (1987) who reported that NPK fertilizers significantly increased the number of pods plant^{-1} of mungbean.

4.2.3.2 Effect of plant population

The number of pods plant^{-1} differed significantly with different plant population treatments (Table 7 and Appendix VII). The result revealed that the lowest plant population of 15 plants m^{-2} (D_4) gave the highest number of pods plant^{-1} (9.88). The number of pods plant^{-1} decreased gradually with the increases in plant population, being the least at the highest plant population of 60 plants m^{-2} (D_1) Generally, the higher the plant population, lesser the number of pods plant^{-1}. The result agreed with the findings of Trung and Yoshida (1985) and El-Habbasha *et al*. (1996) who reported that increasing plant density increased pods plant^{-1} of mungbean.

4.2.3.3 Interaction effect of fertilizer level and plant population

Interaction effect of fertilizer level and plant population in respect of number of pods plant^{-1} was significant (Appendix VII and Figure 4). The highest number of pods plant^{-1} (12.02) was recorded in double of the recommended dose of fertilizer with 15 plants m^{-2} (F_3D_4) followed by F_2D_4. These two interactions showed statistically similar number of pods plant^{-1}. The lowest number of pods plant^{-1} (5.05) was recorded in the interaction of without fertilizer with 60 plants m^{-2} (F_0D_1) interaction treatment.



Here,
F_0 = Without fertilizer/Control
F_1 = Half of the recommended dose of fertilizer
F_2 = Recommended dose of fertilizer
F_3 = Double of the recommended dose of fertilizer
D_1 = 60 plants m^{-2}, D_2 = 45 plants m^{-2}, D_3 = 30 plants m^{-2}, D_4 = 15 plants m^{-2}

Figure 4. Number of pods plant^{-1} of mungbean influenced by the interaction effect of fertilizer level and plant population ($LSD_{(0.05)}$ = 1.13)

4.2.4 Number of seeds pod^{-1}

4.2.4.1 Effect of fertilizer level

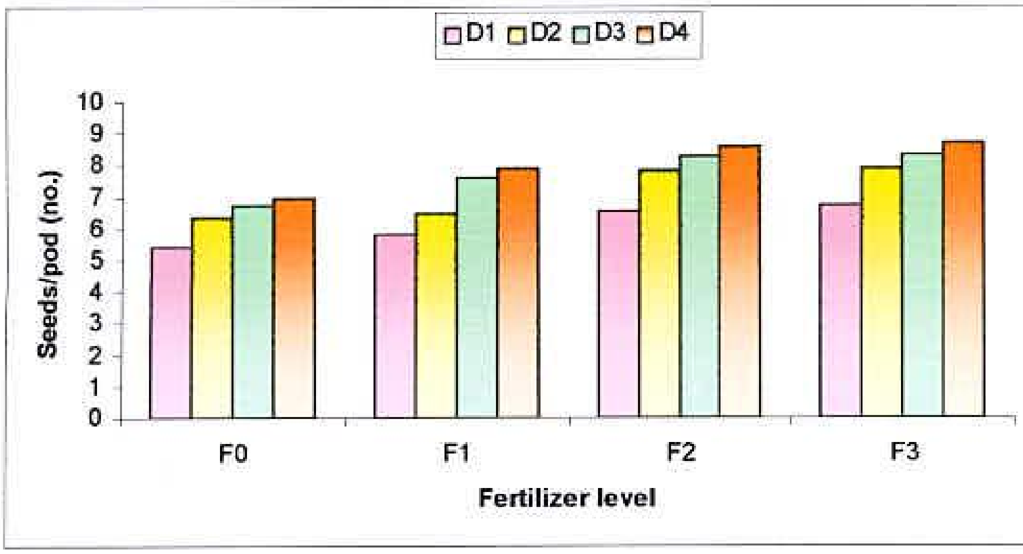
The number of seeds pod^{-1} affected significantly at different fertilizer levels (Appendix VII). The number of seeds pod^{-1} showed positive trend with increasing fertilizer doses. The maximum number of seeds pod^{-1} (7.92) was found in double of the recommended dose of fertilizer, which was statistically similar with recommended dose of fertilizer (7.81). F_0 (control) treatment gave the lowest number of seeds pod^{-1} (Table 6).

4.2.4.2 Effect of plant population

The number of seeds pod^{-1} was affected significantly by plant population (Appendix VII and Table 7). Seeds pod^{-1} showed an inverse trend with the reducing plant population m^{-2}. The maximum number of seeds pod^{-1} (8.04) was produced by the lowest population treatment (15 plant m^{-2}) after that seeds pod^{-1} gradually decreased with the increased plants m^{-2}. The lowest number of seeds pod^{-1} (6.12) was produced by the highest plant population (60 plants m^{-2}). Number of seeds pod^{-1} decreased gradually with the increased plant population probably due to hard competition of space, water, air, nutrient and light to the plants. This result was in agreement with the result of Zahab *et al*. (1981) who reported that increased plant density decreased seeds pod^{-1}.

4.2.4.3 Interaction effect of fertilizer level and plant population

Interaction effect of fertilizer level and plant population was significant in respect of seeds pod^{-1} (Appendix VII and Figure 5). The result revealed that seeds pod^{-1} showed increasing trend with the increased fertilizer doses for all population treatments. Irrespective of fertilizer dose lowest plant population produced higher number of seeds pod^{-1}. However, the highest number of seeds pod^{-1} (8.71) was found in the interaction of F_3D_4, which was statistically similar with interactions of F_3D_3 (8.35), F_2D_3 (8.28) and F_2D_4 (8.58). The lowest number of seeds pod^{-1} (5.41) was found in the interaction of F_0D_1, which was statistically similar with interaction F_1D_1.



