INFLUENCE OF SOWING DEPTH AND SEED SIZE ON GROWTH AND YIELD OF MUNGBEAN

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CERTIFICATE

This is to certify that the thesis entitled, "Influence of sowing depth and seed size on growth and yield of mungbean" submitted to the Department of Agronomy, 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 a bonafide research work carried out by Kaniz Fatima, Registration No. 00908 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Professor Dr. Parimal Kanti Biswas
Supervisor

Dated: 26/12/07
Dhaka, Bangladesh

Dedicated to

My

Beloved Parents

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INFLUENCE OF SOWING DEPTH AND SEED SIZE ON GROWTH AND YIELD OF MUNGBEAN

ABSTRACT

A field experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from March 2007 to June 2007 to find out the influence of varying seed size and sowing depth on growth and yield of mungbean. The experiment was consisted of three sowing depths (2, 4 and 6 cm) and three seed sizes; small (< 3.2 mm), medium (3.2 mm to 4 mm) and large (> 4 mm). The experiment was laid out in a split-plot design with three replications having depth in the main plots and seed size in the sub-plots. Results revealed that the smallest seeds had significantly the highest germination percentage, vigour index and emergence. Large seeds showed significantly the highest epicotyle and hypocotyle length, fresh weight of root, shoot and total plant, pod length, 1000 grain weight and seed yield. Sowing depth also had significant effects. The percentage of emergence was significantly highest at 2 cm depth. However, significantly the highest hypocotyle length, root, shoot and total fresh weight were in maximum depth. Significantly the highest number of pods plant^{-1}, number of seeds pod^{-1}, pod length, 1000 grain weight, seed yield ha^{-1} and harvest index were observed in medium depth. Among the interaction treatments, the highest hypocotyle length, fresh weight of root, shoot and total plant of the seedlings were found in maximum depth with large seeds. Moreover, in the field experiment, medium depth with large seeds showed significantly the highest values of plant height, leaf dry weight, stem dry weight, inflorescence dry weight and total dry weight. Significantly higher NAR was obtained from medium depth with medium seeds at 30 days after sowing (DAS), but from minimum depth with small seeds at 45 DAS. The treatment medium depth with large seeds showed significantly the highest plant height, number of pods plant^{-1}, number of seeds pod^{-1}, pod length, 1000 seed weight, seed yield and harvest index.

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LIST OF ABBRIVIATIONS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
FAO	=	Food and Agricultural Organization
ppm	=	Parts per million
N	=	Nitrogen
DAS	=	Days after sowing
g	=	Gram(s)
kg	=	Killogram(s)
t	=	Tons
SAU	=	Sher-e-Bangla Agricultural University
HI	=	Harvest index
LSD	=	Least significant difference
^{o}C	=	Degree Centigrade
NS	=	Not significant
%	=	Percent
cv	=	Cultivar
CV	=	Coefficient of variance
meq	=	miliequivalent
µg	=	Microgram

Chapter 1
Introduction

CHAPTER 1

INTRODUCTION

Pulses are defined by the Food and Agriculture Organization (FAO, 1988) of the United Nations as annual leguminous crops yielding from one to twelve grains or seeds of variable size, shape and color within a pod. Pulses are used for food and animal feed.

Pulses or grain legumes occupy an important position in world agriculture by virtue of their high vegetable protein content. They are considered as poor man's meal since they are the cheapest source of protein for the under privileged people who cannot afford animal proteins. Pulses contain remarkably higher amount of protein than the cereal crops (Gowda and Kaul, 1982).

Not only in respect of protein, pulses are also superior in containing amino acids, especially those are termed essential. Pulses effectively supplement cereal proteins since they are rich in lysine, which is not generally found in cereals (Kharkwal *et al.*,1986). However, methionine and cystine are the limiting amino acids in pulses. Pulses are also rich in vitamin A and D (Gowda and Kaul, 1982). Pulse can provide all the B vitamins which are lost in polished rice.

In comparison to cereal production, pulses production in Bangladesh is very low which is due to the fact that less area of our land is under pulse cultivation. During 1993-94, the area under pulse cultivation was 1752000 acre, but at present this has been decreased to 0947000 acres. That is, from 1993-94 to 2004-05, 40% of the pulse area has been replaced by other crops (BBS, 2007).

In general, productivity of legumes is very low compared with cereals (Rachie and Roberts, 1974). Yield of pulses in farmers' fields is usually less than 1 t ha^{-1} against the potential yield of 2 to 4 t ha^{-1} (Ramakrishna *et al.*, 2000) indicating a large yield gap. However, in spite of decreasing area under pulses, the productivity has been slightly increased. During 1993-94, the yield of pulses in general was 747 kg ha^{-1}, but during 2004-2005, this has been increased to 824 kg ha^{-1}. That is, from 1993-94 to 2004-05, 10% of the pulse yield has been increased. This increment in yield of pulses, however, is not enough to meet up our national needs. Much of the yield gap may be narrowed down by adopting improved agronomic practices at farm level.

Among the pulse crops, mungbean (*Vigna radiata* (L.) Wilczek) is an important pulse crop in tropical Asia. It is also referred to as green gram, golden gram and chop suey bean. Both upright and vine types of growth habit occur in mungbean, with plants varying from one to five feet in length. The rounds to oblong seeds vary in size from 6,000 to over 12,000 per pound, depending upon variety. Germination is epigeal with the cotyledons and stem emerging from the seedbed.

Mungbean is very rich in protein and it complements the staple rice in Asian diets (AVRDC, 1998). The main reason behind decreasing the popularity of this crop is the low yield potentials. This shortfall makes the crop less competitive with cereals and other high valued crops. To increase production, it is imperative that productivity of mungbean needs to be increased.

One important factor of successfully growing of mungbean is the good availability of its seed . The quality of seed depends upon many factors of which seed size is important. Seed size involves differences not only in weight and volume but also on stage of development of the mother plant. Plants from larger seed have better chance of survivality than those from smalls ones (Harper *et al.*, 1965; Harper and Benton, 1966). The internal seed qualities (i.e germination and vigour) and chemical conditions are physiologically controlled and are affected by environmental situation during the growing period of the crop (Ries and Everson, 1973; Cox *et al.*, 1985). All these environmental factors can not be controlled and may be adjusted to a positive direction for good crop performance in terms of seed yield through optimum seed size.

The characteristics such as seed number and seed size may affect and compensate each other in determining yield (Board *et al.*, 1999). The main factor which directly contributes to yield depends upon plant species and varieties. In principle, seed size has effects on many characters both in the field and laboratory tests. Although genetic background of seeds in individual lines or cultivars is similar, seed sizes in individual lines or cultivars may affect other agronomic characters. Different seed sizes of a cultivar having different levels of starch and other food storage may be one factor which influences the expression of physiological-dependent character (Chiangmai, *et al*., 2000).

Amin (1999) reported that 50 per cent of large seeded mungbean matured earlier than that of small seeded ones. Large seed had an advantage of having more stored energy and supply that to the seedling that leads to the increased seedling vigour. However, it was also reported that although the largest seed had the largest cotyledonary area, the higher photosynthetic rate from smaller seed size could compensate and support seedling's growth (Burries *et al*., 1973).

Sowing depth is one of the most important cultural practices for mungbean cultivation. It has an important role in increasing the yield of mungbean because of the fact that chemical and mineralogical composition, biotic activities, organic matter content, plant nutrient such as N, P and K in soil vary with the change of seeding depth in soil. The moisture content of the soil is also an important factor in crop production. The moisture content of soil is directly proportional to the depth of soil (Miller *et al*., 1965). At deeper root zone, due to low temperature the availability of nutrient element decreases and development of root system is restricted.

Research work on seed size and depth of sowing of mungbean seed under Bangladesh condition is limited. Moreover, some promising varieties have been released during the last decades which are mostly grown in summer. Most frequently, problem of its seed establishment has been reported. This situation could be overcome through sowing optimum sized seeds at the suitable depth of soil. Such effort may play a remarkable role for the improvement of germination and emergence that may also result in the increased yield of mungbean.

Objectives:

i. to find out the effect of depth of sowing on growth and yield of mungbean.

ii. to examine the effect of seed size on growth and yield of mungbean.

iii. to find out the interaction effect of seeding depth and seed size on growth and yield of mungbean.

Chapter 2
Review of literature

CHAPTER 2

REVIEW OF LITERATURE

Literature regarding the effect of sowing depth and seed size of mungbean is not enough. However, the available literature which are pertinent to the present study covering legumes and also some other crops have been presented below.

2.1 Seed quality attributes

2.1.1 Germination

Effect of sowing depth

Oplinger *et al.* (1989) stated that deep planting (2.5-4.0 inches) was necessary to get the seed below the surface of soil so that it did not dry out as for germination, soil moisture is necessary for imbibitions, activate enzymes and dilution of food materials.

Effect of seed size

Wester (1964) stated that the small seeds (5.6 - 6 mm dia.) of soybean showed higher germination capacity and also higher speed of germination than those of medium (6-6.4mm), large (more than 6.4mm) or bulk seeds.

Charjan and Tarar (1991) reported that germination and field emergence were increased with increase of seed size. Similarly, Singh *et al.* (1981) found that large seed showed higher germination percentage, root and shoot length in sorghum.

Kiler and Dhillon (1983) while conducting an experiment on soybean reported that the small seeds (5.6 - 6 mm dia) showed higher capacity and speed of germination and also produced plants with more vigorous growth and higher chlorophyll content in leaves than medium (6 - 6.4 mm), large (more than 6.4 mm) or bulk seeds.

Xu and Gu (1984) described that the relationship of seed weight to germination differed between species. Percentage of germination of large and small seeds of *Carthanmus tinctorius*, *Triticum aestivum* and *Sorghum vulgare* was similar, while it was higher in large seed of *Raphanus sativus* but in small seed of *Gossypium hirsutum* and *Glycine max*. Finally they concluded that there was no close correlation between percentage germination and seed size.

Winter wheat (Chastain *et al.*, 1995) and mungbean (Amin, 1999) when were grown in the field with no stress, large seeds of these plants tended to do better in respect of germination than smaller ones.

In one experiment, seed germination (tested in trials in 1991-92 at Jabalpur, Madhya Pradesh) was studied using 6 soybean cultivars which were graded into large (>6.35 mm), small (>5.56mm) or ungraded. In that study no significant difference was found between cultivars and grades. However, significant differences were found between cultivars and grades for other characteristics (Khare *et al.*, 1996).

2.1. 2 Seed germination vigour

Effect of seed size

Seed size was one of the factors that influenced seed vigour. The term 'seed vigour' had been used by the seed technologists since 19th century to investigate the seed quality in relation to seed germination, field establishment and yield of crops (Jastice, 1965). The international seed testing Association (Perry , 1978) had defined seed vigour as the sum total of those properties of the seed which determine the potential level of activity and performance of the seed lot during germination and seedling emergence. Many studies indicated that germination percentage of winter wheat (Mian and Nafziger, 1994), seedling emergence of soybean (Johnson and Luedders, 1974, Tekrony *et al.*, 1987) and barley (Demirlicakmak *et al.*, 1963) were not affected by seed size. On the contrary, it was also shown that large seeds had higher germination percentage than that of small seeds (Chiangmai *et al.*, 2000).

Khattak *et al* (2003) carried out an experiment on mungbean and found that seed size had positive correlation with hypocotyls length, primary leaf length, primary leaf width and primary leaf area. Seed size was also related with the quantity of storage materials in seed. Large seed had greater quantity of food materials than the small one.

It had been reported that seedling fresh weight, seeding mitochondrial protein and mitochondrial biochemical activities were positively correlated with seed weight (McGinnes, 1960). Higher amount of food materials was reserved in the large seeds (Tompkins, 1965).

Large seeds generally had been shown to have greater seedling vigour than small ones (Kittock and Patterson, 1962). On the other hand, Sivasubramanian and Ramakrishnan (1974) stated that large sized seeds of groundnut were superior to small sized seeds. Hoy and Gamble (1987) reported that the effects of seed size and seed density were usually less pronounced or non-existent in seed lots of extremely high or extremely low vigour. Kalavathi *et al* .(1994) found that large seeds (>6mm) maintained viability during the storage period with minimum loss compared with medium and small ones.

The seed vigour may be influenced by the mineral contents in seed. The effect of seed size and variety were examined on the P, K, Mg and Ca content of 12 varieties of soybeans during 1970 and 1971. Results showed that variety had more influence on mineral contents than seed size. However, Ca and Mg contents, on a dry basis, were influenced by variety. The mineral content decreased with a decrease in seed size (Tiara and Saito, 1977).

In another study, it was observed that the seed size was negatively associated with protein content but positively associated with oil content. It was suggested that seed grading could be used to separate small seeds for protein extraction and large seeds for oil (Reddy *et al.*, 1989).

In soybean, correlation between seed yield and seed composition were often significant, while correlations between seed size and seed composition were usually low. In addition, selection for changes in seed composition had often resulted in seed yield changes but usually no changes in seed size (Tinius *et al.*, 1993).

Proposed explanation of the correlation between seed size and seedling vigour included the higher photosynthesis rate of larger cotyledons from large seeds (Burries *et al.*, 1971). Seedling vigour had been shown to be related to seed size for many legumes (Black,1959). However in other studies, little relationship had been reported between seed size and yield for soybean (Singh *et al.*, 1972 and Johnson and Luedders, 1974). Seed vigour had no effect on specific growth rate (SGR), net assimilation rate (NAR) or seedling weight at 20 days after emergence (Egli *et al.*, 1990).

2.2 Seedling emergence

Effect of sowing depth

Ahlawat and Rana (2002) reported that in heavier soils coupled with moist conditions, sowing depths at 5 cm were more beneficial. For smaller-seeded pulses, sowing depths of 2.5-4.0 cm were adequate under moist conditions. Studies conducted in 2003 on loamy sand soil at the Punjab Agricultural University in Ludhiana revealed that with 8 cm sowing depth, the emergence of seedlings was late by one day than 4 and 6 cm depths.

Otoo (1976) carried out a field trails in the late season of 1975 by sowing soybean at 1.25, 2.54, 3.81 or 5.08 cm depth. Results showed that the seedling emergence was not significantly affected by sowing depth. But in another study, it was seen that the seedling emergence was greater at 2.5 cm than for deeper sowing depth especially in adverse weather conditions (Himmel *et al.*, 1981).

Longer *et al.* (1986) reported that large seeds had a greater percentage of emergence, shoot and root fresh weight than small. Black (1959) reported that the effect of seed size or sowing depth on the performance of seedling emergence depended mainly on soil moisture. When there was no moisture deficit, the better emergence was found from the shallowest sowing depth.

It was reported that the soil density may determine the depth of sowing. In one study it was observed that increasing soil density decreased (a) total seedling mergence and (b) rate of emergence, especially when seeds were sown 7 cm deep. Soil crust strength faced by the germinating seedling increased with increasing soil density. Increasing sowing depth decreased emergence. The highest emergence was seen when seeds were sown at 5 cm deep (Sani and Singh, 1980).

Himmel *et al.*, (1981) in field trails in 1974-76 on silty clay loam and silty loam soil found that soybean seeds when sown at 2.5, 5.0 and 7.5 cm depths showed greater seedling emergence at 2.5 cm than for deeper sowing depths. In another experiment carried out by Gilioli *et al.* (1981) on soybean it was shown that soils with low moisture showed best seed emergence when planted at a depth of 8 cm. It was then concluded that seedlings can emerge from greater depths, but seeding deeper than a particular level delayed emergence, reduced seedling vigor, and delayed crop development. Some seedlings had difficulty forcing their way through crusted soil. If the seedbed dried too fast, emergence from shallow depths might not be uniform.

A field experiment was carried out by Ratnayake and Shaw (1992) on soybean and it was found that seeds when incorporated to a depth of 5 cm, reduced emergence. However, deeper seed placement (up to 7 cm) was not detrimental and also resulted in good germination. Depth of sowing influenced the emergence and establishment of crop especially under rainfed conditions.

Various factors influencing seeding depth included soil texture, date of sowing, soil moisture in the seeding zone, climatic conditions, and seed size. Seed quality was found to be the major factor for the success of emergence (Rahmlanna *et al.*, 1995).

Zheng (2005) carried out experiment on the seed size and sowing depth with *Agriophyllum squarrosum* and reported that small sized seeds when sown at a shallow depth emerged faster than the larger ones sown at deeper depth.

Effect of seed size

From a study it was reported that there was a positive effect of smaller seeds on the speed of seed emergence in spring wheat (Lafond and Baker, 1986) and soybean (Edwards and Hartwig, 1971). This was stated that the small-seeded genotypes were probably physiologically most efficient, especially at warmer sites and higher latitudes (White *et al.*, 1992). However, several reports showed that spring wheat (Lafond and Baker, 1986), and soybean (Edwards and Hartwig, 1971) emerged faster from small seeds than the large seed size for hybrid. There are also reports that the seedling emergence of soybean (Johnson and Luedders, 1974; Tekrony *et al.*, 1987) and barley (Demirlicakmak *et al.*, 1963) were not affected by seed size.

Vanangamudi *et al.* (1984) reported that field emergence, germination percentage, and seedling vigour were found to differ significantly due to sowing different sizes of soybean seeds. From the result of another study, Verma and Ram (1989) reported that seed size was negatively correlated with germination after accelerated aging. Vyas *et al.* (1990) reported that small seeds showed better germination performance than large seeds.

Calton *et al.* (1971) found that the rate of emergence of soybean differed due to using different size of seeds when tested under different moisture regimes of 20.0, 22.5, 25.0, 27.5 and 30.0 %. The small and medium seeds gave rapid emergence and greater root development than the large seeds at each soil moisture level where germination occurred.

Charjan and Tarar (1991) reported that germination and field emergence were increased with seed size. Sung (1992) explained that emergence force were lower, but reached earlier in small seeds than in large seeds.

Sung (1995) explained that the lower emergence percentage of large seed was related to the lower emergence force expressed on a unit cross-sectional area of the cotyledon pair.

From the results of a study, Tekrony *et al.* (1987) reported that emergence was significantly correlated with seed vigour, but showed little relationship to seed size. Burries *et al.* (1973) reported inferior field emergence capability of the smallest seeds within a seed lot. Green *et al.* (1963) however, found larger seeds to have lower field emergence. Edwards and Hartwig (1971) and Hopper *et al.* (1979) noted more rapid emergence from small seeds than from large seeds. However, Ponnuswamy and Ramakrishnan (1985) stated that the larger seeds had significantly higher percentage of germination than the smaller seeds.

Hoy and Gamble (1987) reported that seeds of the largest size and of the lowest density had the lowest percentage of emergence and speed of emergence, provided these seeds came from seed lots of intermediate vigour.

Chiangmai *et al*, (2000) carried out an experiment and reported no effect of seed sizes on speed of emergence in field setting both in rainy and dry season.

2.3 Seedling vigour and growth

2.3.1 Seedling vigour

Effect of seed size

Proposed explanation to the correlation between seed size and seedling vigour included the higher photosynthesis rate of larger cotyledons from large seeds (Burries *et al.*, 1971). Seedling vigour was shown to be related to seed size in many legumes (Black, 1959). Seed size was one of the factors that influenced seed vigour. Large seeds generally showed greater seedling vigour than small seeds (Kittock and Patterson, 1962). Sivasubramanian and Ramakrishnan (1974) from the results of an experiment also reported that large sized seeds were superior to small sized ones.

In an study it was revealed that although seed size had no effect on percentage of germination, flowering or harvesting dates, but larger seed had more vigorous seedlings and produced higher yielding mature plants (Salehuzzaman *et al.*, 1983).

In a field trial in 1988-89 at Rahuri, Maharashtra with mungbeans [*Vigna radiata*] it was found that the largest seed produced seedlings with the highest germination percentage and vigour index (Bhingarde and Dumbre, 1994).

2.3.2 Seedling growth

Effect of seed size

Black (1959) reviewed the effect of different seed size under different seeding depth and showed that the plants from each seed size grew at the same relative rate of legumes. This was then concluded that seed size in a plant having epigeal germination and without endosperm had limited hypocotyle elongation and once emergence has taken place, cotyledonary reserves were of no further significance in the growth of the plants.

Bremner and Saeed (1963) observed that large seed gave rise to large plant than did small seeds in the establishment phase.

Chiangmai *et al.*, (2000) carried out a study to determine the effect of seed size on the speed of emergence in field conditions, which also included the efficiency of germination and sprout production in laboratory test. In that study the correlation among agronomic characters were found positive and significant.

Early growth and development was related to seed size while final yield although occasionally, but in majority of the cases was not related to seed size. The better performance of large seed in respect of emergence, shoot and root production was associated with a greater initial meristematic tissue and a greater amount of reserved material. This reserved material in some species resulted in higher relative growth rate of large than of small seed (Bremner and Saeed, 1963).

Wester (1964) reported that larger seeds of lema bean produced larger plants than smaller seeds from the same lot. Larger seeds when sown were reported to produce lager seedlings (Ries, 1971). It was explained that larger endosperm enhanced emergence ability of large seeds which had greater supply of stored energy to support early seedling growth (Singh *et al.*, 1972). It was then concluded that after the establishment of the seedling, seed size had no direct effect on the relative growth rate (Whitehead *et al.*, 1980).

Inouye and Jin (1981) found that the maximum vertical elongation force (Ef) exerted by 3 cm seedlings was positively correlated with seed weight. The maximum Ef/unit of seed weight was smaller in large seeded varieties than in small seeded varieties. The area of hypocotyle cross-section was positively correlated with maximum elongation force and seed weight. Large seeded varieties had large stems with a large elongation rate.

In soybean, it was seen that the large seed produced the highest total dry matter of seedlings at 30 days after sowing (Kiler and Dhillon, 1983).

In one study, it was observed that large seeds showed increased root and shoot length in sorghum (Singh *et al.*, 1981). Previously, Martincic *et al.* (1997) showed that seed size had no effect on stem length. In another study, it was revealed that seed size had no effect on percentage of germination, flowering or harvesting dates, but larger seed had more vigorous seedlings and produced higher yielding mature plants (Salehuzzaman *et al.*, 1983).

Xu and Gu (1984) stated that seed size was positively correlated with seedling weight. Rate of water absorption of *R. sativas* , *G. hirsectum* and *T. aestivum* was more rapid in smaller seeds than in large seeds, while ATP content during imbibition was higher in larger seeds than in smaller seeds. The smaller seeds of *G. max* and *G. hirsutum* showed a higher tolerance to high or low temperature.

Babu *et al.* (1990) described that in 15 cultivars of V. *radiata*, seed weight was positively correlated with seedling height, dry weight, root length, primary leaf length, breadth and area. Egli *et al.* (1990) reported that the seed size had no effect on specific growth rate (SGR) or net assimilation rate (NAR).

2.3.3 Epicotyle and hypocotyle growth

Effect of sowing depth

Abrecht (1989) reported that in soybean, seeds when germinated rapidly the hypocotyls of the unemerged seedlings had stopped growing within 20 mm of the soil surface. Deep seeding slowed the emergence but increased seedling growth in maize and soybean.

Effect of seed size

Burries *et al.* (1973) described that the largest seeds have the largest cotyledonary area. But smaller seeds had higher photosynthetic rate as a result of which could compensate and support subsequent seedling growth.

Payne and Koszykowshi (1979) described that depending on the relationship between growth habit and seed size, the varieties of different pulses may fall into two groups: (1) those in which no differences in hypocotyl length was related to seed size and (2) varieties in which large seeds (>6.75mm) gave seedling with shorter hypocotyls than those found in seedlings derived from small seeds. Lee *et al.* (1992) reported that hypocotyle length of seedlings was greater with large seeds than with small seeds which increased with increasing 100-seed weight and increasing temperature up to 35°C.

2.4 Plant height

Effect of sowing depth

Shahbaz *et al.* (1988) conducted a field trial in 1982 on a moderately calcareous silty clay loam soil at Islamabad with different varieties of wheat using different size seeds which were sown at depths of 5 or 10 cm. Results showed that seed size had no effect on plant height.

Silva (1991) sowed wheat cv. Candeias at 3.5, 7.0, 10.5 or 14.0 cm soil depth and found that plant height was not significantly affected by sowing depth. Similarly, in the study of Lupu and Lupu (1996) it was also noted that the plant height was unaffected by sowing depth.

Kabir (2000) while carrying out an experiment with soybean to evaluate the effect of different sowing depth (2, 4, 6 and 8 cm) observed that a depth of 2 cm showed the highest plant height. In that experiment, it was also seen that when large sized seeds were sown in medium depth, significantly higher plant height was obtained.

Effect of seed size

An experiment was conducted by Ponnuswamy and Ramakrishnan (1985) on groundnut and it was found that the plant height increased when larger sized seeds were sown. This was attributed to relatively more growth, as influenced by the presence of greater photosynthetic efficiency sooner the seedling had reached the autotrophic stage. It was also stated that the increased height of plant from the larger seed was due to relatively more growth, as was influenced by the presence of large quantity of food reserves in the larger cotyledons in addition to their greater relative photosynthetic efficiency especially sooner the seedling had reached their autotrophic stage.

Reddy *et al.*, (1989) reported that the seed size had no significant influence on plant height. Both seed size and vigour were found to influence plant height at different growth stages. Bhardwaj and Bhagsari (1990) while carrying out an experiment on the on soybean reported that that seed size had significant effect on plant height. Similar report was also given by Kolak *et al.* (1992).

An experiment was conducted with soybean to examine the effect of different seed size (small, medium and large). In that experiment, it was found that with increasing the seed size, plant height was found to be increased significantly. The highest plant height was obtained from sowing large sized seeds (Kabir, 2000). Similar response was also noticed in mungbean (Islam, 2004).

2.5 Number of branches/plant

Effect of sowing depth

In the study of Lupu and Lupu (1996) it was also noted that plant height was unaffected by sowing depth but the insertion of the first branch on the main stem was lower on the stem with increase in sowing depth.

Kabir (2000) while carrying out an experiment with soybean to evaluate the effect of different sowing depth (2, 4, 6 and 8 cm) observed that seeding depth, although did not significantly affect the number of branches per plant, it decreased the number of branches with increasing the sowing depth. In the same experiment, he also found that large seeds when sown at a depth of 2 - 4 cm produced maximum branches per plant.

Effect of seed size

Ponnuswamy and Ramakrishnan (1985) reported that the percent increase in number of branches of groundnut was highest in plants grown from the large sized seeds. It was revealed that the differences in number of primary branches due to seed size was highly significant in the early stages as well as during the final growth phase of the plant.

Kabir (2000) reported that the seed size had no significant effect on number of branches of soybean although, with increasing the seed size, number of branches per plant was increased. Likewise, in another experiment with mungbean it was also found that the highest number of branches was obtained due to sowing the large sized seeds although the effect was not found to be significant (Islam, 2004).

2.6 Number of leaves/plant

Effect of sowing depth

Kabir (2000) reported that sowing depth had no significant effect on number of leaves per plant of soybean, although, with increasing the sowing depth, the number of leaves per plant was found to be decreased. The highest number of leaves per plant was obtained from using 2 cm depth. But, in that experiment, it was also observed that with increasing the seed size and decreasing the sowing depth, number of leaves per plant was decreased significantly. Significantly higher number of leaves per plant was obtained from using the large sized seeds at depths of 2 - 4 cm.

Effect of seed size

Number of leaves/plant was examined under different seed size of soybean (Kabir, 2000). Results showed that the seed size had no significant effect on number of leaves per plant. But, with increasing the seed size, the number of leaves per plant was found to be increased. The highest number of leaves per plant was obtained from using the large sized seed and the lowest number was found using small seeds.

2.7 Leaf area index

Effect of sowing depth

Kabir (2000) examined different sowing depth (2, 4, 6 and 8 cm) of soybean and found that sowing depth of 2 cm showed the highest leaf area index and 8 cm the lowest. In that experiment, it was also found that the interaction effect of seed size and sowing depth was also found to be significant showing the highest leaf area index from sowing the large sized seeds at the depth of 2 cm.

Effect of seed size

Bhardwaj and Bhagsari (1990) carried out an experiment to examine the effect of seed size on the different traits of soybean. In that study it was revealed that small and medium seeded genotypes had a lower leaf area index than large seeded genotypes. Similar result was also obtained by Kabir (2000).

2.8 Fresh weight

Longer *et al.* (1986) reported that large seeds had a greater shoot and root fresh weight than ungraded and small seeds.

2.9 Dry matter accumulation

2.9.1 Shoot dry weight

Effect of sowing depth

Siddique and Loss (1999) while examining the effect of different seeding depths (2.5, 5 and 10 cm) of three pulses (chickpea, faba bean and lentil) reported that the seeding depth had no effect on dry matter production at flowering. In another experiment, soybean seeds were sown at different sowing depth (2, 4, 6 and 8 cm) and it was found that sowing depth of 2 cm showed significantly the highest shoot dry weight of soybean (Kabir, 2000). In that experiment, it was also found that with increasing the seed size and decreasing the sowing depth, shoot dry weight was also found to be increased. The highest shoot dry weight was obtained from using the large sized seeds when sown in 4-6 cm depth gave significantly higher shoot dry weight.

White *at al.* (1992) stated that pulses with hypogeal emergence could tolerate sowing at 5 to 10 cm depth without yield penalty and in some situations such as sowing into stored subsoil moisture, deeper sowing could improve crop establishment and final yield. It was noticed that deep sowing of faba bean resulted in the development of lateral root system and promoted better plant anchorages. The optimum seeding depth for faba bean and lentil (having hypogeal emergence) were found to be from 5 – 10 cm. While, that of lupins (epigeal emergence) was 4- 6 cm (Siddique and Loss, 1999).

Effect of seed size

Kabir (2000) reported that the shoot dry weight of soybean increased significantly due to the sowing of large sized seeds.

2.9.2 Total dry matter

Effect of sowing depth

Kabir (2000) while conducting an experiment to evaluate the effect of different sowing depth (2, 4, 6 and 8 cm) of soybean reported that sowing depth of 2 - 4 cm showed the highest shoot dry weight. On the contrary, the lowest dry matter was produced from the plants sown at 8 cm depth. It was also seen that the highest straw yield was obtained from using the large sized seeds when sown in 2 cm depth.

Effect of seed size

Hammes (1969) and Sharma (1976) reported that the seed size had significant effect on dry matter production of maize seedlings. They observed that total dry matter had positive relationships with seed size.

Bhardwaj and Bhagsari (1990) carried out an experiment on the effect of seed size on the different traits of soybean and observed significant increase in biomass yield due to sowing large sized seeds.

Charjan and Tarar (1991) reported that dry matter production of soybean was increased with the increase in seed size. In another experiment, Kabir (2000) found that seed size (small, medium and large) had significant effect on total dry weight showing the highest dry weight from using the large sized seeds.

2.10 Yield attributes and yield

2.10.1 Number of pods/plant

Effect of sowing depth

Kabir (2000) examined different sowing depth (2, 4, 6 and 8 cm) of soybean and reported that seeding depth significantly affected the number of pods per plant.. The highest number of pods per plant was obtained from 2 cm depth which, however, was identical those of 4 and 6 cm depth.

Effect of seed size

Ponnuswamy and Ramakrishnan (1985) stated that the accumulation of dry weight by the pod was an important process during reproductive growth in pulses. Pod length and width were positively correlated with final seed size. Seed of pulses showed rapid water uptake during early seed development and water content (mg/seed) reached a maximum before seed reaches physiological maturity.

Martincic *et al.* (1997) showed that seed size had no effect on number of seeds /pod. However, Kabir (2000) reported that the highest number of pods per plant of soybean was obtained from using the large sized seeds. It was also seen that with increasing the seed size and decreasing the sowing depth, number of pods per plant of soybean was found to be decreased. The highest number of pods per plant was obtained from using the large sized seeds when sown in 2 cm depth. Similar result was also found by Islam (2004) in mungbean.

2.10.2 Number of seeds/pod

Effect of sowing depth

Kabir (2000) reported that the highest number of seeds per pod of soybean was obtained when seeds were sown at 2 cm depth, although statistically identical results were obtained with 4 and 6 cm depth. In that study it was also found that with increasing the seed size and decreasing the sowing depth, number of seeds per pod was found to be decreased. The highest number of seeds per pod was obtained from using the large sized seeds when sown in 2 cm depth.

Effect of seed size

In soybean, number of seeds/plant was negatively correlated with seed size, whereas, seed size was strongly correlated with pod width (Saka *et al.*, 1996). In a trial with mungbeans cv. Pusa Baisakhi, sowing large (retained on an

8/64-inch mesh sieve), medium (retained on a 7/64-inch sieve), small (passing a 7/64-inch sieve), graded (bold) seeds and bulk ungraded seeds, it was seen that the highest number of seeds/pod was obtained with graded (bold) seeds (Reddy *et al.*, 1989).

Kabir (2000) stated that seed size of soybean had significant effect on number of seeds per pod. In his study, it was seen that the highest number of seeds per pod was obtained from using the large sized seeds. Likewise, Islam (2004) reported that with increasing the seed size, number of seeds per pod of mungbean was increased.

2.10.3 1000 seed weight

Effect of sowing depth

Silva (1991) while sowing wheat seeds at depths of 3.5, 7.0, 10.5 or 14.0 cm found that the 1000 grain weight was not significantly affected by sowing depth. However, Wajid *et al.* (1997) reported an opposite result. Similar report was also given by Kabir (2000) in soybean. In his study it was observed that the highest 1000 seed weight was obtained from using the large sized seeds when sown in 4 cm depth.

Effect of seed size

Seed size had no significant influence on 1000 seed weight of soybean (Reddy *et al.*, 1989). Charjan and Tarar (1991) reported that 1000 seed weight was increased with seed size. In another study, the seed size was strongly correlated with pod width and in tern with 1000 seed weight (Saka *et al.*, 1996).

Martincic *et al.* (1997) showed that seed size had no effect on 1000-seed weight. But there was a significant correlation between pod number/plant and seed yield. Kabir (2000) in his study with soybean showed that the highest 1000 seed weight was obtained when large sized seeds were sown. Similar result was also obtained by Islam (2004) who worked with mungbean.

2.10.4 Seed yield

Effect of sowing depth

Kabir (2000) tested different sowing depths (2, 4, 6 and 8 cm) of soybean and reported that seeding depth significantly affected the seed yield. The highest seed yield was obtained when seeds were sown at 2 cm depth, although that was identical with that of 4 cm depth. In that study it was also revealed that large sized seeds coupled with shallow sowing depth (2 cm) resulted in the highest seed yield.

A field experiment was carried out by Williums (1967) on legume, *Vicia dasycarpa*. It was shown that the seed yield decreased with greater depth of sowing which was attributed to the decreased seed reserves needed for the emergence of seedlings from the greater depth. Vander -Graff (1962) noted that deep sowing reduced yields and caused lower branching in peas.

Himmel *et al.* (1981) reported that yields were generally decreased at the deeper sowing depths. Rezenda and Arantes (1982) evaluating the results of their experiment reported that a sowing depth of 5 - 6 cm in light or sandy soils and 2 - 3 cm in heavy soils gave similar results.

A study was carried out by Stucky (1976) on soybean where seeds were sown at 5 and 7.5 cm depths. The results indicated that no significant difference in seed yield was noticed dur to sowing depths. However, Visarurat *et al.*, (1992) reported that yield of groundnut increased significantly as the depth of sowing was increased.

In the study of Lupu and Lupu (1996) the mean seed yield of soybean ranged form 1.71 and 2.04 t/ha from 8cm sowing depth. But a higher yield (2.20 t/ha) was obtained from 4 cm sowing depth (control).

Effect of seed size

From the works on sorghum and soybean, it was reported that the seed size did not affect yield significantly (Suh *et al.*, 1974; Sexton *et al.*, 1994). Suh *et al.* (1974) explained that seed weight per se would have little influence on yield of the resulting crop. However, White *et al.* (1992) found that small seeded genotypes were probably physiologically most efficient over large seeded ones in common bean at warmer areas and higher latitudes showing higher yield. In a trial with mungbeans cv. Pusa Baisakhi, it was seen that sowing large (retained on an 8/64-inch mesh sieve), medium (retained on a 7/64-inch sieve), small (passing a 7/64-inch sieve), graded (bold) and bulk ungraded seeds gave seed yields of 1.45, 1.54, 1.07, 1.81 and 1.37 t/ha, respectively (Bhingarde and Dumbre, 1994).

In a field trial in 1988-89 at Rahuri, Maharashtra of India, mungbeans (*Vigna radiate)* cv. S-8 seeds were grouped in ungraded, large (>3.35 mm), medium (3.35-3.01 mm) or small (<3.01 mm) and sown. Results showed that the seed yield/plant was the highest from the largest seed (Bhingarde and Dumbre, 1994).

The component compensation may be the reason that why seed size did not affect yield in soybean (Singh *et al.*, 1972; Hoy and Gamble, 1987), mungbean (Amin, 1999) and common bean (Perin *et al.*, 2002). Board *et al.* (1999) stated that the seed number and seed size may both affect and compensate each other in determining yield of soybean and the main factor which directly contributed to yield was dependent upon plant species and plant varieties.

Amin (1999) reported that 50% of large-seeded mungbean matured earlier than that of small-seeded type. Although large seed had an advantage of having higher stored energy supply but did not show any significant effects of seed size on yield.

Kabir (2000) while conducting an experiment with soybean using varying depth of sowing (2, 4, 6 and 8 cm) and seed size (small, medium and large) found that the highest seed yield was obtained from sowin the large sized seeds. In another study with mungbean, Islam (2004) also reported similar results.

Burries *et al*. (1973) stated that the seed yield of pulses depended on the length of time during which leaves were active. In the interval between appearance of successive leaves, a temperature accumulation of about 77°C was required. The 4^{th} leaf from the top should be used for measurements of physiological characteristics and anatomical observations. Leaf growth rate was affected at the middle part of the plant had the longest life span and when they appeared flowering began. The higher the leaf growth rate the earlier the maximum leaf area was attained which resulted in the expected seed yield.

Amin (1999) reported that 50% of large seeded mungbean matured earlier than that of small seeded type. Although large seed had an advantage of having higher stored energy supply but was not found to affect yield. Although the large sized seeds had the largest cotyledonary area, the higher photosynthetic rate was exhibited by smaller ones, which could compensate and support seedling growth (Burris *et al.*, 1973). Several studies reported that difference in seed size of sorghum (Suh *et al.*,1974) and soybean (Sexton et al ., 1994) did not affect yield of these crops.

Suh *et al* . (1974) explained that seed weight per se would have little influence on yield of the resultant crop. White *et al.*,(1992) found that small seeded genotypes were probably physiologically most efficient over large seeded genotypes in common bean at warmer areas and higher latitudes for higher yield.

Ries (1971) reported that the larger seed produced larger seedlings which in tern resulted in higher yields. Similarly Wester (1964) reported that large sized lema bean seeds produced higher yields than small seeds from the same lot. It was concluded that the seed size could affect the yield (Smith and Camper, 1975). Fontes and Ohlrogge (1972) reported an increase in soybean yield with large seeds in one test, but found no yield differences in another test.

Kiler and Dhillon (1983) tested different size of soybean seeds (5.6 – 7.4 mm dia) and noticed higher capacity and speed of germination and produced plants with more vigorous growth and higher chlorophyll content in leaves than medium (6 - 6.4 mm), large (more than 6.4 mm) or bulk seeds. However, the difference in seed yields due to different seed sizes was not found to be significant In another experiment conducted by Ferer *at al*. (1984) it was observed that seed size did not affect yield. Singh *et al*., (1972), Johnson and Leudder (1974) and Johnson and Wax (1978) also found no relationship between soybean seed size and yield.

Bhardwaj and Bhagsari (1990) noticed significant variation in harvest index, yield, leaf area index, biomass and height due to using small and medium seeded genotypes but yield differences due to seed size groups was not significant. However, yield was positively correlated with harvest index in large and small seeded genotypes.

Sisodia (1987) grew soybean from large, small and ungraded seeds and found seed yields of 2.87, 2.52 and 2.04 t/ha, respectively. Later on, an field experiment was carried out in rabi season of 1992 at Hyderabad, Andra Pradesh of India, soybeans cv. seeds having 3.5 or 5.5 mm size or ungraded were sown and seed yields of 1352, 1565 and 1651 kg/ha, respectively were obtained. The differences among the yields were significant.

Martincic *et al*., (1997) showed that seed size had no effect on stem length, seed number/pod or 100-seed weight but the pod/plant increased significantly with increasing the seed size. There was also a significant correlation between pod number/plant and seed yield. Similarly the number of seeds/plant was negatively correlated with seed size and again the seed size was strongly correlated with pod width (Saka *et al.*, 1996).

Kiler and Dhillon, (1983) reported that the difference in seed yields due to difference in seed size were not found to be significant in soybean. Similarly in another study it was revealed that seed size had no effect on percentage of germination, flowering or harvesting dates, but larger seed had more vigorous seedlings and produced higher yielding mature plants (Salehuzzaman *et al.*,1983).