Here,
F_0 = Without fertilizer/Control
F_1 = Half of the recommended dose of fertilizer
F_2 = Recommended dose of fertilizer
F_3 = Double of the recommended dose of fertilizer
D_1 = 60 plants m^{-2}, D_2 = 45 plants m^{-2}, D_3 = 30 plants m^{-2}, D_4 = 15 plants m^{-2}

Figure 5. Seeds pod^{-1} of mungbean influences by the interaction effect of fertilizer level and plant population ($LSD_{(0.05)}$ = 0.768)

4.2.5 Weight of 1000 seeds

4.2.5.1 Effect of fertilizer level

The weight of 1000 seeds was significantly influenced by the fertilizer levels (Appendix VII and Table 6). The highest 1000 seed weight (40.45 g) was obtained from double of the recommended dose of fertilizer treatment and recommended dose of fertilizer treatment produced the second highest number of 1000 seed weight (40.26 g). Fertilizer applied lower than the recommended dose reduced the 1000 seed weight and without fertilizer showed the lowest value (38.56 g) of 1000 seed weight. These two lower treatment produced 2% and 4.41% lower 1000 seeds weight than recommended dose and 2.48% and 4.90% lower than the double of the recommended dose of fertilizer dose. The result agreed with the findings of

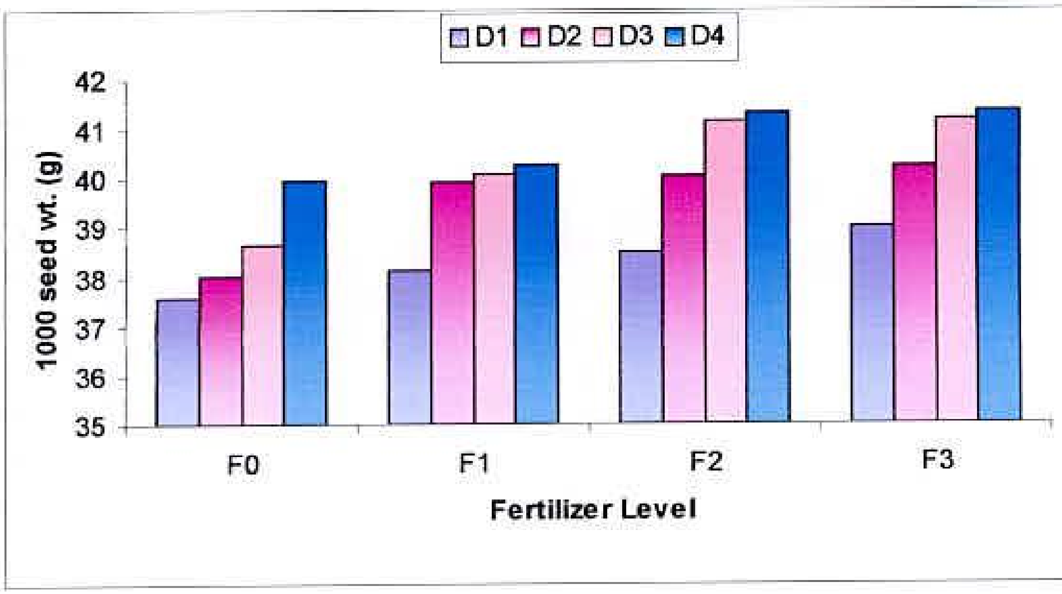
Bali *et al.* (1991), Quah and Jaafar (1994) and Sardana and Verma (1987) who reported increased 1000 seed weight with the increased application of NPK.

4.2.5.2 Effect of plant population

The weight of 1000 seeds was influenced significantly by plant population (Appendix VII and Table 7). The highest 1000 seed weight (40.75 g) was found with widest spacing (15 plants m^{-2}) followed by second widest spacing (30 plants m^{-2}). The trend of 1000 seeds weight decreased gradually with the increases of plant population and the lowest weight (38.31 g) was observed in the closest spacing (60 plants m^{-2}). Weight of 1000 seeds was statistically similar with 60 and 45 plants m^{-2}. However, 1000 seeds weight appeared to be increased perhaps due to with less number of plants m^{-2}, which provided scope for increased photosynthetic activities and translocation of more metabolites to the seed sink. The present finding was in agreement with Singh *et al.* (1988), and Rahman and Miah (1995) who reported reduced 1000 seed weight in mungbean due to increased planting density.

4.2.5.3 Interaction effect of fertilizer level and plant population

Interaction effect of fertilizer level and plant population was significant in respect of 1000 seeds weight (Appendix VII and Figure 6). The figure showed that the trend of 1000 seed weight increased gradually with the increases of spacing i.e. decreasing plant densities irrespective of fertilizer doses. On the other hand, irrespective of plant densities, increased fertilizer doses steadily increased the 1000 seed weight. It appeared from the figure that the interaction of F_3D_4 (double of the recommended dose of fertilizer with 15 plants m^{-2}) showed the highest weight of 1000 seeds (41.36 g) followed by the interactions of F_2D_4 (41.34), F_3D_3 (41.19), F_2D_3 (41.16), F_1D_4 (40.30), F_3D_2 (40.25), F_2D_2 (40.07), F_1D_3 (40.11), F_0D_4 (39.97) and F_1D_2 (39.35). The lowest 1000 seed weight (37.60 g) was recorded in without fertilizer with 60 plants m^{-2} (F_0D_1).



Here,
F_0 = Without fertilizer/Control
F_1 = Half of the recommended dose of fertilizer
F_2 = Recommended dose of fertilizer
F_3 = Double of the recommended dose of fertilizer.
D_1 = 60 plants m^{-2}, D_2 = 45 plants m^{-2}, D_3 = 30 plants m^{-2}, D_4 = 15 plants m^{-2}

Figure 6. Weight of 1000 seeds of mungbean influenced by the interaction effect of fertilizer level and plant population ($LSD_{(0.05)}$ = 2.15)

4.2.6 Seed yield

4.2.6.1 Effect of fertilizer level

Seed yield of mungbean was influenced significantly by fertilizer level (Appendix VIII and Table 8). The seed yield increased progressively with the increased fertilizer rate. The highest seed yield (1.05 t ha^{-1}) was found in the double of the recommended dose of fertilizer treatment, which was statistically similar with recommended dose of fertilizer (1.03 t ha^{-1}) treatment. The lowest seed yield (0.52 t ha^{-1}) was found in the no fertilizer treatment that means recommended and double of the recommended dose of fertilizer dose treatment out yielded over no fertilizer by 0.51 and 0.53 t ha^{-1}, respectively. The finding was in agreement with Malik *et al.* (2003), Sharma *et al.* (2001), Bali *et al.* (1991) and Sardana and

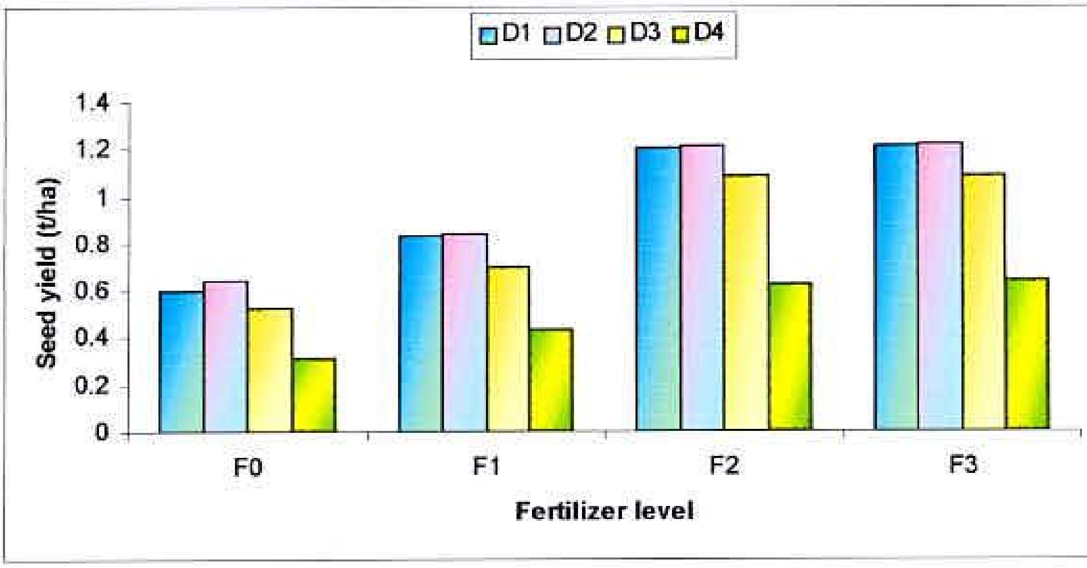
Verma (1987) who reported significant increasesd seed yield of mungbean with the application of NPK fertilizers.

4.2.6.2 Effect of plant population

Seed yield influenced significantly by plant population (Appendix VIII Table 9). The result reveled that a gradual increase of plant population/unit area upto a tolerable limit, increased the seed yield, thereafter it decreased with the increases of plant population. The highest seed yield (0.98 t ha^{-1}) was obtained by 45 plants m^{-2} (D_2) and the lowest (0.51 t ha^{-1}) was recorded in 15 plants m^{-2} (D_4) teatment. The result indicated that 45 plants m^{-2} produced 92.16 % and 13.95 % higher yield over 15 and 30 plants m^{-2} treatments, respectively. It could be attributed due to optimum number of plants and more number of total pods per unit area in 45 plants m^{-2} population treatment. Similar findings in respect of seed yield were also reported by Mimber (1993), Trung and Yoshida (1985), and Beech and Wood (1978).

4.2.6.3 Interaction effect of fertilizer level and plant population

Seed yield of mungbean influenced significantly by the interaction effect of fertilizer level and plant population (Appendix VIII and Figure 7). The highest seed yield (1.22 t ha^{-1}) was obtained from the interaction of F_3D_2 (double of the recommended dose of fertilizer with 45 plants m^{-2}) followed by the F_2D_2 (1.21 t ha^{-1}), F_3D_1 (1.21 t ha^{-1}) F_2D_1 (1.19 t ha^{-1}), F_2D_3 (1.09 t ha^{-1}), and F_3D_3 (1.09 t ha^{-1}). The lowest seed yield (0.31 t ha^{-1}) was obtained from the interaction of F_0D_1.



Here,
F_0 = Without fertilizer/Control
F_1 = Half of the recommended dose of fertilizer
F_2 = Recommended dose of fertilizer
F_3 = Double of the recommended dose of fertilizer.
D_1 = 60 plants m^{-2}, D_2 = 45 plants m^{-2}, D_3 = 30 plants m^{-2}, D_4 = 15 plants m^{-2}

Figure 7. Interaction effect of fertilizer level and plant population on Seed yield ($LSD_{(0.05)}$ = 0.133)

Table 8. Influence of fertilizer level on yield and other crop characters of mungbean

Fertilizer levels	Seed yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
F_0	0.52	1.25	1.77	29.93
F_1	0.70	1.58	2.28	31.25
F_2	1.03	2.00	3.03	34.05
F_3	1.05	2.02	3.06	34.35
$LSD_{(0.05)}$	0.077	0.114	0.133	1.97
CV (%)	10.91	7.73	6.07	7.04

Here,
F_0 = Without fertilizer/Control
F_1 = Half of the recommended dose of fertilizer
F_2 = Recommended dose of fertilizer
F_3 = Double of the recommended dose of fertilizer

Table 9. Influence of plant population on yield and other crop characters of mungbean

Number of Plants /m^2	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
D_1	0.96	2.09	3.04	30.78
D_2	0.98	2.13	3.11	31.07
D_3	0.86	1.67	2.53	33.50
D_4	0.51	0.96	1.46	34.23
$LSD_{(0.05)}$	0.057	0.119	0.134	1.37
CV (%)	9.59	9.55	7.29	7.12

Here,
D_1 = 60 plants m^{-2}, D_2 = 45 plants m^{-2}, D_3 = 30 plants m^{-2}, D_4 = 15 plants m^{-2}.