Little relationship has been reported between seed size and yield for soybean (Singh *et al.*, 1972 and Johnson and Luedders, (1974). But different seed sizes (>6.35 mm), small(>5.56mm) or upgraded) tested in a trial showed that the seed yield of soybean due to varying seed sizes were significant (Khare *et al.*, 1996).

Ferer *et al.* (1984) observed that seed size did not affect seed yield of soybean. Singh *et al.* (1972), Johnson and Leudder (1974) and Johnson and Wax (1978), likewise, found no relationship between soybean seed size and yield. In another study, it was also seen that seed size had no significant influence number of seeds/plant and yield/plant (Reddy *et al.*, 1989).

Hoy and Gamble, (1987) reported that seed size had no effect on yield of soybean in early or late sowings, but high density seeds out yielded low density seeds in the late sowing. But, Wester (1964) reported that larger seeds of lema bean gave higher yields than smaller seeds from the same lot. In another study, Gupta and Singh (1969) and Singh and Malhotra (1970) obtained positive association between seed size and seed yield in mungbean. Similar report was given by Ries (1971).

Smith and Camper, (1975) described that the seed size could affect the yield and other characteristics of field grown crops and such relationships have also been demonstrated in soybean. However, Fontes and Ohlrogge (1972) reported that an increase in soybean yield was obtained with large seeds, whereas, in another experiment, no yield differences were obtained due to differential seed size.

In an experiment, soybeans was grown from large, small and ungraded seeds and seed yields of 2.87, 2.52 and 2.04 t/ha were obtained respectively (Sisodia,1987). On the contrary, Kolak *et al.* (1992) reported that seed size did not have significant effect on seed yield.

Bhardwaj and Bhagsari (1990) carried out an experiment on the effect of seed size on the different traits of soybean. In that study it was revealed that yield differences between seed size groups were not significant. However, the yield was positively correlated with harvest index in large and small seeded genotypes.

2.10.5 Harvest index

Effect of sowing depth

Harvest index was not found to be affected by sowing depth in soybean (Kabir, 2000). In one study, the effect of different sowing depth (2, 4, 6 and 8 cm) and seed size (small, medium and large) was evaluated. It was observed that the highest harvest index was obtained from the crop of which seeds were sown in 2 cm depth instead of sowing seeds at 4 and 6 cm depths. In that trial, it was also revealed that with increasing the seed size and decreasing the sowing depth, harvest index was decreased. The highest harvest index was obtained from using the large sized seeds when sown in 2 cm depth.

Effect of seed size

Bhardwaj and Bhagsari (1990) carried out an experiment on the effect of seed size on the different traits of soybean. In that study it was revealed that small and medium seeded genotypes had a higher harvest index than large seeded genotypes. However, previously it was reported that the seed size had no significant influence on the harvest index (Reddy *et al.*, 1989).

In soybean, Kabir (2000) found that seed size had significant effect on harvest index. With increasing the seed size, the harvest index was increased. In that study, it was also found that sowing different sized seeds affected differently when sown at different depths. In another study, Islam (2004), however, found that seed size had no significant effect on harvest index although, with increasing the seed size, harvest index was found to be increased.

Chapter 3

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

The details of methodology followed to find out the effect of three level of sowing depth and three sizes of seed on growth and yield of mungbean seed have been presented in this chapter.

3.1 Site description

3.1.1 Geographical location

The experimental area was situated at 23°77′N latitude and 90°33′E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004).

3.1.2 Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.3 Soil

The soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace soils under Tejgaon series. Soil pH was 7.1 and had organic matter 1.08%. The experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resource and Development Institute (SRDI), Dhaka. The chemical properties of the soil are presented in Appendix II.

3.2 Source of seed

The seeds of mungbean variety BARI mung – 5 was collected from Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.

3.3 Treatments

Two sets of treatment were included in the experiment as follows:

A. Main plot (Sowing depth): 3

1. Low (2 cm) – D_1
2. Medium (4 cm) – D_2
3. High (6 cm) – D_3

B. Sub Plot (Seed size):3

1. Small (< 3.2 mm) – S_1
2. Medium (3.2 mm to 4 mm) – S_2
3. Large (> 4 mm) – S_3

As such the total numbers of treatments were 9.

3.4 Experimental design and lay out

The experiment was conducted following Split Plot design with 3 replications. The size of each plot was 4m × 2.4m. Block to block distance was 1 m and plot to plot distance was 0.5 m (Appendix III).

3.5 Land preparation

The land was first ploughed by a tractor drawn disc plough and subsequently cross ploughed four times with power tiller and ladder. The corners of the land were spaded. It was then harrowed to bring the soil in a good tilth condition. The final land preparation was done by disc harrow. The land was then thoroughly leveled by a ladder. Weeds and stubbles were removed from the field. All the clods were broken into small pieces. The unit plots were also prepared smoothly with spade before sowing.

3.6 Fertilizer dose

Fertilizers were applied at the rate of 21- 46 - 33 kg of N, P_2O_5 and K_2O hectare^{-1}, respectively (BARI, 2006).

3.7 Method of fertilizer application

Whole amount of Urea, TSP and MP fertilizer's were applied as basal dose during final land preparation.

3.8 Seed grading

Seeds were graded by mashes into three sizes as per experimental treatments.

3.9 Sowing of seeds

Seeds were sown on 27th March, 2007 by hand. Mungbean seeds were sown in line maintaining line to line distance of 30 cm and plant to plant 10 cm.

Seeds were sown in furrows the depth of which were maintained as per treatments. The depth of the furrows were maintained by using a measuring scale. In each furrow, the seeds were sown in solid line and were then covered properly with soil.

3.10 Thinning

The thinning was done 15 days after sowing maintaining plant to plant distance of 10 cm.

3.11 Intercultural operations

3.11.1 Weeding

The experimental crops were found to be infested with weeds of different kinds which were controlled manually by nirani. Weeding was done two times; 15 and 25 days after sowing (DAS).

3.11.2 Application of insecticides

The mungbean plants were infested at seedling stage by cutworm and at vegetative stage by hairy caterpillars. The were controlled by spraying Nogos and Savin – 85 SP respectively, as per recommendation. Irrigation was given as per necessity of the crop.

3.12 Harvesting

Mungbean pods were harvested on 9 June , 2007. Ten plants from each plot were selected at random before harvesting and were uprooted for data recording .The harvested pods were dried in sun for consecutive three days.

3.13 Threshing

The pods were then threshed by a bamboo stick and seeds were separated from the plants.

3.14 Drying

The separated seeds were then dried in sun for consecutive three days.

3.15 Cleaning and weighing

The threshed and dried seeds were then cleaned by using a winnower.

3.16 General observations

The crop was frequently monitored to note any change in plant characters. The crop looked promising since the initial stage and it maintained a satisfactory growth till harvest.

3.17 Determination of maturity

At the time when 80% of the pods turned brown in colour , the crop was assessed to attain maturity.

3.18 Recording of data

Different growth and yield data were recorded from the experiment.

A. Growth characters

i. Percentage of germination (%)

ii. Seed vigor index

iii Seedling root, shoot and total fresh weight (g) iv Seedling root length (cm)

v. Percentage of emergence (%)

vi. Plant height at different growth stages (cm)

vii. Number of primary branches plant^{-1}

viii. Leaf dry weight plant^{-1} (g)

ix. Shoot dry weight plant^{-1} (g)

x. Root dry weight (g)

xi. Total dry matter production (g)

xii. Number of leaflet plant^{-1}

xiii. Leaf area index

xiv. Crop Growth Rate (CGR) (g m^{-2} day^{-1})

xv. Net Assimilation Rate (NAR) (g m^{-2} day^{-1})

B. Yield and yield components

i. Number of pods plant^{-1}

ii.Pod length (cm)

iii Number of seeds pod^{-1}

iv. Weight of 1000 seeds (g)

v. Seed yield (tha^{-1})

vi. Shelling percentage(%)

vii. Harvest index (%)

3.19 Procedure of recording data

The detail outline of data recording is given below

3.19.1 Germination percentage and vigour index

Before sowing, percent germination and vigour index of the seeds were monitored. For doing this, 100 seeds were placed on filter papers in 4 petridishes. The germination was counted on 3, 4 and 5[th] days after setting of the germination test. The seeds from which the radicle was imerged were considered as germinated.

The vigour index was determined by using the following formulae (Agrawall, 1991);

$$\text{Vigour index} = \frac{\text{No. of seeds germinated at first count}}{\text{Days required to first count}} + \frac{\text{No. of seeds germinated at final count}}{\text{Days required to final count}}$$

3.19.2 Seedling emergence

Emergence percentage and different growth attributes (hypocotyle and epicotyle length, hypocotyle and epicotyle fresh weight, root length) were monitored in polybags (cm × cm). The polybags were filled with soil from the field and the seeds were sown as per the treatments. As no seedlings were observed to emerge before 7[th] DAS, the emergences were monitored from 7[th] to 15[th] DAS. The seedlings of which cotyledons emerged on the soil surface in polybags were considered as emerged. For the measurement of hypocotyle and epicotyle length, hypocotyle and epicotyle fresh weight and root length, the polybags were removed at 15 DAS and the soil along with the seedlings were separated. This was then kept along with flowing water and the seedlings were separated from the soil.

3.19.3 Epicotyle, hypocotyle and root length of seedlings

Five plants were randomly taken from each polybag at 15 (DAS).The lengths of epicotyle, hypocotyle and root were measured with a meter scale.

3.19.4 Seedling fresh weight (shoot and root)

Five plants were taken randomly from each polybag at 15 DAS. The weight of root was measured with electronic balance. The fresh weight of the shoot and root were recorded separately.

3.19.5 Plant height (cm)

The height of pre selected ten plants were measured from the ground level to tip of the plants and then averaged. It was taken at 15, 30, 45 AND 60 days after sowing from some selected plants.

3.19.6 Number of leafletsplant^{-1}

The number of leaflets of the sampled plants were counted and recorded at all the growth stages (15, 30 and 45 DAS).

3.19.7 Number of primary branchesplant^{-1}

Total number of primary branches were counted from five plants and then averaged. It was taken at different DAS separately.

3.19.8 Leaf area index

Twenty leaflets were collected randomly from the field and the length and breadth of each leaflet were measured. Length and breadth were multiplied to get the area of individual leaflets. All the area were summed up and divided by 20 to get the average leaflet area. Real leaf area was then determined by using the following formulae;

Real leaf area = Area of an individual leaflet × Number of leaflets per plant × 0.65

Where, for determining the real leaf area, the product of length and breadth of a leaf multiplied by the calibration factor (Alagarswamy and Wani, 2008). The calibration factor used for mungbean was 0.65.

3.19.9 CGR and NAR calculation

Leaf area was converted to square centimeter and dry matter weights were converted to g per square meter and the two were used to compute the following parameters. according to Radford (1967) and Watson (1952) as follows;

$$\text{Leaf area index (LAI)} = \frac{\text{LA (cm}^2)}{\text{GA (cm}^2)}$$

Where, LA = leaf area in square centimeter

GA = Ground area in square centimeter

$$\text{Crop growth rate (CGR)} = [\{(W_2 - W_1)/(T_2 - T_1)\} \times 1/GA] \ g/m^2/day$$

Where, W_1 = Weight of dry matter at time T_1

W_2 = Weight of dry matter at time T_2

$$\text{Net assimilation rate (NAR)} = \{(\ln LA_2 - \ln LA_1)/(LA_2 - LA_1)\} \times \{(W_2 - W_1)/(T_2 - T_1)\} \ g/m^2/day$$

Where, LA = Leaf area

LA_1 = Leaf area at time T_1

LA_2 = Leaf area at time T_2

Ln = Natural logarithm

3.19.10 Dry weightplant^{-1} (g)

Ten plants were collected randomly from each plot at 15, 30, 45 and 60 days after sowing. Those were then segmented into leaf, stem and root. At 45 and 60 days after sowing, inflorescences were also separated from the plants. Leaflets contained petioles with them.

The sampled plants were oven dried for 24 hours at 70° C and the dry weightplant^{-1} was determined by using the following formula :

$$\text{Dry weightplant}^{-1}\ (g) = \frac{\text{Dry weight (g)}}{\text{Number of plants}}$$

The dry weight of each segment was measured individually. The total weight was calculated by summing up the weight of all the segments at all the growth stages.

3.19.11 Number of podsplant^{-1}

The number of pods of each plant was counted and the mean was found out by using a calculator.

3.19.12 Number of seedspod^{-1}

The number of seed of each randomly selected ten pod was counted and the mean was found out by dividing the number of pods.

3.19.13 Weight of thousand seeds (g)

One thousand seeds were randomly taken from the harvest sample of each plot. The seeds were then sun dried for seven days and weighted with a sensitive electrical balance. The 1000 seed weight was recorded at 12% moisture level.

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

The pods from the central four lines was harvested plot wise as per experimental treatments and threshed. Seeds were then cleaned and sun dried for seven days. The seed yield/plant was recorded at 12% moisture level.

3.19.15 Shelling percentage

The pods of the sampled plants were taken. The seeds were separated from the pods. The chaff weight was also taken. The chaff weight was devided by the pod weight and the results was then multiplied by 100 as per following formulae.

$$\text{Shelling percentage (\%)} = \frac{\text{Chaff dry weight (g)}}{\text{Pod dry weight (g)}} \times 100$$

3.19.16 Harvest index (HI)

Harvest index was calculated by using the dry weight of plant where the root weights were excluded .Harvest Index was taken plot wise as per experimental treatments by the following formula

$$\text{HI (\%)} = \frac{\text{Grain yield (g plant}^{-1}\text{)}}{\text{Straw yield (g plant}^{-1}\text{)} + \text{grain yield (g plant}^{-1}\text{)}} \times 100$$

3.20 Statistical analysis

The data collected on different parameters were statistically analyzed using the IRRISTAT computer package program. Least Significant Difference (LSD) technique at 5% level of significance was used to compare the mean differences among the treatments (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Germination and vigor index

4.1.1 Effect of seed size

Seed size had significant effect on germination of seedling (Fig. 1). Germination rate increased gradually with the decrease in seed size. At 3rd day, germination percentage of S_1 (small seeds) was significantly higher than S_2 (medium seeds) and S_3 (large seeds).

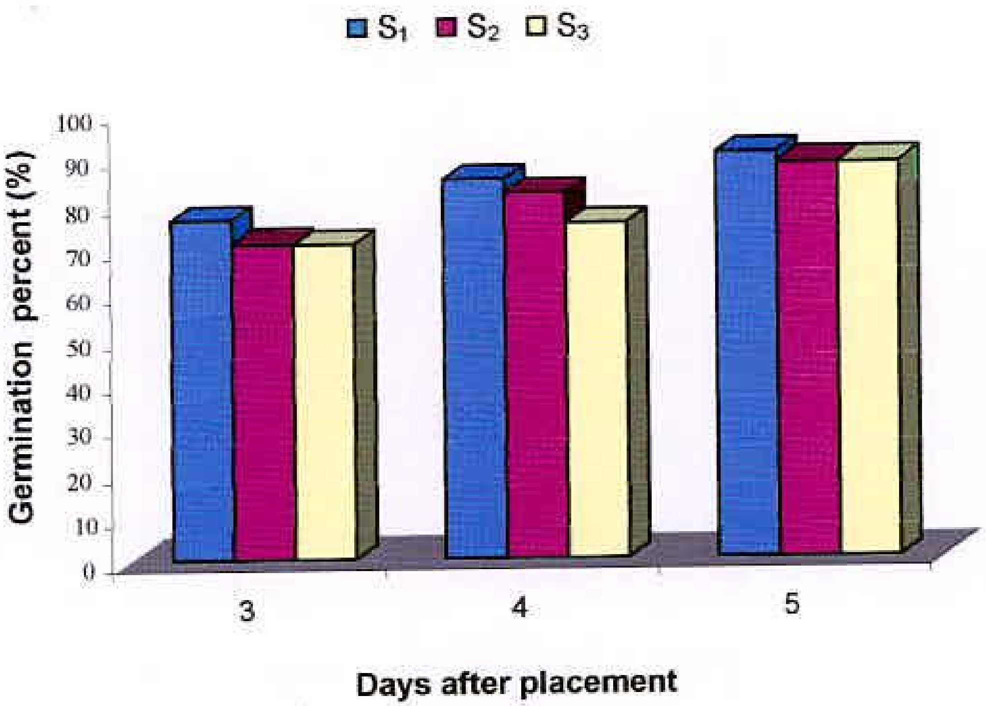

Fig: 1 Germination rate of mungbean seeds as influenced by seed size ($LSD_{0.05}$ = 2.107, 3.324 and 3.324 % at 3, 4 and 5 days, respectively)

At 4th day small seeds germinated significantly faster than S_2 and S_3 but there was no significant difference among S_1 and S_2. At 5th days, germination percentage of S_1 was numerically higher than S_2 and S_3 but there was no real difference observed among S_1, S_2 and S_3. Similar results were also reported by Wester (1964), Kler and Dhillon (1983) and Vyas *et al.*, (1990) who reported that small seeds showed better germination performance than large seeds of different pulse and oil crops.

4.1.2. Seed vigor index

Seed size had significant effect on vigor index of seed (Fig. 2). Seed vigour index increased gradually with the decrease in seed size. Vigor index of S_1 was significantly higher than S_2 and S_3.

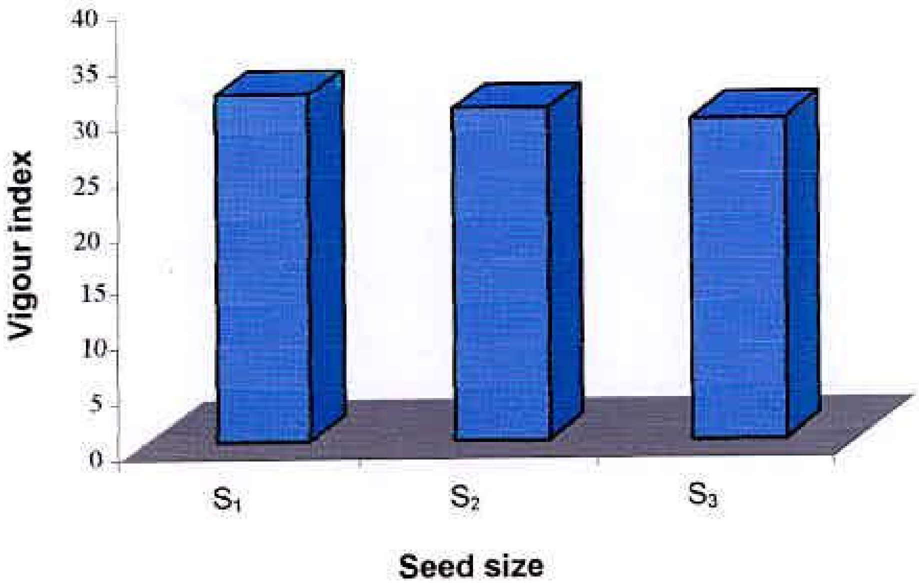

Fig: 2 Vigour index of mungbean seeds as influenced by seed size ($LSD_{0.05}$ = 0.99)

4.2. Emergence

4.2.1 Effect of sowing depth

Seeds under the treatment D_1 started emerging 7 days after of sowing and those under D_2 and D_3 after 9 days of sowing. However, the trend of emergence of all the sowing depth treatments were similar (Fig. 3). The seedlings emerged rapidly up to 12 DAS and thereafter the emergence almost ceased.

Sowing depth had significant effect on emergence of seedling. At 7 DAS, emergence occurred only with 2 cm (D_1). At 8 DAS, percentage of emergence was significantly higher at 2 cm depth (D_1) than 4 cm (D_2). On that day no seedling emerged from 6 cm depth (D_3). At 9 DAS, all the sowing depth treatments showed seedling emergence The maximum emergence was shown by D_1 which was significantly higher than those of 4 cm and 6 cm depth. The same observation was found at 10, 11, 12 and 13 DAS. That is, at all the stages significantly the lowest emergence was shown at 6 cm depth (Fig.3). The emergence rate increased gradually with the decreasing in sowing depth. The reasons for faster emergence of 2 cm depth of sowing might be due to optimum water content of soil that might contribute higher oxygen supply to the germinating seeds. At the deeper seeding depth, the soil with higher water content may have lower oxygen supply to the germinating seeds and reduced germination. Moreover, the seeds sown deeper probably encountered the mechanical impedance from the above soil as a result of which, the rate of emergence decreased with increasing depth of sowing. Sani and Singh (1980) also reported that increasing the sowing depth the rate of emergence was decreased.