4.2.7 Straw yield

4.2.7.1 Effect of fertilizer level

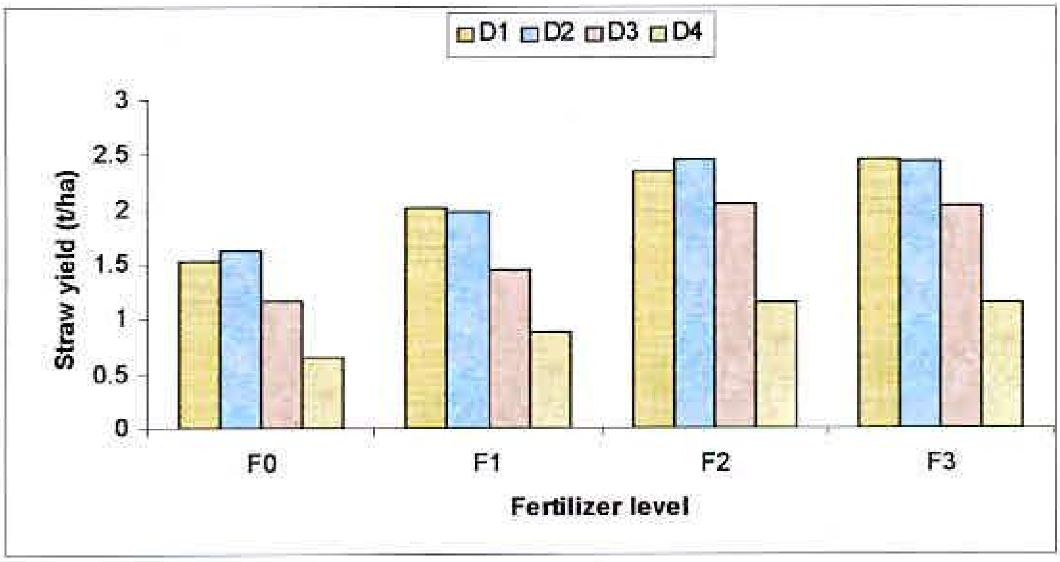
Straw yield was influenced significantly by the fertilizer levels (Appendix VIII and Table 8). The table showed that yield increased progressively with the increase of fertilizer rate. The highest straw yield (2.02 t ha^{-1}) was found in the double of the recommended dose of fertilizer treatment which was statistically similar with recommended dose of fertilizer (2.00 t ha^{-1}) treatment. The minimum straw yield (1.25 t ha^{-1}) was obtained from control (without fertilizer treatment). This result agreed with the findings of Mahmoud *et al.* (1988) and Sarkar and Banik (1991) who reported that application of fertilizer resulted in significant increases in straw yield of mungbean.

4.2.7.2 Effect of plant population

Straw yield was significantly influenced by plant population (Appendix VIII and Table 9). The highest straw yield was obtained from 45 plants m^{-2} populated plots. Plant population higher and lower than 45 plants m^{-2} reduced the straw yield gradually. However, the lower level of straw yield was recorded from 30 and 15 plants m^{-2}. Plant population of 45 plants m^{-2} showed 29.54 % and 121.87 % higher straw yield than 30 and 15 plants m^{-2} plant populated plots, respectively

4.2.7.3 Interaction effect of fertilizer level and plant population

Significant variation was observed in straw yield due to the interaction effect of fertilizer level and plant population (Appendix VIII and Fig. 8). It appeared from the figure that irrespective of fertilizer dose, 45 plants m^{-2} showed the highest straw yield than other population. The highest straw yield (2.46 t ha^{-1}) was observed in the interaction of F_2D_2 followed by the interaction effect of F_3D_1 (2.45 t ha^{-1}) F_3D_2 (2.44 t ha^{-1}) F_2D_1 (2.34 t ha^{-1}. The lowest straw yield (0.65 t ha^{-1}) was observed in the interaction F_0D_4.



Here,
F_0 = Without fertilizer/Control
F_1 = Half of the recommended dose of fertilizer
F_2 = Recommended dose of fertilizer
F_3 = Double of the recommended dose of fertilizer.
D_1 = 60 plants m^{-2}, D_2 = 45 plants m^{-2}, D_3 = 30 plants m^{-2}, D_4 = 15 plants m^{-2}

Figure 8. Interaction effect of fertilizer level and plant population on Straw yield ($LSD_{(0.05)}$ = 0.275)

4.2.8 Biological yield

4.2.8.1 Effect of fertilizer level

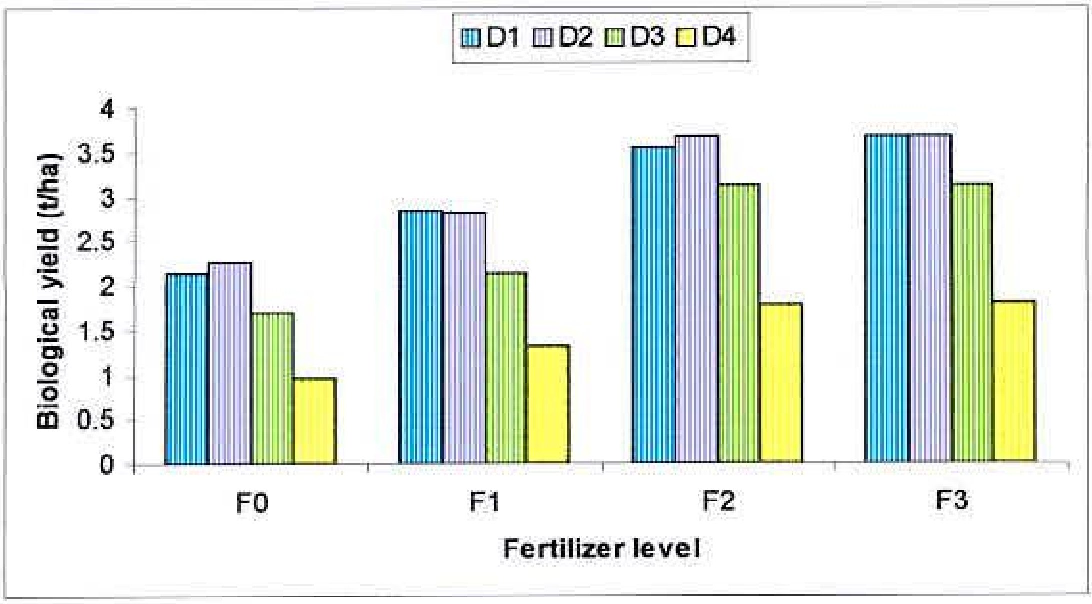
Fertilizer level exerted significant influence on biological yield of mungbean (Table 8 and Appendix VIII). The maximum biological yield (3.06 t ha^{-1}) was obtained from double of the recommended dose (F_3) followed by recommended dose of fertilizer (3.03 t ha^{-1}). Fertilizer doses lower than recommended reduced the biological yield significantly. The minimum biological yield (1.77 t ha^{-1}) was obtained from without fertilizer dose treatment.