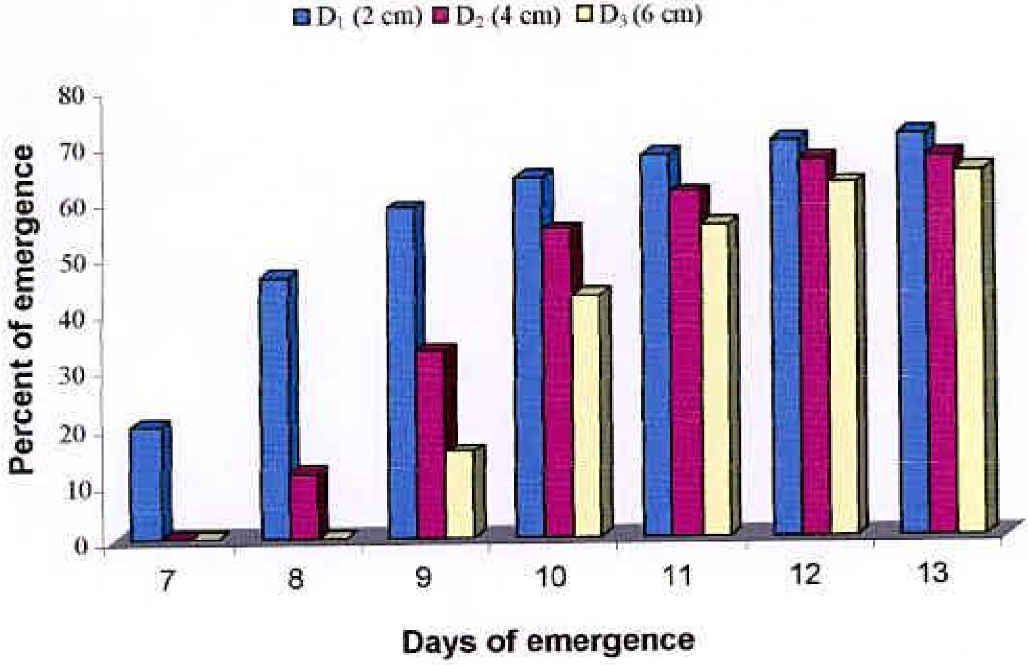

Fig. 3 Percent of emergence of mungbean seedlings as influenced by sowing depth ($LSD_{0.05}$ = 1.291, 2.426, 4.185, 2.678, 2.825, 2.689 and 1.791 % at 7, 8, 9, 10, 11, 12 and 13 days, respectively)

4.2.2 Effect of seed size

Seed size had also significant effect on emergence of seedling (Fig. 4). Unlike with sowing depth, seedlings from all of seed sizes were found to start emerging from 7 DAS. After starting the emergence, seedling of all the seed sizes emerged almost linearly up to 12 DAS and thereafter it almost ceased. At 7 DAS, percentage of emergence became similar with S_1, S_2 and S_3. However, at 8 DAS, small seeds emerged significantly faster than S_2 and S_1. Similar result was also found at 13 DAS. At 9 DAS, significantly the maximum emergence was shown by

S_2 which was higher than S_1 and S_3 and similar results were observed at 10, 11, and 12 DAS. At all the stages, significantly the lowest emergence was shown at S_3. The results indicated that the emergence rate increased gradually with the decrease in seed size. The reasons for faster emergence of small seeds might be due to the rapid activation of the physiological process and reduced soil mechanical resistance encountered during emergence of seeds. Similar results were also reported by Sung (1992), Ponnuswamy and Ramakrishnan (1985), Hoper *et al.* (1979) and Calton *et al.* (1971).

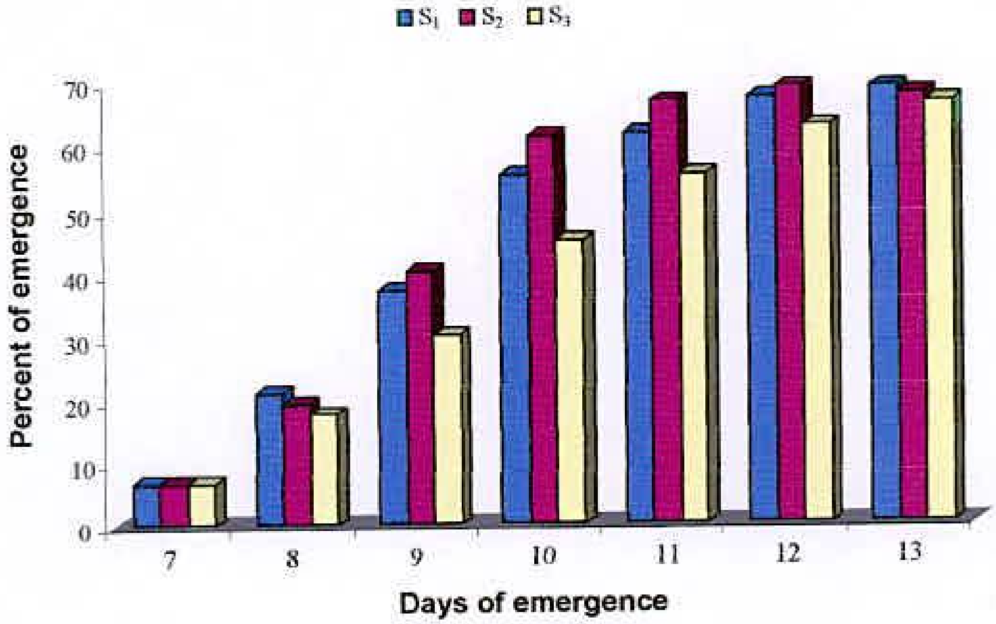

Fig. 4 Percent of emergence of mungbean seedlings as influenced by seed size ($LSD_{0.05}$ = 0.24, 0.83, 1.92, 1.76, 2.01, 2.03 and 1.67 % at 7, 8, 9, 10, 11, 12 and 13 days, respectively)

4.2.3 Interaction effect of sowing depth and seed size

The interaction of sowing depth and seed size had significant effect on emergence of seedling (Fig. 5). It was observed that at the lowest sowing depth, the emergence of seedling decreased with the increase in seed size however, at medium sowing depth (4 cm) and deepest sowing depth (6 cm) the emergence of seedling increased up to the S_2 and thereafter decreased.

At 7 DAS, the interaction of D_1S_1, D_1S_2 and D_1S_3 showed numerically similar emergence of seedling and at that stage there was no seedling emerged in other treatments.

At 8 DAS, D_1S_1 showed the highest emergence of seedling (49.67) which was significantly higher than other treatments. The second highest emergence was in D_1S_2 (47.07). D_2S_2 showed the lowest (11.00) emergence of seedling which, however, was significantly lower than other treatments but numerically similar to D_2S_3. At that stage there was no seedling emerged in deeper depth irrespective of seed size.

At 9 DAS, D_1S_1 interaction showed the highest emergence of seedling (65.25) which was significantly higher than other treatments. The second highest emergence was in D_1S_2 (61.33). Third highest emergence was in D_1S_3 (48.58). D_3S_3 showed the lowest (11.00) emergence of seedling which, however, was not significantly differ to D_3S_2 interaction.

At 10 DAS, D_1S_1 showed the highest emergence of seedling (67.70) which was not significantly higher than D_1S_2. The second highest emergence was found in D_2S_2 (62.33). D_3S_3 showed the lowest (29.33) emergence of seedling which, however, was significantly lower than other interactions.

At 11 DAS, D_1S_1 showed the highest emergence of seedling (70.17) which was not significantly differ to D_1S_2 and D_2S_2 interaction. The next highest emergence was observed in D1S3 (62.33) which was statistically similar to D_2S_1 and D_3S_2 treatments. D_3S_3 showed the lowest (47.67) emergence of seedling.

At 12 DAS, D_1S_1 showed the highest emergence of seedling (71.33) which was not significantly differing to D_1S_2 D_2S_1 and D_2S_2 interactions. D_3S_3 showed the lowest (58.67) emergence of seedling which, was significantly lower than other interactions.

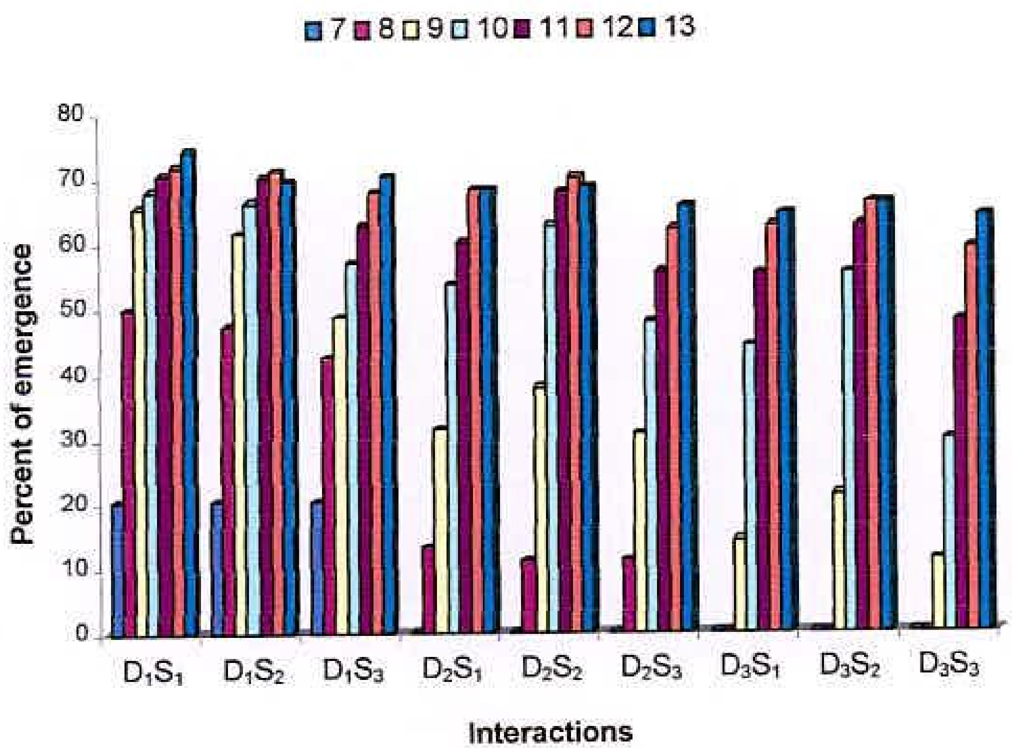

Fig. 5 Interaction effect of sowing depth and seed size on the percent of emergence of mungbean seedling ($LSD_{0.05}$ = 0.37, 1.43, 3.33, 3.06, 3.48, 3.52 and 2.89 % at 7, 8, 9, 10, 11, 12 and 13 days, respectively)

At 13 DAS, D_1S_1 showed the highest emergence of seedling (73.83) which was significantly higher than other treatments. D_3S_3 showed the lowest (63.80) emergence of seedling which, however, was not significantly differ to D_2S_1, D_2S_2, D_2S_3, D_3S_1, D_3S_2 interactions treatments.

Similar findings was found by Zheng *et al*. (2005) and Ahlawat and Rana (2002) who reported that small sized seeds when sown at a shallow depth emerged faster than the large seeds sown at deeper depth.

4.3 Seedling epicotyle length

Results of epicotyle length was presented in Fig. 6, 7, and 8. The epicotyle length of mungbean ranged from 4.40-5.07 cm at 15 DAS.

4.3.1 Effect of sowing depth

The sowing depth had no significant effect on epicotyle length at 15 DAS (Fig. 6). At that stage, epicotyle length increased with the increase of seeding depth up to 4 cm however it decreased at 6 cm depth. The epicotyle length ranged from 4.51 - 4.67 cm. At that growth stage, the maximum epicotyle length was shown by the medium (4 cm) depth and the minimum epicotyle length was shown by the lowest (2 cm) depth.

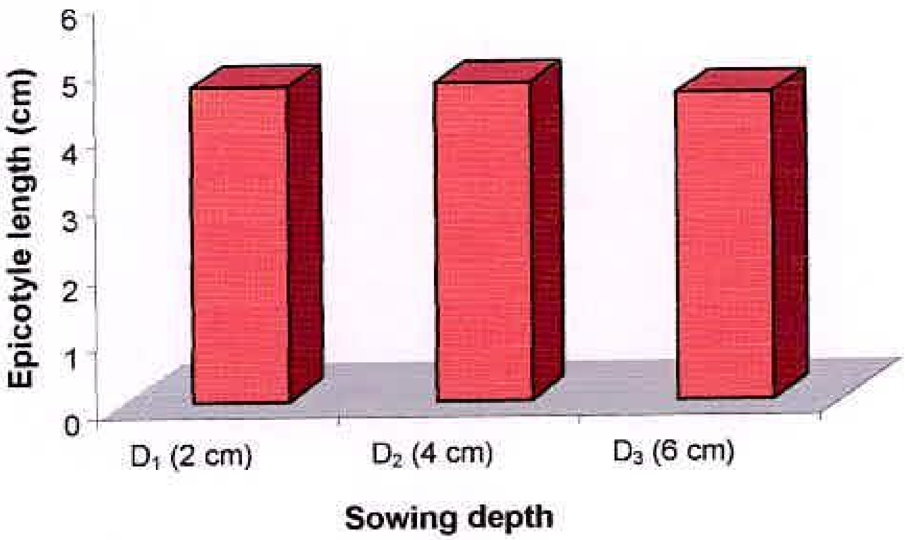

Fig. 6 Epicotyle length of mungbean seedlings as influenced by sowing depth ($LSD_{0.05}$ = 0.22 cm)

4.3.2 Effect of seed size

At 15 DAS, epicotyle length was found to be increased with the increasing rate of seed size (Fig. 7). The seed size had significant effect on epicotyle length. The highest epicotyle length (4.94 cm) was obtained from S_3 which was significantly higher than S_1 and S_2 treatments. The lowest epicotyle length (4.25 cm) was obtained from the S_1 seed which was significantly lower than S_2 and S_3 treatments.

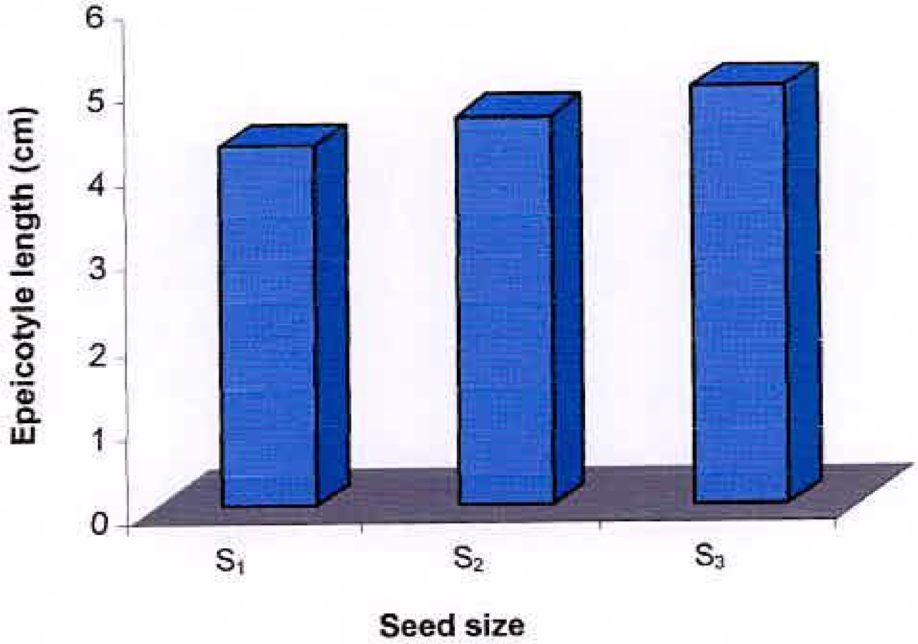

Fig. 7 Epicotyle length of mungbean seedlings as influenced by seed size ($LSD_{0.05}$ = 0.21 cm)

4.3.3 Interaction effect of sowing depth and seed size

The difference epicotyle length among the treatments was significant due to interaction of sowing depth and seed size (Fig. 8). It was observed that at a certain sowing depth, epicotyle length increased with the increase in seed size but at 6 cm depth, the largest seed size showed slightly lower value in epicotyle length than that by the medium seed size. The highest epicotyle length (5.13 cm) was found in D_1S_3 which was not significantly differd to D_2S_3 values. The lowest epicotyle length was found in D_3S_1 (3.92cm) which was significantly lower than other interactions.

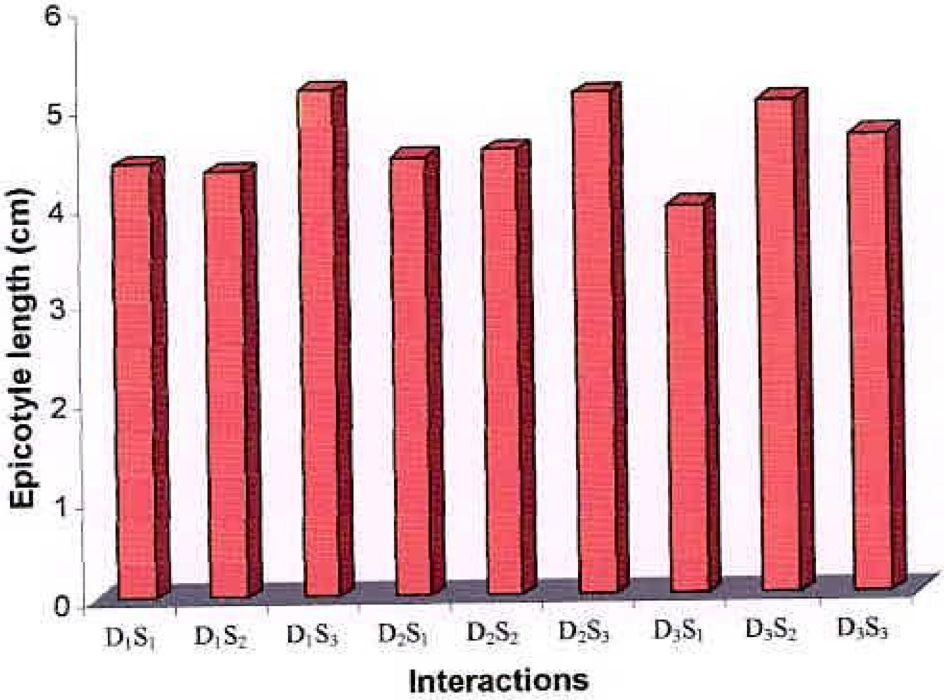

Fig. 8 Interaction effect of sowing depth and seed size on epicotyle length of mungbean seedlings ($LSD_{0.05}$ = 0.36 cm)

4.4. Seedling hypocotyle length (cm)

Results of hypocotyle length was presented in Fig. 9, 10 and 11. The hypocotyle length of mungbean ranged from 5.59 - 8.00 cm at 15 DAS.

4.4.1 Effect of sowing depth

The sowing depth had significant effect on hypocotyls length at 15 DAS (Fig. 9). At that stage, hypocotyle length increased with the increase of seeding depth. The maximum hypocotyle length was shown by the highest (6 cm) depth. The minimum hypocotyle length was shown by the smallest (2 cm) depth.

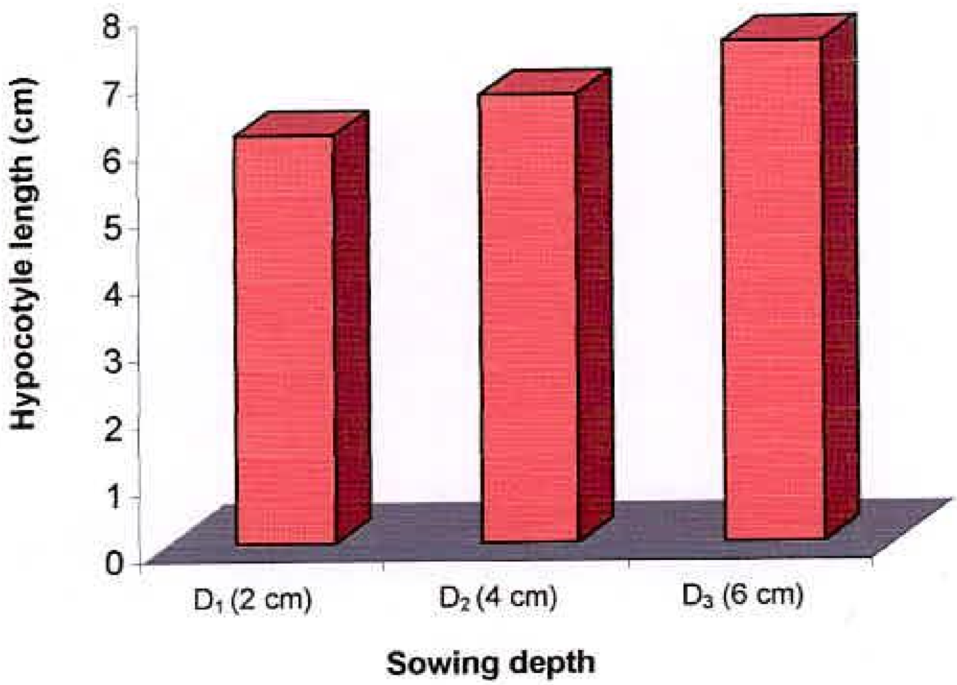

Fig. 9 Hypocotyle length of mungbean seedlings as influenced by sowing depth ($LSD_{0.05}$ = 0.29 cm)

4.4.2 Effect of seed size

Significant effect of seed size was noticed on hypocotyle length. The hypocotyle length was found to be increased with the increase of seed size (Fig. 10). At 15 DAS, the highest hypocotyle length (7.34cm) was obtained from S_3 which was significantly higher than S_1 and S_2 treatments. The lowest hypocotyle length (6.34cm) was obtained from the S_1 seed which was significantly lower than S_3. Similar findings were given by found in Khattak *et al.* (2003) and Inouye and

Jin (1981) who reported that seed size had positive correlation with hypocotyle length and large seed produced higher hypocotyle length. Lee *et al.* (1992) reported that hypocotyle length was greater with large than small seeds.

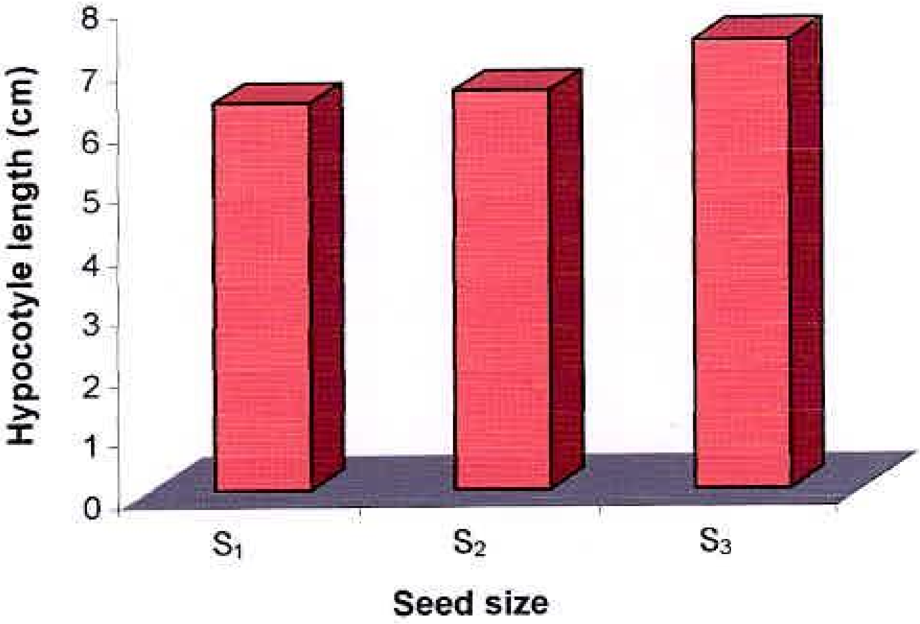

Fig. 10 Hypocotyle length of mungbean seedlings as influenced by seed size ($LSD_{0.05}$ = 0.28 cm)

4.4.3 Interaction effect of sowing depth and seed size

The difference of hypocotyle length among the treatments was significant due to interaction of sowing depth and seed size (Fig. 11). At 15 DAS, it was observed that at a certain sowing depth, hypocotyle length increased with the increase in seed size .The highest hypocotyle length (8.00cm) was found in D_3S_3 which was significantly higher than other interactions. The second highest hypocotyle length was observed in D_2S_3 (7.25cm) which was similar to D_3S_1 and D_3S_2. The lowest hypocotyle length was found in D_1S_1 (5.59cm) which was similar to D_1S_2.

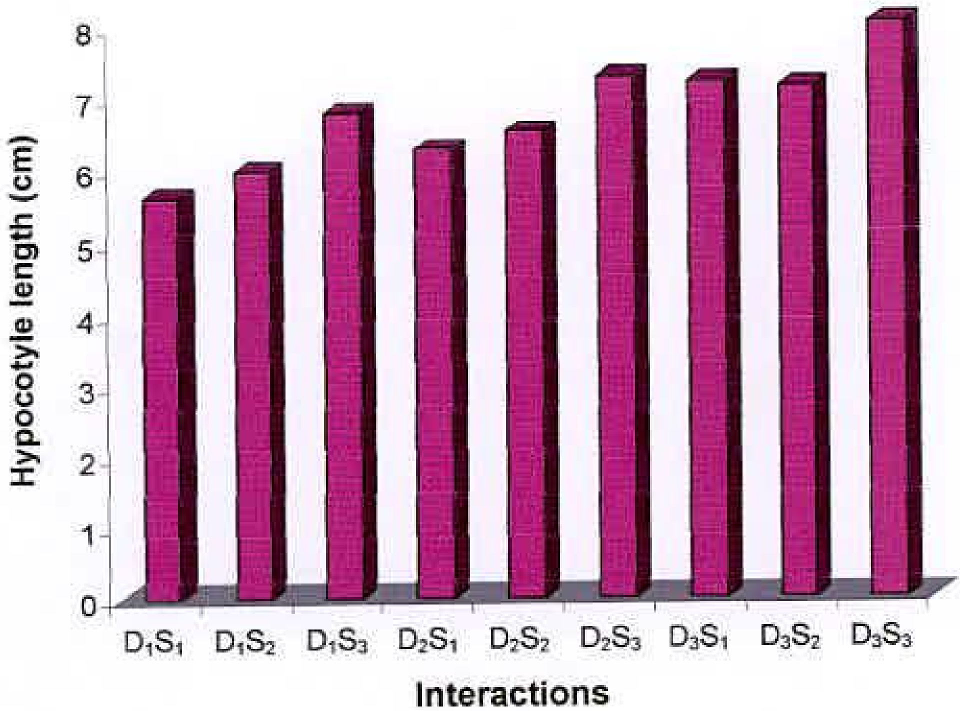

Fig. 11 Interaction effect of sowing depth and seed size on the hypocotyle length of mungbean seedlings ($LSD_{0.05}$ = 0.36 cm)

4.5 Seedling root fresh weight

Results of root fresh weight was presented Fig. 12, Fig. 13 and Fig. 14. The root fresh weight of mungbean seedlings ranged from 0.07-0.11 g plant^{-1} at 15 DAS. The root fresh weight at harvest ranged from 0.08-0.11 g plant^{-1}.

4.5.1 Effect of sowing depth

The sowing depth had significant effect on root fresh weight (Fig. 12). Root fresh weight increased with the increase of seeding depth. Significantly the maximum root fresh weight (0.11 gplant^{-1}) was shown by the largest (6 cm) depth and the minimum root fresh weight was shown by the smallest (2 cm) depth.

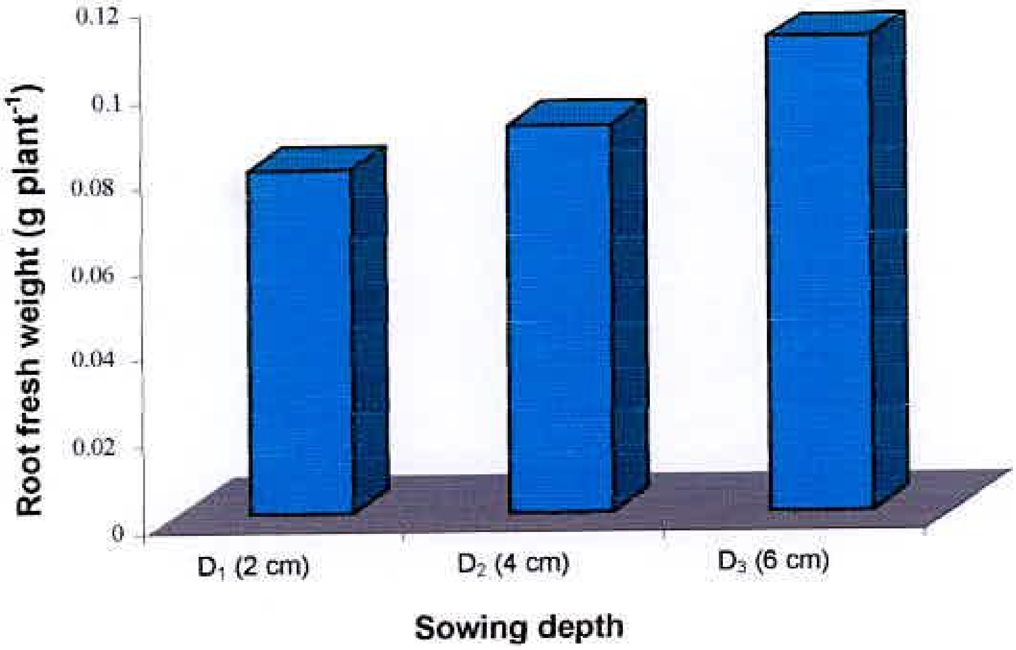

Fig. 12 Root fresh weight of mungbean seedlings as influenced by sowing depth ($LSD_{0.05}$ = 0.001 g)

4.5.2 Effect of seed size

The seed size had significant effect on root fresh weight. At 15 DAS root fresh weight was found to be increased with the increasing rate of seed size (Fig. 13). Significantly the maximum root fresh weight (0.11 g plant^{-1}) was obtained from S_3 and the lowest root fresh weight (0.08 g plant^{-1}) was obtained from the S_1.

Longer *et al.* (1986) reported that large seeds had greater root fresh weight accumulation than ungraded and small seeds.

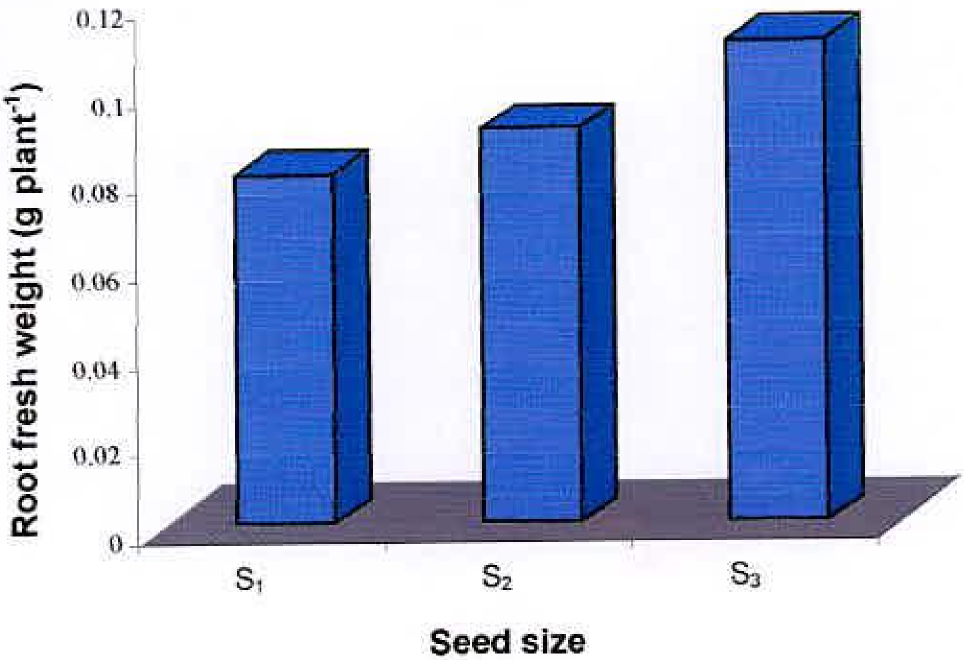

Fig. 13 Root fresh weight of mungbean seedlings as influenced by seed size ($LSD_{0.05}$ = 0.004 g)

4.5.3 Interaction effect of sowing depth and seed size

The root fresh weight was significant by differed due to interaction of sowing depth and seed size(Fig. 14). At 15 DAS, it was observed that at a certain sowing depth, root fresh weight increased with the increase in seed size except at 6 cm depth. The maximum root fresh weight (0.11g $plant^{-1}$) was found in deeper depth irrespective of their seed size along with D_2S_3. The minimum root fresh weight was found in D_1S_1 (0.07 g $plant^{-1}$) interaction.

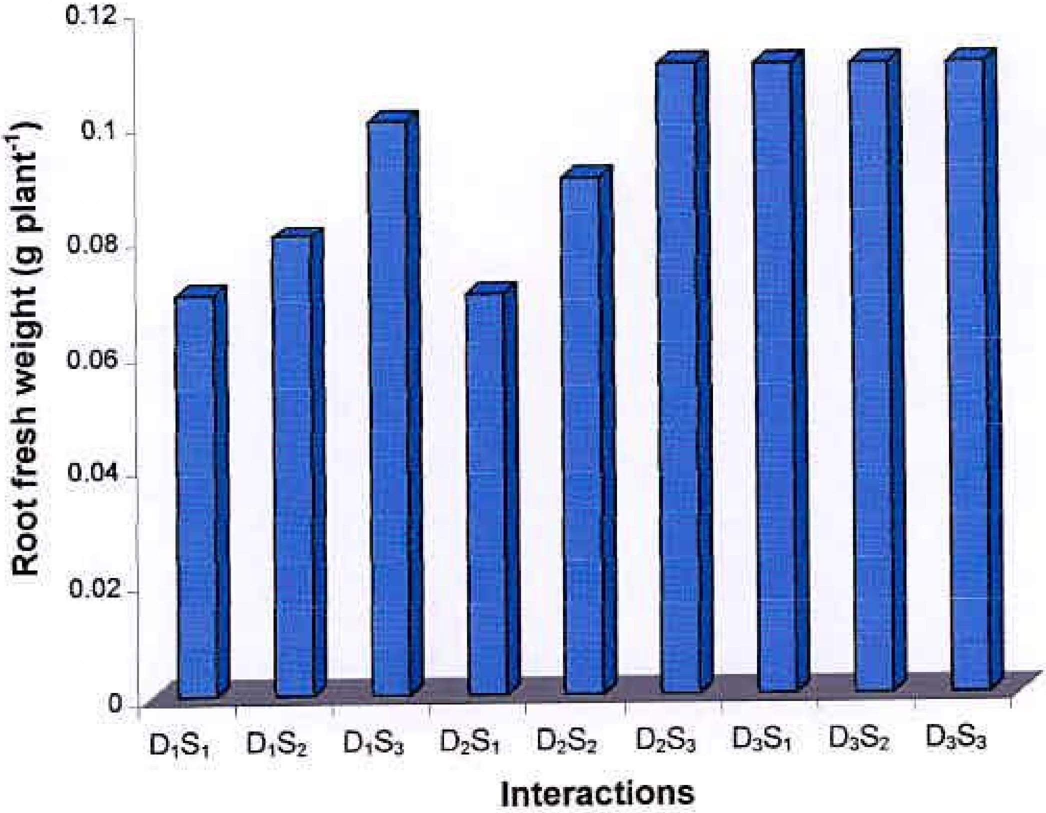

Fig. 14 Interaction effect of sowing depth and seed size on the root fresh weight of mungbean seedlings ($LSD_{0.05}$ = 0.003 g)

4.6. Seedling Shoot fresh weight

Result of shoot fresh weight was presented in Fig. 15, 16 and 17. The shoot fresh weight of mungbean ranged from 0.21 - 0.38 g plant^{-1} at 15 DAS.

4.6.1 Effect of sowing depth

The sowing depth had no significant effect on shoot fresh weight at 15 DAS (Fig. 15). The shoot fresh weight increased with the increase of seeding depth. The shoot fresh weight ranged from 0.24-0.36 g plant^{-1}. The maximum shoot fresh weight (0.36 g plant^{-1}) was shown by the large (6 cm) depth. The minimum shoot fresh weight was shown by the smallest (2 cm) depth.

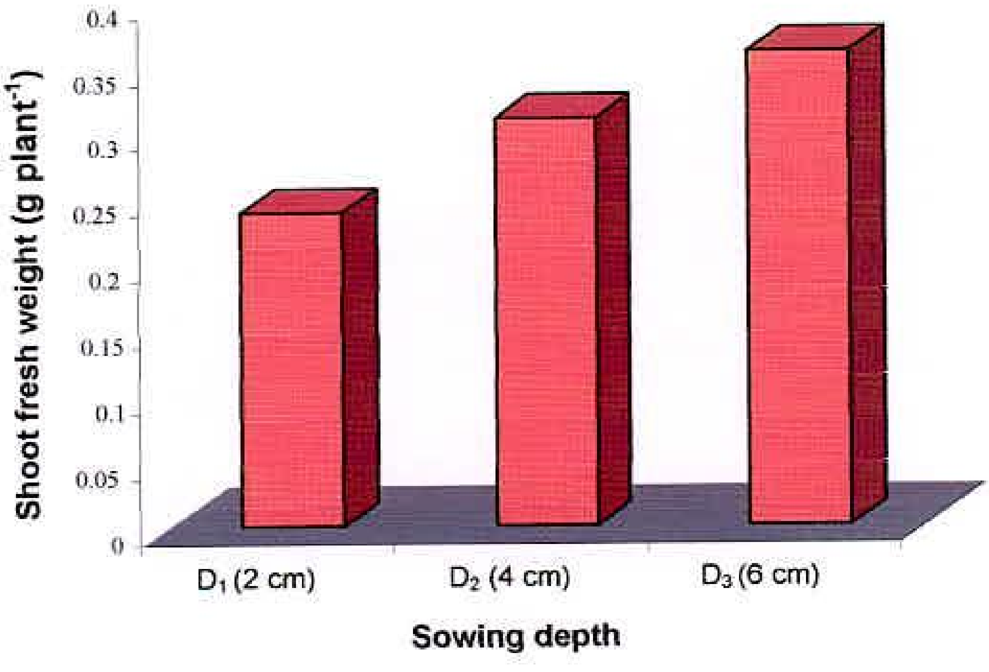

Fig. 15 Shoot fresh weight of mungbean seedlings as influenced by sowing depth ($LSD_{0.05}$ = 0.007 g)

4.6.2 Effect of seed size

At 15 DAS the shoot fresh weight was found to be increased with the increase of seed size(Fig.16). The seed size had no significant effect on shoot fresh weight though the maximum shoot fresh weight (0.33 g plant^{-1}) was obtained from S_3. The minimum shoot fresh weight (0.28 g plant^{-1}) was obtained from the S_1. Longer *et al.* (1986) reported that large seeds had a greater shoot fresh weight accumulation than upgraded and small seeds.

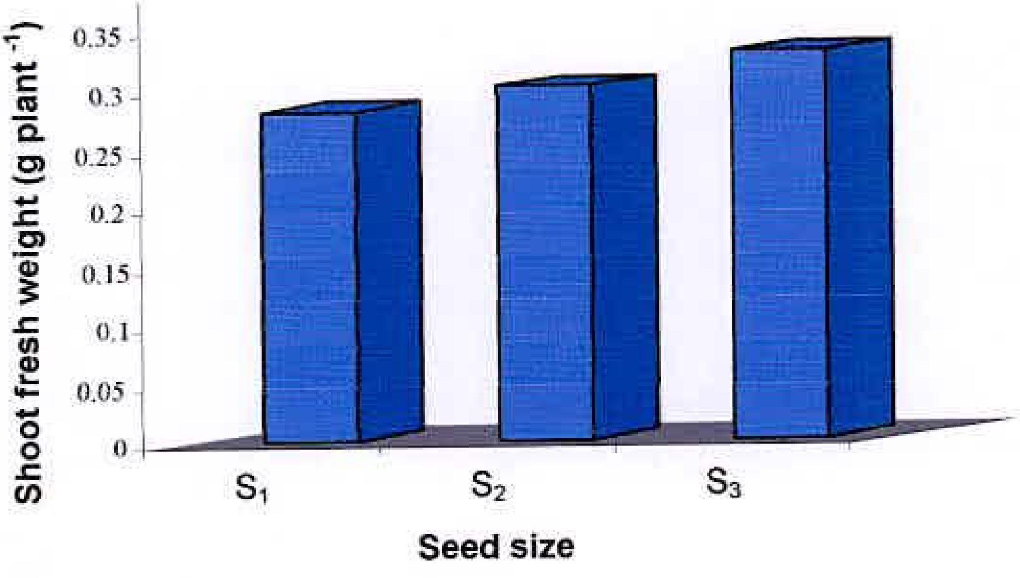

Fig. 16 Shoot fresh weight of mungbean seedlings as influenced by seed size ($LSD_{0.05}$ = 0.003 g)

4.6.3 Interaction effect of sowing depth and seed size

The difference of shoot fresh weight among the treatments was significant due to interaction of sowing depth and seed size (Fig. 17). At 15 DAS, it was observed that at a certain sowing depth, shoot fresh weight increased with the increase in seed size. The highest shoot fresh weight (0.38 g plant^{-1}) was found in D_3S_3 which was similar to D_1S_3, D_2S_1, D_2S_2, D_2S_3, D_3S_1 and D_3S_2. The lowest shoot fresh weight was found in D_1S_1 (0.21 g plant^{-1}).