4.2.8.2 Effect of plant population

Biological yield was influenced significantly by plant population (Appendix VIII and Table 9). The highest biological yield (3.11 t ha^{-1}) was recorded at 45 plants m^{-2} plot. Lower than 45 and 60 plants m^{-2} showed statistically similar biological yield. The lowest biological yield (1.46 t ha^{-1}) was recorded at 15 plants m^{-2} (D_4).

4.2.8.3 Interaction effect of fertilizer level and plant population

Biological yield was affected significantly by the interaction effect of fertilizer level and plant population (Appendix VIII and Figure 9). The highest biological yield (3.67 t ha^{-1}) was obtained from the interaction of F_3D_1 that followed by the interaction of F_3D_2 (3.66 t ha^{-1}), F_3D_1 (3.66 t ha^{-1}) and F_2D_1 (3.53 t ha^{-1}), which were statistically similar. The lowest biological yield (0.96 t ha^{-1}) was produced by F_0D_4 followed by F_3D_1 (1.32 t ha^{-1}) which was statistically similar.



Here,
F_0 = Without fertilizer/Control
F_1 = Half of the recommended dose of fertilizer
F_2 = Recommended dose of fertilizer
F_3 = Double of the recommended dose of fertilizer.
D_1 = 60 plants m^{-2}, D_2 = 45 plants m^{-2}, D_3 = 30 plants m^{-2}, D_4 = 15 plants m^{-2}

Figure 9. Interaction effect of fertilizer level and plant population on biological yield ($LSD_{(0.05)}$ = (0.311)

4.2.9 Harvest index

4.2.9.1 Effect of fertilizer level

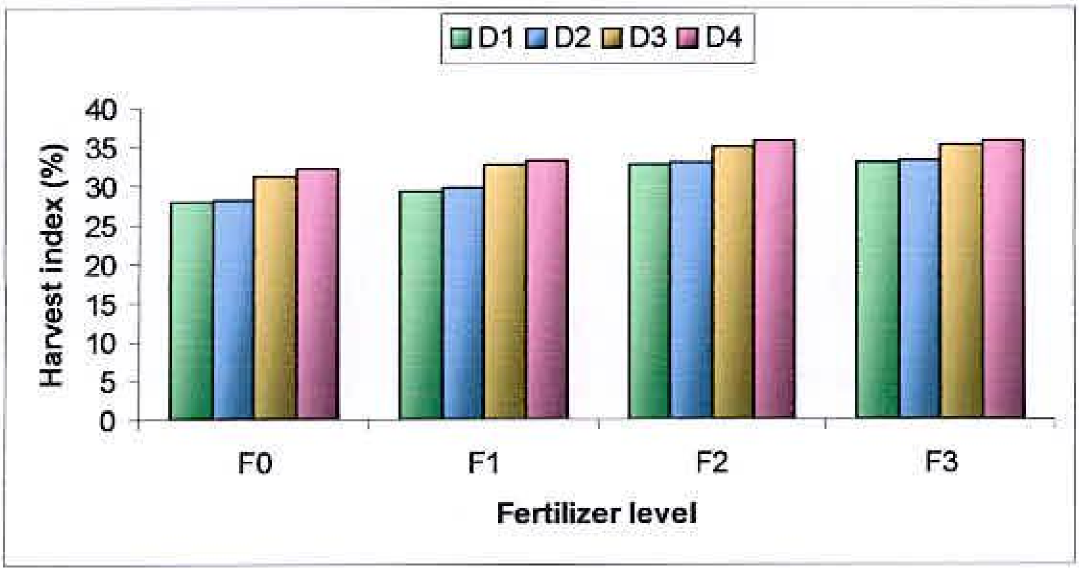
The harvest index was significantly influenced by different level of fertilizer dose (Appendix VIII and Table 8). The highest harvest index (34.35 %) was found in double of the recommended dose (F_3) treatment followed by recommended dose (34.05 %). Harvest index obtained from F_3 and F_2 treatments were statistically similar and the lowest harvest index (29.93 %) was found in without fertilizer (F_0) treatment. The result agreed with the findings of Mozumder (1998) in respect of harvest index.

4.2.9.2 Effect of plant population

Plant population exerted significant effect on harvest index (Appendix VIII and Table 9). The highest value of harvest index (34.23 %) was produced at 15 plants m^{-2} (D_4) treatment that was followed by 30 plants m^{-2} (33.50 %). These two treatments showed statistically similar harvest index. The lowest harvest index (30.78 %) was observed at 60 plants m^{-2} (D_1) plot. The result was in agreement with the findings of Tsiung (1978) who reported decreased harvest index in mungbean due to decreased planting density.

4.2.9.3 Interaction effect of fertilizer level and plant population

Harvest index affected significantly by the interaction effect of fertilizer level and plant population (Appendix VIII and Figure 10). The highest harvest index (35.76 %) was obtained from the interaction of F_3D_4 that followed by the interaction of F_2D_4 (35.68 %), F_3D_3 (35.18 %), F_2D_3 (34.88 %), F_3D_2 (33.35 %), F_1D_4 (33.24 %), F_3D_1 (33.10 %), F_2D_2 (32.94 %), F_1D_3 (32.78 %), F_2D_1 (32.71 %) and F_0D_4 (32.21 %). The lowest harvest index (28.10 %) was produced by the interaction F_0D_1 which was statistically similar with the interaction of F_0D_3 (31.16 %), F_1D_2 (29.75 %), F_1D_1 (29.22 %) and F_0D_2 (28.24 %).



Here,
F_0 = Without fertilizer/Control
F_1 = Half of the recommended dose of fertilizer
F_2 = Recommended dose of fertilizer
F_3 = Double of the recommended dose of fertilizer.
D_1 = 60 plants m^{-2}, D_2 = 45 plants m^{-2}, D_3 = 30 plants m^{-2}, D_4 = 15 plants m^{-2}

Figure 10. Interaction effect of fertilizer level and plant population on harvest index ($LSD_{(0.05)}$ = 3.80)

Chapter 5

Summary and Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The present piece of work was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka from April, 2007 to June, 2007 to find out the influence of fertilizer level and plant population on mungbean. The treatment of the experiment consists of four fertilizer level viz. without fertilizer/ control, half of the recommended dose of fertilizer, recommended dose of fertilizer and double of the recommended dose of fertilizer and four plant population viz. 60 plants m^{-2}, 45 plants m^{-2}, 30 plants m^{-2} and 15 plants m^{-2}. Summer mungbean variety BARI mung 5 was used as test crop. The experiment was laid out in Split-plot design with three replications. The sowing was done on April 3, 2007.

Observation were made on plant height, dry matter production, number of branches $plant^{-1}$, number of pods $plant^{-1}$, pod length, number of seeds pod^{-1}, weight of 1000 seeds, seed yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index. Ten plants were randomly selected from each unit plot for taking observations on plant height with 15 days interval at 15, 30 and 45 days and at harvest and number of branches $plant^{-1}$, number of pods $plant^{-1}$ and pod length. Dry weight $plant^{-1}$ was taken at 15 days interval and at harvest starting from 15 DAS. Harvested ten sample plants were used for taking plant characters data and plants of three square metter area were used for taking grain and stover yield and than converted into t ha^{-1}.

Fertilizer had significant effect on plant height and dry weight for all the growth stages. The treatment F_3 (double of the recommended dose of fertilizer) treated plots had the tallest plant for all growth stages and control treatment had the shortest plants for all the growth stages. Double of the recommended dose and recommended dose of fertilizer gave the highest dry weight plant^{-1} for all the growth stages whereas the lowest was in control.

Fertilizer influenced the number of branches plant^{-1}, number of pods plant^{-1}, pod length, thousand seed weight, seed yield, straw yield and harvest index (%). The fertilizer treatment F_3 showed higher level of branches plant^{-1} followed by F_2 treatment and control treatment showed the lowest. The highest pod length was found from F_3 followed by F_2 treatment and lowest was found from F_0 treatment. Maximum number of pods plant^{-1} was found from double of the recommended dose of fertilizer and the minimum was found in control. The highest seeds pod^{-1}, weight of 1000 seed, seed yield (t ha^{-1}), stover yield (t ha^{-1}), biological yield and harvest index (%) were found from double of the recommended dose of fertilizer followed by recommended dose of fertilizer where the lowest in F_0 (without fertilizer) treatment.

Plant population influenced plant height, dry matter plant^{-1}, number of branches plant^{-1}, number of pods plant^{-1}, pod length, thousand seed weight, seed yield, stover yield and harvest index (%) almost of the growth stages. Among the plant population 60 plants m^{-2} produced the highest plant height at 30 DAS, 45 DAS and at harvest and 15 plants m^{-2} produced the lowest plant height for all the growth stages. In case of dry weight plant^{-1} 15 plants m^{-2} gave the highest dry matter and 60 plants m^{-2} gave the lowest dry matter for all the growth stages. Maximum number of branches plant^{-1} was found in 15 plants m^{-2} followed by 45 plants m^{-2} whereas the lowest was found at 60 plants m^{-2}. The highest pod length, pods plant^{-1} and seeds pod^{-1} was found in 15 plants m^{-2} whereas, the lowest was found in 60 plants m^{-2}. Maximum weight of 1000 seed and harvest index was obtained in 60 plants m^{-2} followed by 45 plants m^{-2}. The plant population treatment D_1 (60 plants

m^{-2}) and D_2 (45 plants m^{-2}) showed significantly higher level of seed yield and stover yield and D_4 (15 plants m^{-2}) treatment showed the lowest.

The interaction effect of fertilizer and plant population was found significant in plant height, dry matter plant^{-1}, number of branches plant^{-1}, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, weight of 1000 seeds, seed yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%). In respect of plant height there was no significant interaction effect at 15 DAS but 30, 45 and at harvest interaction effect of F_3D_1 (double of the recommended dose with 60 plant m^{-2}) produced the highest plant height and lowest in F_0D_4 (control with 15 plant m^{-2}) interaction treatment. Dry weight plant^{-1} was found highest in the interaction of F_3D_4 (double of the recommended dose of fertilizer with 15 plants m^{-2}) followed by F_2D_4 and F_3D_3 and the lowest was found in F_0D_1 (control with 60 plants m^{-2}) for all the growth stages and at harvest. Branches plant^{-1}, pod length and seeds pod^{-1} was highest in double of the recommended dose of fertilizer with 15 plants m^{-2} and lowest in control with 60 and 45 plants m^{-2}. Maximum pods plant^{-1} was found in double of the recommended dose of fertilizer with 15 plants m^{-2} and minimum was found in control with 60 and 45 plants m^{-2}. Maximum weight of 1000 seed was found in double of the recommended dose and recommended dose of fertilizer with 15 and 30 plants m^{-2} and lowest was found in control with 60 plants m^{-2}. Maximum seeds yield was found from double of the recommended dose and recommended dose of fertilizer with 45, 60 and 30 plants m^{-2} respectively and lowest was found in control with 15 plants m^{-2}. Straw yield was highest in double of the recommended dose and recommended dose of fertilizer with 45 and 60 plants m^{-2} and lowest was found in control with 15 plants m^{-2}. Harvest index was highest in double of the recommended dose and recommended dose of fertilizer with 15 plants m^{-2} and lowest was found in control with 60 and 45 plants m^{-2}.

Based on the results of the present study the conclusion may be drawn:

Recommended dose of fertilizers should be recommended although seed yield between recommended and double of the recommended dose of fertilizer was similar. For higher seed yield at 45 plants m^{-2} was found promising. The interaction of recommended dose of fertilizer with 45 plants m^{-2} seams to be promising.