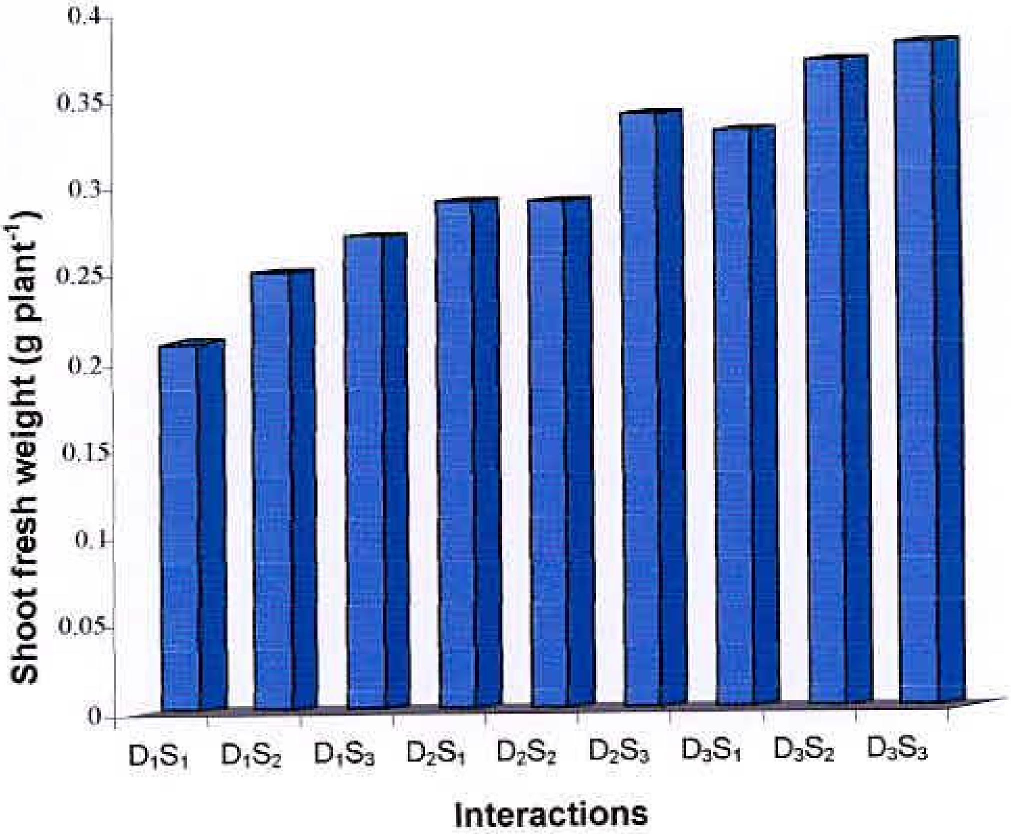

Fig. 17 Interaction effect of sowing depth and seed size on the shoot fresh weight of mungbean seedlings ($LSD_{0.05}$ = 0.001 g)

4.7 Total fresh weight

Results of total fresh weight was presented in Fig. 18, Fig. 19 and Fig. 20. The total fresh weight of mungbean ranged from 0.28-0.48 g plant^{-1} at 15 DAS.

4.7.1 Effect of sowing depth

The sowing depth had no significant effect on total fresh weight at 15 DAS (Fig. 18) though the total fresh weight increased with the increase of seeding depth. The maximum total fresh weight (0.46 g $plant^{-1}$) was shown by the large (6 cm) depth. The minimum total fresh weight (0.32 g $plant^{-1}$) was shown by the smallest (2 cm) depth.

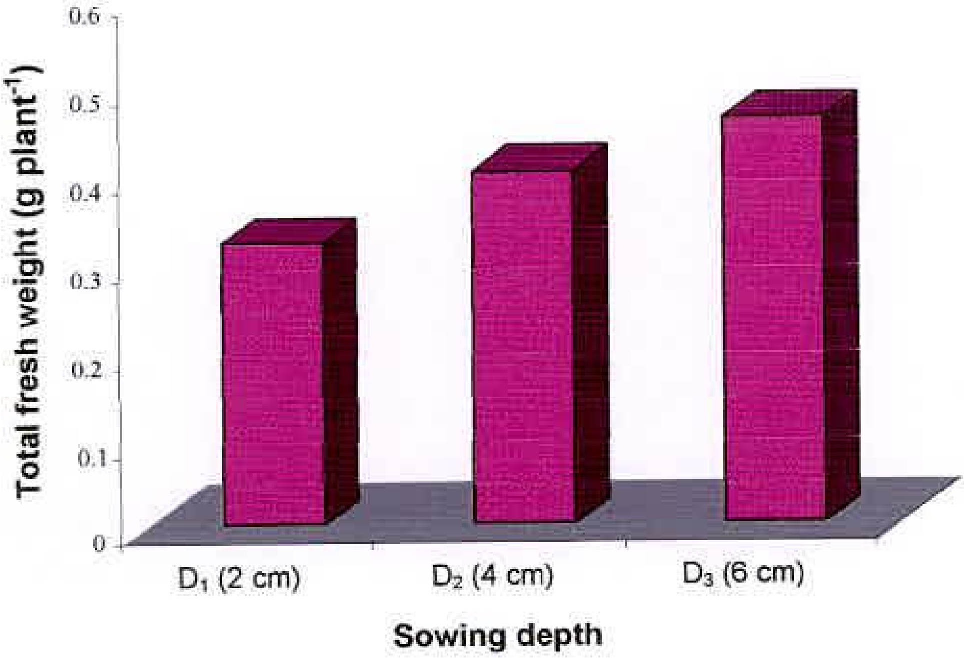

Fig. 18 Total fresh weight of mungbean seedlings as influenced by sowing depth ($LSD_{0.05}$ = 0.001 g)

4.7.2 Effect of seed size

At 15 DAS the total fresh weight was found to be increased with the increase of seed size (Fig. 19). The seed size had no significant effect on total fresh weight $plant^{-1}$ though the maximum total fresh weight (0.43 g $plant^{-1}$) was obtained from S_3 and the minimum total fresh weight (0.36gplant^{-1}) was obtained from the S_1. Longer *et al.* (1986) reported that large seeds had a greater shoot and root fresh weight accumulation than ungraded and small seeds.

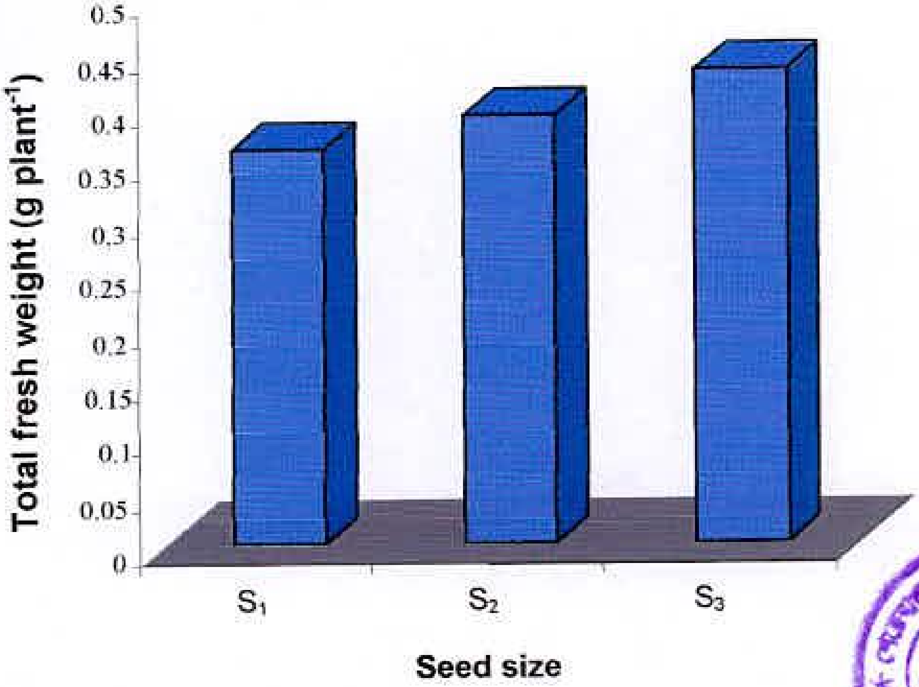

Fig. 19 Total fresh weight of mungbean seedlings as influenced by seed size ($LSD_{0.05}$ = 0.001 g)

4.7.3 Interaction effect of sowing depth and seed size

The total fresh weight among the treatments was not significant due to interaction of sowing depth and seed size (Fig. 20). At 15 DAS, it was observed that at a certain sowing depth, shoot fresh weight increased with the increase in seed size. The maximum total fresh weight (0.48 g plant^{-1}) was found in D_3S_3 and the maximum total fresh weight was found in D_1S_1 (0.28 g plant^{-1}).

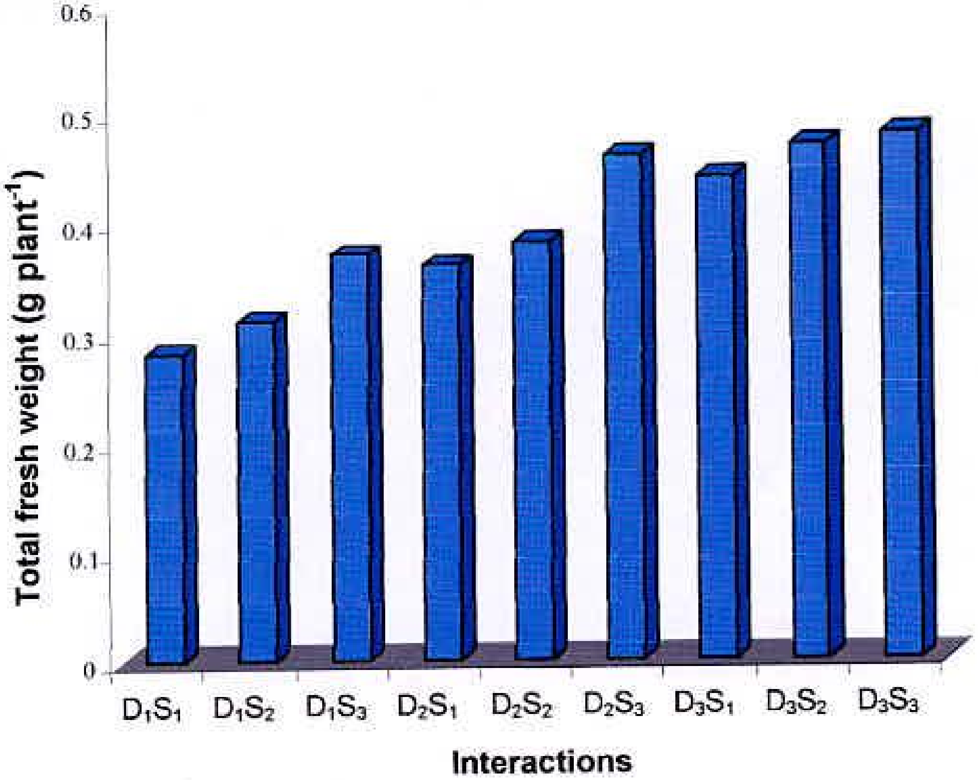

Fig. 20 Interaction effect of sowing depth and seed size on the Shoot fresh weight of mungbean seedlings ($LSD_{0.05}$ = 0.003 g)

4.8.Seedling root length.

Results of seedling root length was presented in Fig. 21, 22 and 23. The seedling root length of mungbean ranged from 8.63 - 14.19 cm at 15 DAS.

4.8.1 Effect of sowing depth

The sowing depth had significant effect on seedling root length at 15 DAS (Fig. 21). The seedling root length decreased with the increase of seeding depth. The seedling root length at 15 DAS ranged from 10.81- 13.07 cm. The highest seedling root length (13.07 cm) was shown by the small (2cm) depth. The minimum seedling root length was shown by the largest (6 cm) depth. This was in conformation with the findings of Kabir (2000) who worked on seed size and sowing depth for soybean crop and found that 2 cm depth showed the highest root length.

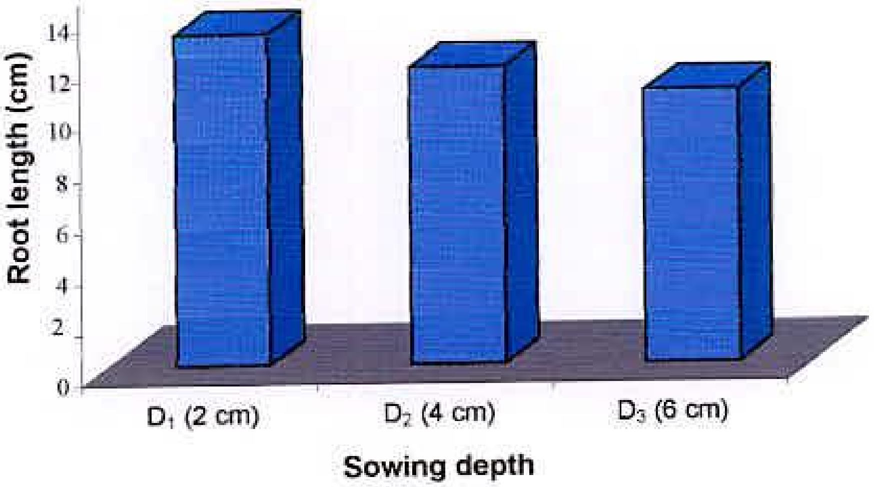

Fig. 21 Root length of mungbean seedlings as influenced by sowing depth ($LSD_{0.05}$= 0.82 cm)

4.8.2 Effect of seed size

At 15 DAS the seedling root length was found to be increased with the increase of seed size up to 4 cm there after it decreased (Fig. 22). The seed size had significant effect on seedling root length plant^{-1}. The highest seedling root length (13.17 cm) was obtained from S_2 which was significantly higher than S_1 and S_3. The lowest seedling root length (10.74 cm) was obtained from the S_1 which was significantly lower than S_2 and S_3. Previous work was in agreement with this result. It was reported that the medium sized seed gave greater root development than the large seed at each soil moisture level where germination occurred (Calton *et al.*, 1971). Seed weight was positively correlated with root length (Babu *et al.*, 1990).

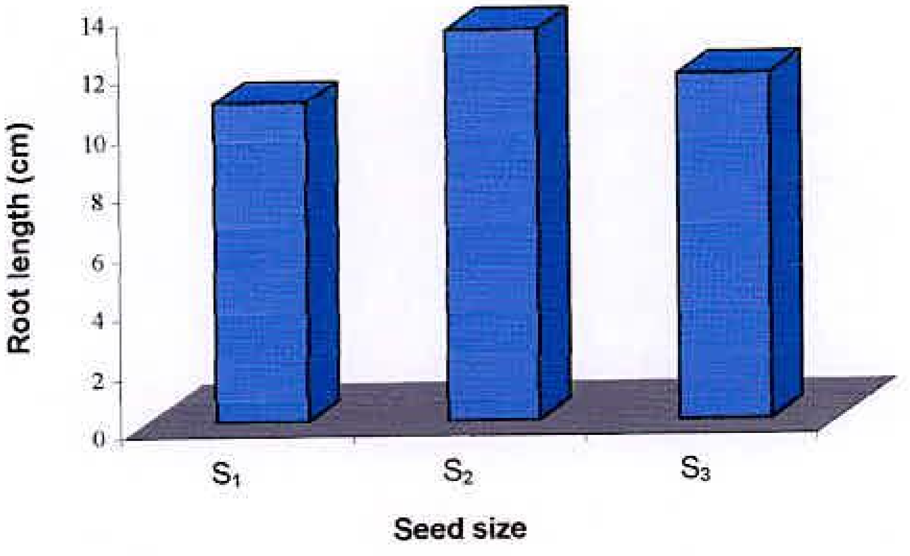

Fig. 22 Root length of mungbean seedlings as influenced by Seed size ($LSD_{0.05}$ = 0.80 cm)

4.8.3 Interaction effect of sowing depth and seed size

The seedling root length was significant due to interaction of sowing depth and seed size (Fig. 23). At 15 DAS, it was observed that at a certain sowing depth, seedling root length increased with the increase in seed size but at 6 cm depth, the largest seed size showed lower value in seedling root length than that by the medium size seed. The highest seedling root length (14.19 cm) was found in

D_1S_3 which was similar to D_1S_2, and D_3S_2. The lowest seedling root length was found in D_3S_1 (9.98 cm). The other interactions showed intermediate seeding root length.

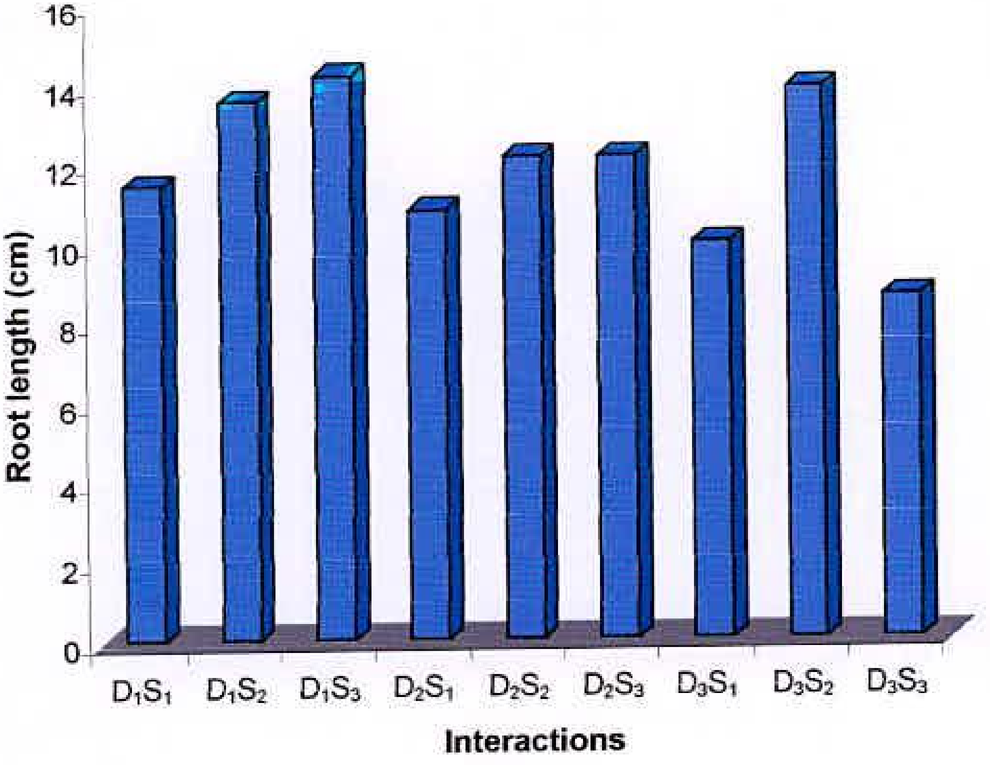

Fig. 23 Interaction effect of sowing depth and seed size on the root length of mungbean seedlings ($LSD_{0.05}$ = 1.38 cm)

4.9 Plant height

Results of plant height at different growth stages have been presented in Table 1. Plant height increased gradually from 15 DAS to harvest. Irrespective of treatment differences, plant height of mungbean ranged from 10.01 - 12.40 cm, 26.58-30.91 cm, 57.39-64.72 cm and 62.42-68.81 cm at 15, 30, 45 DAS and at harvest, respectively.

4.9.1 Effect of sowing depth

The sowing depth had a significant effect on plant height (Table 1). At all the growth stages, plant height increased with the increase of seeding depth up to 4 cm and thereafter it decreased when the seeds were sown at 6 cm depth. The tallest plant was obtained from 4 cm sowing depth and shortest from 6 cm at 30 and at harvest, however at 15 and 45 DAS, 2 cm sowing depth showed shortest plant. The plant height of 4 cm depth was always significantly higher than those of 2 and 6 cm sowing depth. Probably, at the top soil layer (2 cm) there was moisture deficit, while, at the middle layer there was no deficit of soil moisture. From the deep layer (6 cm), the cotyledons might faced physical impediment during emergence. This resulted loss of energy that probably resulted in reduced seedling vigor causing decreased plant height (Silva, 1991).