However, to reach a specific conclusion and recommendation, more research work on wider range of fertilizer and plant population of mungbean should be done over different Agro-ecological zones.

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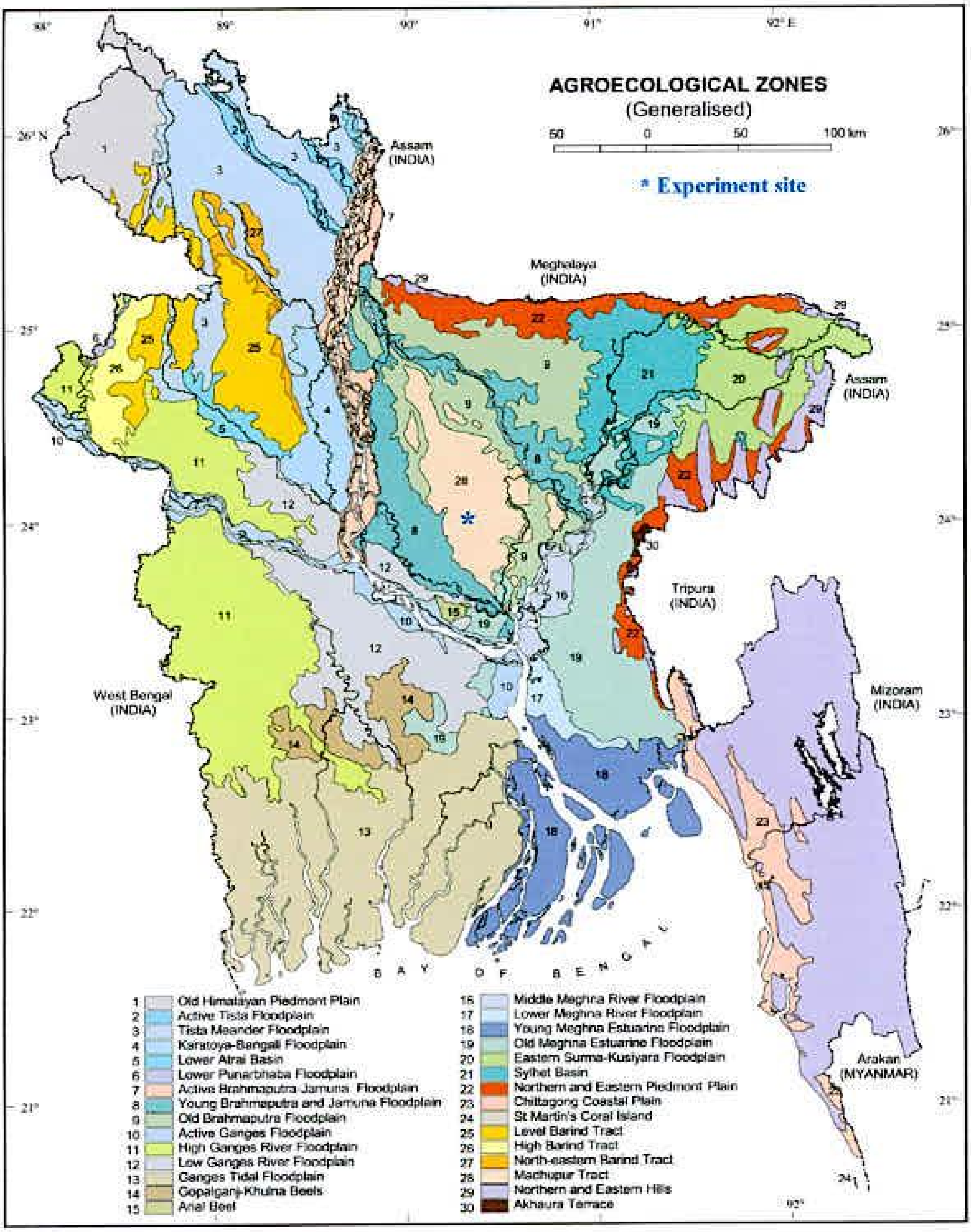
APPENDICES

APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. The mechanical and chemical characteristics of soil of the experimental site as observed prior to examination (0-15 cm depth)

Mechanical composition :

Particle size constitution

Sand : 26%

Silt : 45%

Clay : 29%

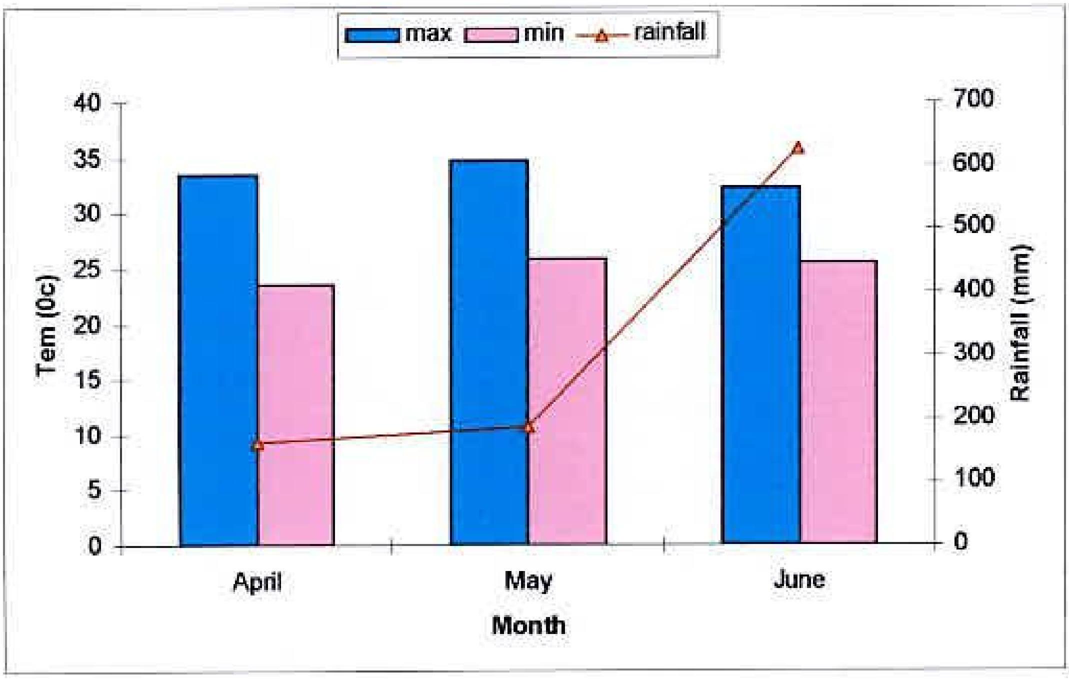
Texture : Silty clay

Chemical composition :