The result of this study does not agree with that of Kabir (2000) who worked on soybean and found that with increasing the sowing depth, plant height decreased. Probably, the top soil layer had more nutrient than that in the middle or bottom layer. This soil fertility coupled with enough moisture supply helped in increasing the plant height (Peeper *at al.*, 2008).

4.9.2 Effect of seed size

At all the growth stages the plant height was found to be increased with the increasing rate of seed size (Table 1). The tallest plant was obtained from largest seeds and the shortest plant from the smallest one.

At all the growth stages, significantly the maximum plant height was shown by largest seed size. However, at harvest, the largest seed size showed similar plant height with the medium size seed. But there was no significant difference observed between the medium and large as well as small size seed. Significantly, the minimum plant height was always seen with the smallest seed size at 15, 30, 45DAS and at harvest. The reduction in plant height due to the reduction in seed size of this study was in agreement with the finding of Ponnuswamy (1985). The reason behind the increasing height of seedlings produced from the large seeds was probably due to the availability of relatively more food materials stored and also higher seed vigor of highest seeds. Moreover, presence of larger amount of carbohydrate in the larger cotyledons of the largest seeds might produced more assimilates in the process of photosynthesis.

4.9.3 Interaction effect of sowing depth and seed size

The interaction of seed size and sowing depth had significant effect on plant height (Table 1). At all the growth stages, it was observed that at a certain sowing depth, the plant height increased with the increase in seed size. However, at the deepest sowing depth (6 cm), the plant height increased up to the medium size seeds and thereafter decreased.

At 15 DAS, D_2S_3 showed the highest plant height (12.40 cm). However, there was no significant difference observed among the plant height of D_1S_3 and D_2S_2. D_1S_1 showed the lowest plant height (10.13 cm) which, however, was statistically similar to that of D_2S_1. Most of the other interaction treatments did not show significant difference among them.

At 30 DAS, D_2 S_3 showed the highest plant height (30.91cm). However, there was no significant difference observed among the plants of D_2S_3 with those of D_1S_3 and D_2 S_2. D_1S_1 showed the lowest plant height (26.58 cm) which, however, was not significantly, but lower than that of D_2S_1, D_3S_1 and D_3S_3. Most of the other interaction treatments showed plant height values which were in between the values of the highest and lowest and did not show any significant difference among them.

At 45 DAS, D_2 S_3 showed the highest plant height (64.72cm). That was significantly higher than other interaction treatments. The second highest plant height was D_2S_2 which was not significant to D_2S_1. D_1S_1 showed the lowest plant height (57.39cm) which, however, was statistically similar to D_1S_2. Most of the other interaction treatments did not show any significant difference among themselves.

At harvest, D_2S_3 showed the highest plant height (68.81 cm). However, there was no significant difference observed among the plants of D_1S_3 and D_2S_2. D_3S_3 showed the lowest plant height (62.42 cm). All other interaction treatments showed the plant height values and those were in between the values of the highest and lowest

Table: 1 Effect of sowing depth, seed size and their interaction on plant height of mungbean cv. BARI mung 5 at different growth stages

	Plant height (cm)at different days after sowing			
Treatments	**15**	**30**	**45**	**60**
Sowing depth (D)				
D_1	10.70	28.22	57.99	66.68
D_2	11.47	29.50	62.83	67.71
D_3	10.78	27.54	59.96	64.84
LSD (0.05)	0.67	0.80	1.28	0.65
CV (%)	3.23	5.36	12.35	10.32
Seed size (S)				
S_1	10.12	27.10	59.49	65.79
S_2	11.14	28.64	60.29	66.83
S_3	11.69	29.53	61.00	66.60
LSD (0.05)	0.64	0.67	0.91	0.84
CV (%)	4.25	3.25	10.32	9.32
Interaction (D X S)				
D_1S_1	10.13	26.58	57.39	65.40
D_1S_2	10.36	28.09	58.15	66.07
D_1S_3	11.60	30.00	58.42	68.58
D_2S_1	10.20	27.73	61.10	66.05
D_2S_2	11.82	29.87	62.67	68.27
D_2S_3	12.40	30.91	64.72	68.81
D_3S_1	10.01	26.99	59.97	65.93
D_3S_2	11.25	27.96	60.05	66.16
D_3S_3	11.08	27.67	59.87	62.42
LSD (0.05)	**1.10**	**1.15**	**1.58**	**1.45**
CV (%)	4.25	3.25	10.32	9.32

D_1 = 2 cm, D_2 = 4 cm, D_3 = 6 cm; S_1 = < 3.2 mm, S_2 = 3.2 to 4 mm, S_3 = > 4 mm

and they did not show any significant difference among themselves. The result of this study agreed with that of Kabir (2000) who worked on soybean and found that medium size seed produced the maximum plant height when sown in 4 cm depth.

4.10 Leaf dry weight

Results of dry weight of leaf have been presented in Table 2. The dry weight of leaf increased gradually up to harvest. Irrespective of treatment differences, dry weight of leaf of mungbean ranged from 0.069-0.111 g, 0.778-1.504 g , 3.336-5.349 g and 4.870-5.585 g at 15, 30, 45 DAS and at harvest, respectively.

4.10.1 Effect of sowing depth

The sowing depth had a significant effect on dry weight of leaf (Table 2). At all the growth stages, dry weight increased with the increase of seeding depth up to 4 cm and thereafter it decreased when the seeds were sown at 6 cm depth. Higher dry weight was obtained from 4 cm sowing depth and lower dry weight from 2 cm depth at 45 DAS but at 15, 30 DAS and at harvest there was no significant difference observed among 2, 4 and 6 cm depth.

4.10.2 Effect of seed size

At all the growth stages the dry weight of leaf was found to be increased with the increasing rate of seed size. The seed size had significant effect on the dry weight (Table 2). At 15 and 45 DAS where maximum dry weight of leaves was shown by largest seed size but at 30 DAS and at harvest there was no significant difference observed among S_1, S_2 and S_3. At 15 DAS and 45 DAS, S_3 showed significantly highest leaf dry weight that was similar to S_2. The lowest leaf dry weight was observed in smaller seed size.

4.10.3 Interaction effect of sowing depth and seed size

The interaction had significant effect on dry weight of leaf (Table 2). At all the growth stages, it was observed that at a certain sowing depth, the dry weight increased with the increase in seed size however, at the deepest sowing depth (6 cm), the dry weight increased up to the medium sized seed and thereafter decreased with the increase of seed size though there were no significant difference observed for medium and larger seed size at deeper sowing depth.

At 15 DAS, D_3S_2 showed the highest leaf dry weight (0.111 g plant^{-1}). However, there was no significant difference observed among the dry weight of D_3S_2, D_1S_3, D_2S_3 and D_3S_3. D_1S_1 showed the lowest leaf dry weight (0.069g plant^{-1}). This however, was statistically similar to D_1S_2, D_2S_1 and D_3S_1.

At 30 DAS, D_2S_3 showed the highest dry weight (1.504g plant^{-1}). However, there was no significant difference observed between the dry weight of D2S2 and D_2S_2. D_3S_1 showed the lowest dry weight (0.778g plant^{-1}) which was statically similar to D2S1 and D1S1. The other interaction treatments did not show significant differences among them in this respect.

At 45 DAS, D_2S_3 showed the highest dry weight (5.349g $plant^{-1}$) which was significantly higher than other interaction. The second highest interaction

Table : 2 Effect of sowing depth, seed size and their interaction on leaf dry matter of mungbean cv. BARI mung 5 at different growth stages.

	Leaf dry matter (g)at different days after sowing			
Treatments	**15**	**30**	**45**	**At harvest**
Sowing depth(D)				
D_1	0.086	1.038	3.736	5.148
D_2	0.095	1.246	4.545	5.326
D_3	0.086	1.014	4.328	5.003
LSD (0.05)	NS	NS	**0.182**	NS
CV (%)	5.36	6.52	8.79	11.02
Seed size (S)				
S_1	0.077	0.818	3.560	4.935
S_2	0.092	1.230	4.297	5.146
S_3	0.098	1.249	4.745	5.396
LSD (0.05)	**0.012**	NS	**0.197**	NS
CV (%)	4.56	3.25	14.23	11.23
Interaction (D X S)				
D_1S_1	0.069	0.833	3.336	4.877
D_1S_2	0.087	1.137	3.617	4.986
D_1S_3	0.101	1.144	4.257	5.579
D_2S_1	0.083	0.844	3.571	5.058
D_2S_2	0.097	1.391	4.716	5.337
D_2S_3	0.105	1.504	5.349	5.585
D_3S_1	0.084	0.778	3.773	4.870
D_3S_2	0.111	1.163	4.557	5.115
D_3S_3	0.106	1.100	4.655	5.024
LSD (0.05)	NS	**0.156**	**0.351**	**0.971**
CV (%)	4.56	3.25	14.23	11.23

D_1 = 2 cm, D_2 = 4 cm, D_3 = 6 cm; S_1 = < 3.2 mm, S_2 = 3.2 to 4 mm, S_3 = > 4 mm

was D_2S_2 (4.716 g plant^{-1}) which had no significant difference to treatments D_3S_3 and D_3S_2. D_1S_1 showed the lowest dry weight (3.336 g plant^{-1}) which was similar to those of D_1S_2, D_2S_1 and D_3S_1 treatments.

At harvest, D_2S_3 showed the maximum dry weight (5.585g plant^{-1}) which had no statistical difference with other treatments. Numerically minimum dry weight (4.87 g plant^{-1}) was recorded from D_3S_1.

4.11. Stem dry weight

Results of dry weight of stem of mungbean was presented in Table 3.The dry weight of stem increased gradually up to the harvest. Irrespective of treatment differences, dry weight of mungbean stem ranged from 0.022-0.031g, 0.440-0.77 g, 1.260-2.553 g and 4.170-5.300 g plant^{-1} at 15, 30, 45 DAS and at harvest, respectively.

4.11.1 Effect of sowing depth

The sowing depth had no significant effect on dry weight of stem (Table 3). At all the growth stages, the numerically maximum dry weight observed with the increasing of seeding depth up to 4 cm and thereafter it decreased when the seeds were sown at 6 cm. The higher dry weight was obtained with 4cm depth and lower dry weight was obtained from the 2 cm depth at all the growing stages.

This was in conformation with the findings of Kabir (2000) who worked on seed size and sowing depth of soybean and reported that 2 cm depth showed the highest stem dry weight.

4.11.2 Effect of seed size

At all the growth stages, the dry weight of stem was not found to increased with the increase of seed size except at harvest (Table 3). At harvest the highest dry weight of stem was obtained from S_3 seeds and the lowest dry weight was obtained from S_1 seed size.

A similar influence of seed size on shoot dry matter production was evident from the studies of Babu and Rao (1985) and Sivasubramanian and Ramakrishnan (1974).Increased shoot dry matter from large seeds might be due to higher vigor of the plant. Earlier establishment of photosynthetic activity and greater shoot area increased the accumulation of dry matter in the shoots of seedlings raised from large seeds.

4.11.3 Interaction effect of sowing depth and seed size

The interaction treatments had significant effect on stem dry weight at 45 DAS and at harvest (Table 3). At 15 DAS, D_2S_3 showed the numerically highest stem dry weight (0.031 g plant^{-1}). D_1S_1 showed the minimum (0.022 g plant^{-1}) dry weight. Similar trend of stem dry weight also observed at 30 DAS.

At 45 DAS, D_2S_3 showed the highest dry weight (2.55g plant^{-1}) which was significantly differed from other treatments. The second highest stem dry weight was in D_3S_2 (1.88 g plant^{-1}) which was not significantly differed to D_2S_2 and D_3S_3. D_1S_1 showed the lowest dry weight (1.26 g plant^{-1}) which was similar to

Table :3 Effect of sowing depth, seed size and their interaction on stem dry matter of mungbean cv. BARI mung 5 at different growth stages

Treatments	Stem dry weight (g) at different days after sowing			
	15	30	45	At harvest
Sowing depth (D)				
D_1	0.02	0.55	1.39	4.36
D_2	0.03	0.60	1.92	4.58
D_3	0.03	0.53	1.69	4.38
LSD (0.05)	NS	NS	NS	NS
CV (%)	4.23	5.69	9.63	16.25
Seed size (S)				
S_1	0.02	0.48	1.32	4.25
S_2	0.03	0.58	1.67	4.39
S_3	0.03	0.60	2.00	4.69
LSD (0.05)	NS	NS	NS	**0.18**
CV (%)	10.25	12.32	3.65	8.89
Interaction (D X S)				
D_1S_1	0.02	0.44	1.26	4.21
D_1S_2	0.02	0.58	1.28	4.17
D_1S_3	0.03	0.63	1.63	4.70
D_2S_1	0.02	0.45	1.34	4.33
D_2S_2	0.03	0.64	1.87	4.50
D_2S_3	0.03	0.69	2.55	4.90
D_3S_1	0.02	0.56	1.37	4.20
D_3S_2	0.03	0.53	1.88	4.49
D_3S_3	0.03	0.49	1.82	4.46
LSD (0.05)	NS	NS	**0.16**	**0.32**
CV (%)	10.25	12.32	3.65	8.89

D_1 = 2 cm, D_2 = 4 cm, D_3 = 6 cm; S_1 = < 3.2 mm, S_2 = 3.2 to 4 mm, S_3 = > 4 mm

D_1S_2, D_2S_1 and D_3S_1. Rest other interactions showed intermediate values with no significant difference among themselves.

At harvest, D_2S_3 showed the highest dry weight (4.90g plant^{-1}) which was statistically similar to D_1S_3. D_1S_2 showed the lowest dry weigh (4.17g plant^{-1}) which was not significantly differed to D_1S_1 D_2S_1, D_3S_2, D_3S_2 and D_3S_3 in interactions.

The result of this study partially agree with that of Kabir (2000) who reported that medium size seed produced the maximum stem dry weight when sown in 2-4 cm depth of soil.

4.12 Root dry weight

Results of root dry weight of mungbean have been presented in Table 4. The dry weight of root increased gradually from 15 DAS to harvest. Irrespective of treatment difference, root dry weight ranged from 0.01-0.02g, 0.17-0.25g, 0.68-1.12 g and 2.09-2.54 g at 15, 30, 45 DAS and at harvest.

4.12.1 Effect of sowing depth

At all the growth stages, root dry weight increased numerically with the increasing of seeding depth up to 4 cm and thereafter it decreased when the seeds were sown in 6 cm depth. The maximum dry weigh was obtained with 4cm depth and minimum from 2 cm depth at all the growing stages. There was no significant differences as was observed among 2 cm, 4 cm and 6 cm depth for root dry weight at all the growth stages studied.

4.12.2 Effect of seed size

At all the growth stages the dry weight of root was found to be increased with the increase of seed size (Table 4). The seed size had significant effect on the dry weight of root at harvest. The highest dry weigh was obtained with S_3 seeds and lowest dry weight was obtained from the S_1.

At all the growth stages, numerically the maximum dry weight of roots was shown by S_3 seed size but there was no significant difference among S_1, S_2 and S_3 at all the growth stages except at harvest. At harvest, the largest seed size showed significantly the highest value in root dry weight (2.40 g plant^{-1}) that was similar to S_2 (2.34 g plant^{-1}).The lowest dry weight (2.18 g plant^{-1}) was given by the smallest seed size.

4.12.3 Interaction effect of sowing depth and seed size

The interaction treatments had no significant effect on dry weight of root except at harvest (Table 4). At 15 DAS, D_2S_2 showed a numerically the highest dry weight (0.02 g plant^{-1}). Similar value of dry weight in D_2S_3 was found at 30 and 45 DAS.

At harvest, D_1S_3 showed the highest dry weight (2.54 g plant^{-1}). That was statistically similar to treatments D_2S_3 and D_3 S_2. D_1S_1 showed the lowest dry weight (2.09g plant^{-1}) which was similar to D_2S_1 and D_3S_1.The other treatments showed intermediate root dry weight which had no significant difference among themselves.

Table: 4 Effect of sowing depth, seed size and their interaction on root dry matter of mungbean cv. BARI mung 5 at different growth stages

Treatments	Root dry matter (g) at different days after sowing			
	15	30	45	At harvest
Sowing depth (D)				
D_1	0.01	0.19	0.76	2.31
D_2	0.01	0.23	0.95	2.31
D_3	0.01	0.22	0.88	2.30
LSD (0.05)	NS	NS	NS	NS
CV (%)	8.36	3.69	4.32	3.25
Seed size (S)				
S_1	0.01	0.19	0.82	2.18
S_2	0.01	0.23	0.85	2.34
S_3	0.01	0.23	0.93	2.40
LSD (0.05)	NS	NS	NS	**0.11**
CV (%)	5.36	9.36	14.26	10.16
Interaction (S X D)				
D_1S_1	0.01	0.17	0.68	2.09
D_1S_2	0.01	0.21	0.73	2.29
D_1S_3	0.01	0.21	0.86	2.54
D_2S_1	0.01	0.19	0.80	2.27
D_2S_2	0.01	0.25	0.93	2.30
D_2S_3	0.02	0.25	1.12	2.36
D_3S_1	0.01	0.20	0.96	2.17
D_3S_2	0.01	0.23	0.88	2.43
D_3S_3	0.01	0.22	0.80	2.30
LSD (0.05)	NS	NS	NS	**0.19**
CV (%)	5.36	9.36	14.26	10.16

D_1 = 2 cm, D_2 = 4 cm, D_3 = 6 cm; S_1 = < 3.2 mm, S_2 = 3.2 to 4 mm, S_3 = > 4 mm

4.13. Inflorescence dry weight

Results of dry weight of inflorescence have been presented in Fig. 24, Fig. 25 and Fig. 26. The dry weight of inflorescence increased gradually from 15 DAS to harvest. Irrespective of treatment differences, dry weight of inflorescence of mungbean ranged from 0.15-0.43g and 9.54-12.84g at 45 DAS and at harvest, respectively.

4.13.1 Effect of sowing depth

The dry weight of inflorescence increased with the increasing of seeding depth up to 4 cm and thereafter it decreased when the seeds were sown at 6 cm(Fig. 24). The highest dry weight was obtained with 4cm depth and lowest dry

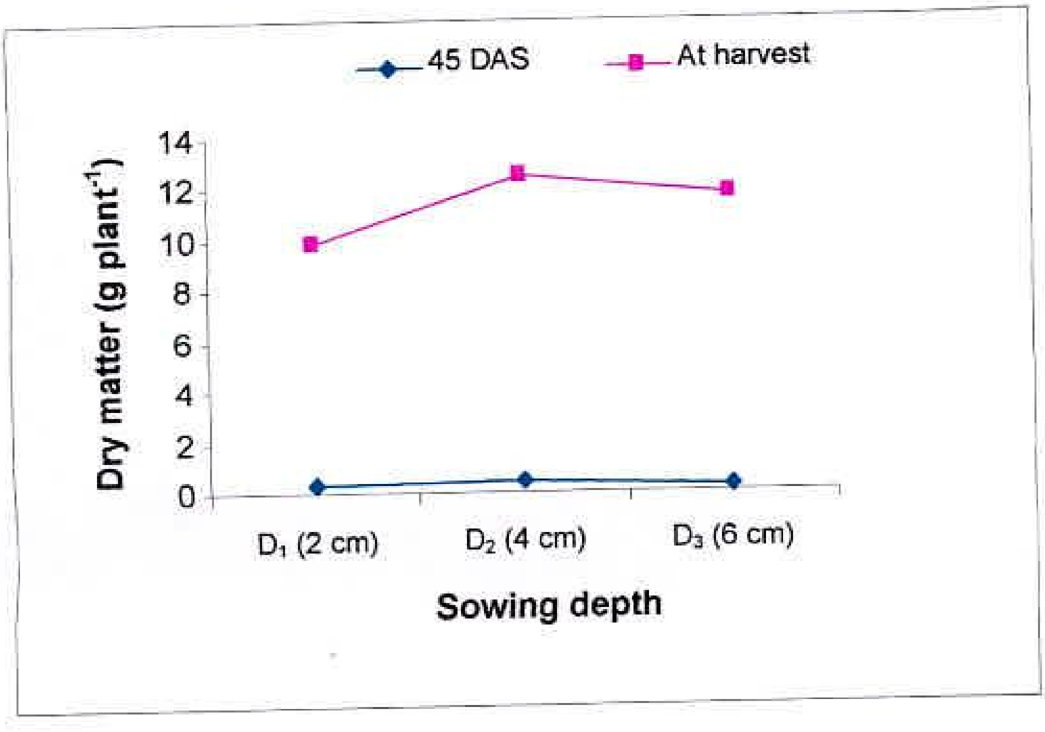

Fig. 24 Inflorescence weight of mungbean as influenced by sowing depth ($LSD_{0.05}$ = NS and 0.58 at 45 DAS and at harvest, respectively)

weight at 2 cm depth. There was no significant differences observed among 2cm, 4cm and 6 cm depth at 45 DAS. However at harvest 4 cm depth showed significantly highest dry weight (12.44 g plant^{-1}) and the lowest inflorescence dry weight (9.92 g plant^{-1}) was given by 2 cm sowing depth.