Soil characters	Value
P^H	7.1
Organic matter	1.08 %
Total Nitrogen	0.054 %
Potassium	0.27 meq/100 gm soil
Calcium	3.50 meq/100 gm soil
Magnesium	0.46 meq/100 gm soil
Phosphorus	10.46 ppm
Sulphur	18 ppm
Boron	0.04 ppm
Copper	1.60 ppm
Iron	14 ppm
Manganese	36.80 ppm
Zinc	1.84 ppm

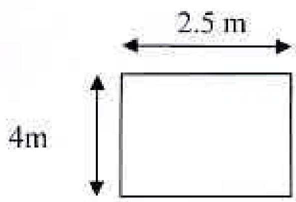
Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka

Appendix III. Monthly recordes of temperature and rainfall of the experimental site during the period from April 2007 to June 2007

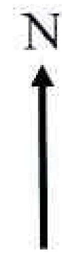


Source: Bangladesh Meterological Department (Climate Division), Agargao, Dhaka 1212

APPENDIX – IV. Experimental layout



Plot size: 4 m×2.5 m
Between Plot: 1m
Between replication: 1.5 m



F_0D_1	F_0D_4	F_3D_4	F_3D_1	F_2D_4	F_2D_3
F_0D_2	F_0D_3	F_3D_2	F_3D_3	F_2D_1	F_2D_2
F_3D_3	F_3D_1	F_0D_1	F_0D_2	F_1D_2	F_1D_3
F_3D_4	F_3D_2	F_0D_3	F_0D_4	F_1D_1	F_1D_4
F_2D_1	F_2D_3	F_1D_1	F_1D_4	F_3D_3	F_3D_4
F_2D_4	F_2D_2	F_1D_2	F_1D_3	F_3D_2	F_3D_1
F_1D_2	F_1D_1	F_2D_1	F_2D_4	F_0D_3	F_0D_4
F_1D_3	F_1D_4	F_2D_3	F_2D_2	F_0D_2	F_0D_1
Replication I		**Replication II**		**Replication III**	

Appendix V. Means square values for plant height of mungbean at different days after sowing

Sources of variation	Degrees of freedom	Means square values			
		15 DAS	30 DAS	45 DAS	At harvest
Replication	2	1.44	3.83	5.99	2.29
Fertilizer (F)	3	15.56**	172.20**	147.85**	177.15**
Error (a)	6	1.75	2.23	8.52	5.86
Plant population (D)	3	4.76 NS	86.96**	74.33**	85.44**
F X D	9	0.25 NS	4.93	1.95	1.16
Error (b)	24	4.47	8.97	4.01	4.02
CV (%)		12.90	6.98	4.14	3.95

** Significant at 1% level
NS = Not significant

Appendix VI. Means square values of total dry matter weight of mungbean at different days after sowing

Sources of variation	Degrees of freedom	Means square values			
		15 DAS	30 DAS	45 DAS	At harvest
Replication	2	0.001	0.06	0.62	0.06
Fertilizer (F)	3	0.054**	3.31**	13.31**	3.31**
Error (a)	6	0.000	0.13	0.37	0.13
Plant population (D)	3	0.044**	4.23**	7.45**	4.23**
F X D	9	0.000	0.01	0.02	0.01
Error (b)	24	0.001	0.05	0.78	0.05
CV (%)		9.12	9.81	13.91	10.01

** Significant at 1% level

Appendix VII. Means square values for branch plant^{-1}, pod length, pods plant^{-1}, seeds pod $^{-1}$ and weight of 1000 seeds of mungbean

Source of variation	Degree of freedom	Means square values				
		Branch plant^{-1} (no.)	Pod length	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	Weight of 1000 seed (g)
Replication	2	0.022	1.02	0.408	0.006	9.22
Fertilizer (F)	3	3.68**	9.34**	40.08**	6.52**	9.32
Error (a)	6	0.018	0.233	0.111	0.103	0.610**
Plant population (D)	3	2.73**	2.58**	21.40**	8.57**	11.46**
F X D	9	0.104	0.083	0.570	0.099	0.632
Error (b)	24	0.102	0.351	0.438	0.207	1.63
CV (%)		15.19	7.24	7.95	6.27	3.22

** Significant at 1% level

Appendix VIII. Means square values for seed yield, straw yield, biological yield and harvest index of mungbean

Source of variation	Degree of freedom	Means square values			
		Seed yield	Straw yield	Biological yield	Harvest index
Replication	2	0.014	0.008	0.041	9.52
Fertilizer (F)	3	0.79**	1.63**	4.68**	55.83**
Error (a)	6	0.008	0.017	0.023	5.21
Plant population (D)	3	0.58**	3.54**	6.94**	35.67**
F X D	9	0.012	0.03	0.078*	0.511
Error (b)	24	0.006	0.026	0.034	5.31
CV (%)		9.59	9.55	7.29	7.12

*Significant at 5% level

** Significant at 1% level

PLATES

PLATES

Plate-1: Field view of experimental plot

60 Plants m^{-2}

45 Plants m^{-2}

30 Plants m^{-2}

15 Plants m^{-2}

Plate-2: Field view of experimental plots showing different plant population of mungbean

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Vegetative stage

Flowering stage

Pod initiation stage

Pod maturity stage

Plate-3: Field view of experimental plots showing different growth stages of mungbean

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সংযোজন নং 56 Agro
স্বাক্ষর ... তাং 07/06/09