4.13.2 Effect of seed size

The dry weight of inflorescence was found to be increased with the increasing rate of seed size. The seed size had significant effect on the dry weight of inflorescence (Fig. 25) at harvest where the highest dry weight (11.60 g plant^{-1}) was obtained with S_3 seeds that similar to S_2 (11.34 g plant^{-1}) and the lowest dry weight (11.09 g plant^{-1}) was obtained from the S_1 which was statistically similar to S_2.

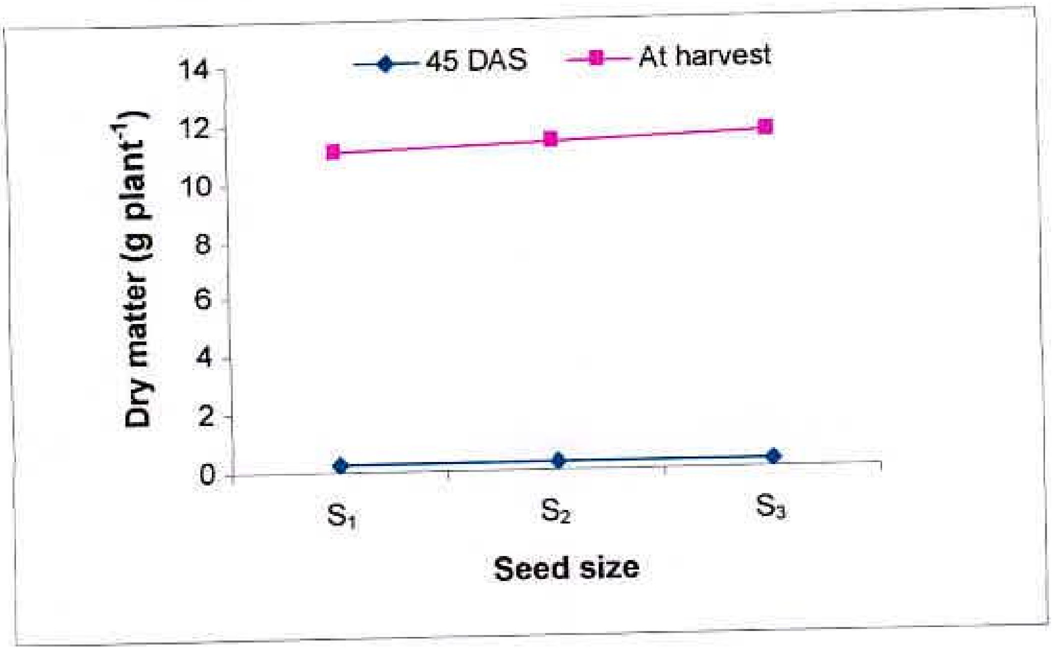

Fig. 25 Inflorescence weight of mungbean as influenced by seed size ($LSD_{0.05}$ = NS and 0.40 g at 45 DAS and at harvest, respectively)

4.13.3 Interaction effect of sowing depth and seed size

The interaction had significant effect on dry weight of inflorescence at harvest (Fig. 26). It was observed that the dry weight increased with the increase in seed size at D_1 and D_2 however, decreased with the increase if seed size at D_3.

At 45 DAS, D_2S_3 showed the maximum dry weight (0.43 g $plant^{-1}$) and D_3S_3 showed minimum dry weight (0.15g $plant^{-1}$). However, there was no significant difference observed among the dry weight of other interaction treatments.

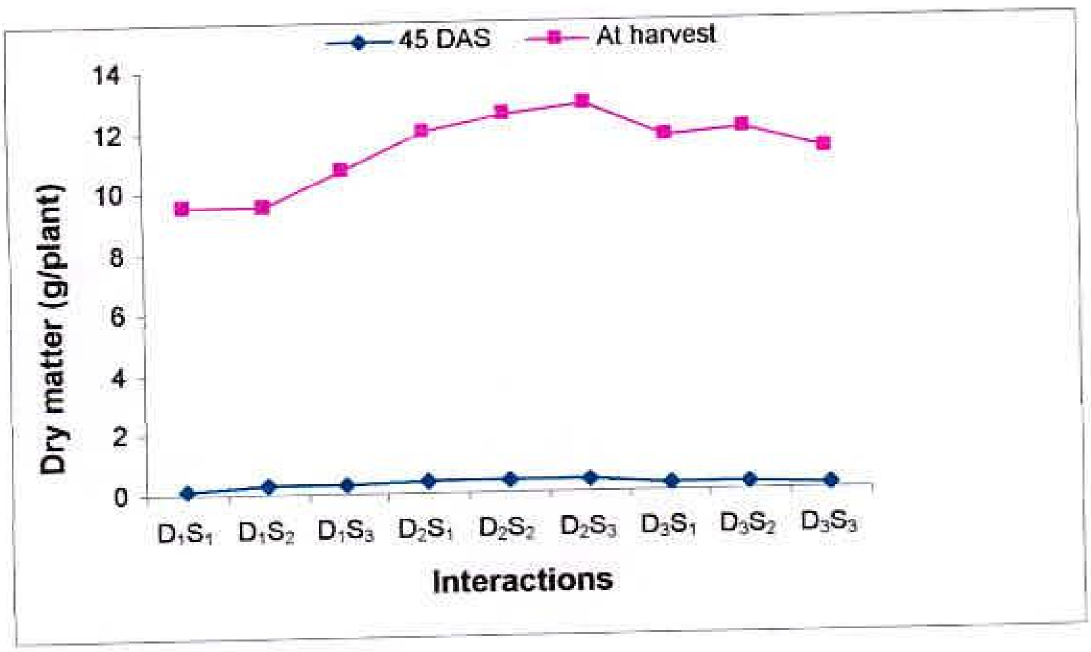

Fig. 26 Interaction effect of sowing depth and seed size on Inflorescence weight of mungbean ($LSD_{0.05}$ = NS and 0.72 g at 45 DAS and at harvest, respectively)

At harvest, D_2S_3 showed the highest dry weight (12.84g plant^{-1}).That was similar to the dry weight of D_2S_2.The second highest dry weight was found in D_2S_1 (12.00 g plant^{-1}) which was not differed with the interaction treatments of D_3S_1 and D_3S_2. D_1S_1 showed the lowest (9.54 g plant^{-1}) dry weight which was not significantly differed D_1S_2 treatment.

4.14. Total dry weight

Results of total dry weight were presented in Fig. 27, Fig. 28 and Fig. 29. It revealed that total dry weight increased gradually up to harvesting. Irrespective of treatment differences, total dry weight of mungbean ranged from 0.10-0.15g, 1.44-2.45 g, 5.46-9.46 g and 20.72-25.69 g at 15, 30, 45 DAS and at harvest, respectively.

4.14.1 Effect of sowing depth

The sowing depth had a significant effect on the total dry weight of mungbean. At all the growth stages, total dry weight was significantly increased with the increase of seeding depth up to 4 cm however, it decrease at 6 cm depth. The highest dry weight was obtained from 4cm sowing depth and lowest dry weight from 2 cm.

At 15 and 30 DAS, there was no significant difference observed among 2,4 and 6 cm sowing depth. At 45 DAS and at harvest significantly the highest dry weight was shown by the 4 cm depth however it decreased at the higher as well as lower sowing depth. The total dry weight of 2 cm depth was always lowest compared to 4cm and 6 cm sowing depth at all the growth stages.

This was in conformation with the findings of Kabir (2000) who work of seed size and sowing depth on soybean and found that 2-4 cm depth showed the highest dry weight.

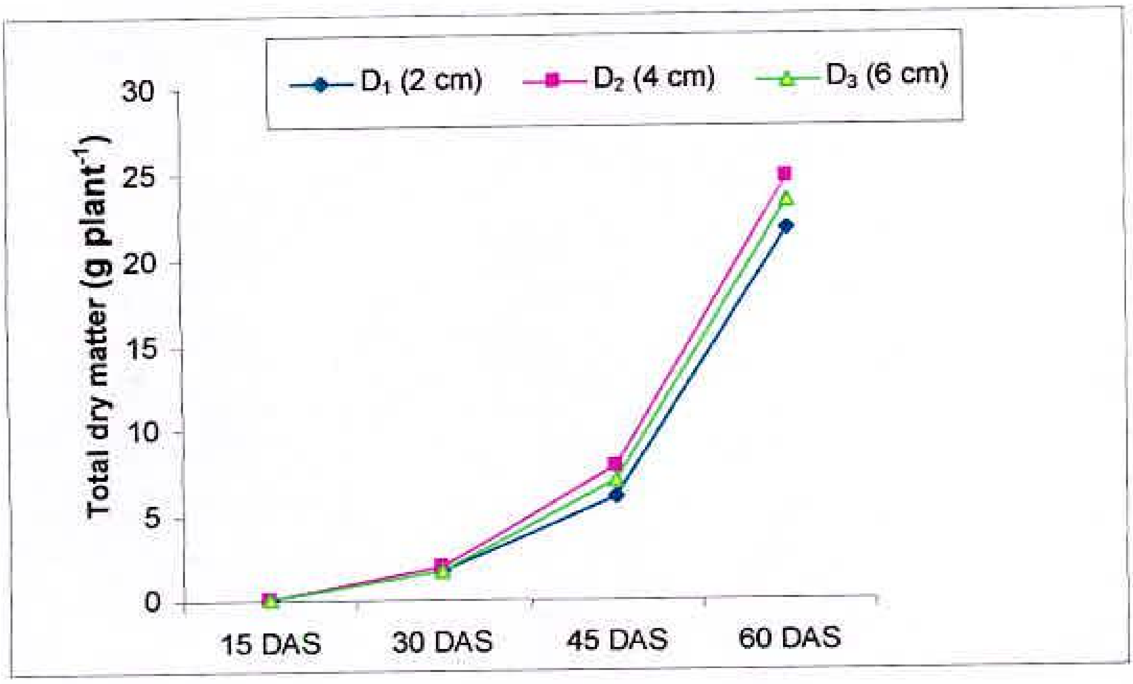

Fig. 27 Total dry weight weight of mungbean as influenced by sowing depth ($LSD_{0.05}$ = NS, NS, 0.42 and 1.02 g at 15, 30 and 45 DAS and at harvest, respectively)

4.14.2 Effect of seed size

At all the growth stages the total dry weight was found to be increased with the increase of seed size. The seed size had significant effect on the total dry weight. The highest dry weight was obtained with S_3 seeds and lowest dry weight was in S_1.

At 45 DAS and at harvest, significantly the maximum total dry weight was shown by S_3 and lowest dry weight was shown in S_1 but there was no significant difference observed between S_1 and S_2at harvest. At 15 and 30 DAS there was no significant difference in dry weight among S_1, S_2 and S_3.The minimum dry weight was always revealed with the smallest seed size.

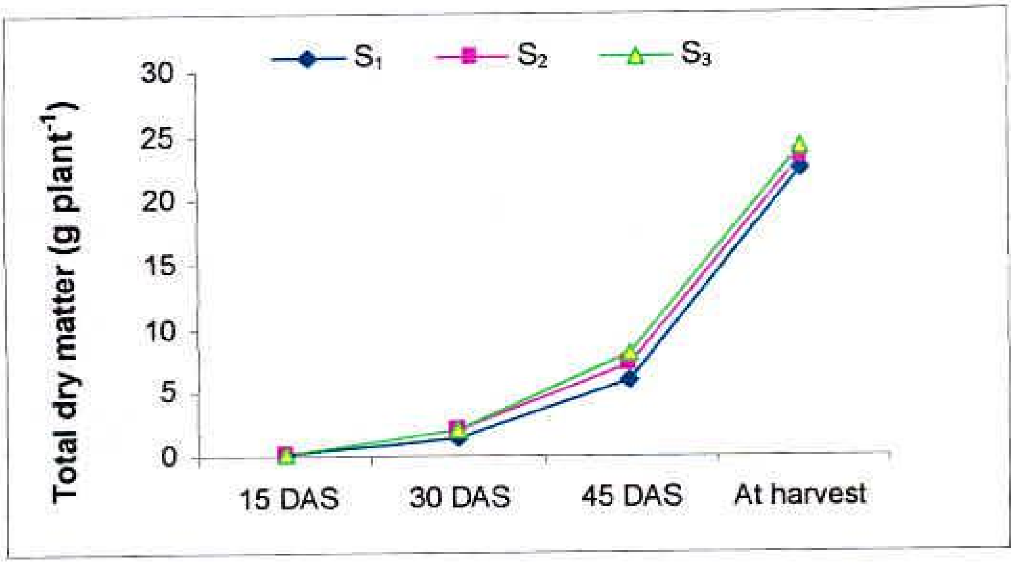

Fig. 28 Total dry weight weight of mungbean as influenced by seed size ($LSD_{0.05}$ = NS, NS, 0.20 and 0.78 g at 15, 30 and 45 DAS and at harvest, respectively)

A similar influence of seed size on total dry matter production was evident from the studies of Kler and Dhillon (1983), Hammes (1969) and Sharma (1976) in Soybean and Maize. Increased total dry matter from large seeds was due to vigorous growth of the plant earlier establishment of photosynthetic activity and greater shoot area increased the accumulation of total dry matter in the seedlings raised from large seeds.

4.14.3 Interaction effect of sowing depth and seed size

The treatment had significant effect on total dry weight. At all the growth stages, it was observed that at a certain sowing depth, the total dry weight increased with the increase in seed size up to the depth of 4 cm and decreased thereafter.

At 15 DAS, D_2S_3 showed the maximum dry weight (0.15 g plant^{-1}). However, there was no significant difference observed among the dry weights of other interactions. D_1S_1 showed the minimum (0.10 g plant^{-1}) dry weight which was lower than other interaction treatments.

At 30 DAS, D_2S_3 showed the highest dry weight (2.45g plant^{-1}) that was statistically similar to the dry weights of D_2S_2. D_1S_1 showed the lowest dry weight (1.44 g plant^{-1}) which was statistically similar to D_2S_1, D_3S_1 and D_3S_3. The other treatments showed intermediate dry matter production.

At 45 DAS, D_2S_3 showed significantly the highest dry weight (9.46 g plant^{-1}). D_2 S_2 showed the second highest dry weight (7.93 g plant^{-1}). D_1S_1 showed the lowest dry weight (5.64 g plant^{-1}) which was similar to D_1S_2, D_2S_1 and D_3S_1.The other treatments showed intermediate value which was not significantly differed among themselves.

At harvest, D_2S_3 showed significantly the highest dry weight (25.69g plant^{-1}). The second highest total dry matter (24.62 g plant^{-1}) was found in D_2S_2.

D_1S_1 showed the lowest dry weight (20.72g plant^{-1}) that was similar to D_1S_2 (21.00 g plant^{-1}).

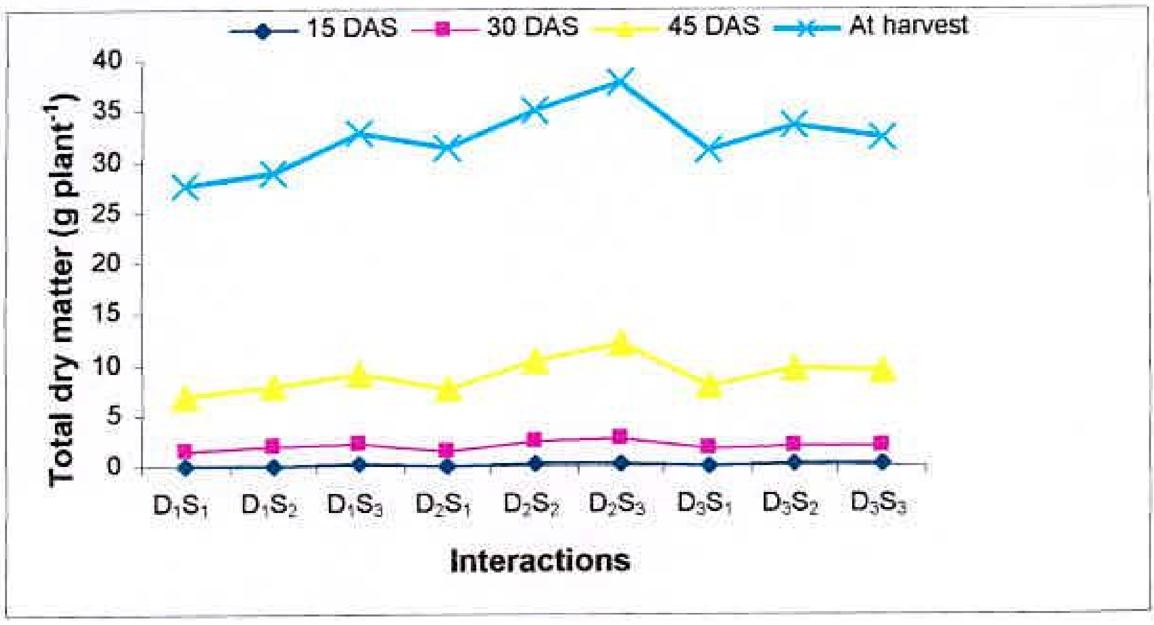

Fig. 29 Interaction effect of sowing depth and seed size on total dry matter of mungbean($LSD_{0.05}$ = NS, 0.17,0.35 and 0.36 g at 15, 30, 45 DAS and at harvest, respectively)

4.15 Number of leaf let plant^{-1}

Results of number of leaflet plant^{-1} was presented in Table 5. The number of leaf let plant^{-1} increased gradually up to harvesting. Irrespective of treatment differences, no of leaflet plant^{-1} of mungbean ranged from 6.33-7.53, 12.20-13.49, 25.30-29.39 at 15, 30, and 45 DAS, respectively.

4.15.1 Effect of sowing depth

The sowing depth had a significant effect on number of leaflet plant^{-1} at 45 DAS (Table 5). At 15 and 30 DAS, numerically the maximum number of leaflet was shown by the medium (4 cm) depth and there was no significant difference observed among the other depth. At 45DAS significantly the highest number of leaflet plant (28.73) was shown at 4cm depth. The lowest number of leaflet plant^{-1} (26.23) was shown by 2 cm depth. The finding was supported by Kabir (2000) who worked on soybean and reported that sowing depth had significant effect on number of leaflet plant^{-1}.

4.15.2 Effect of seed size

At all the growth stages number of leaflet plant^{-1} was found to be increased with the increasing rate of seed size (Table 5). The seed size had significant effect on the number of leaf let plant^{-1}. The highest number of leaflet plant^{-1} was obtained with S_3 and lowest was obtained from the S_1.

At 15 DAS, the maximum number of leaflet plant^{-1} (7.09) was shown by S_3 but there was no significant difference observed among 30 and 45 DAS, the largest seed size (S_3) showed significantly higher number of leaflet plant^{-1} that similar to medium sized seed. At all the growth stages significantly the lowest number of leaflet plant^{-1} was shown in S_1. This was in conformation with the findings of Kabir (2000) who work on soybean and found that large seed showed the highest leaves of soybean.

4.15.3 Interaction effect of sowing depth and seed size

The interaction had significant effect on number of leaflet plant^{-1} (Table 5).At 15 DAS, D_2 S_3 showed significantly highest number of leaflet plant^{-1} (7.53). With no significant difference among D_2S_1, D_2S_2 ,D_3S_1, D_3S_2 and D_3S_3.

Table : 5 Effect of different sowing depth, seed size and their interaction on number of leaflet of mungbean cv. BARI mung 5 at different growth stages

Treatments	Number of leaflet at different days after sowing		
	15	30	45
Sowing depth (D)			
D_1	6.52	12.51	26.23
D_2	7.29	12.92	28.73
D_3	7.18	12.34	27.07
LSD (0.05)	NS	NS	**0.633**
CV (%)	4.36	5.56	10.20
Seed size (S)			
S_1	6.86	12.24	26.51
S_2	7.05	12.63	27.62
S_3	7.09	12.89	27.89
LSD (0.05)	NS	**0.26**	**0.44**
CV (%)	6.25	10.45	7.48
Interaction (S X D)			
D_1S_1	6.33	12.20	25.30
D_1S_2	6.57	12.52	26.43
D_1S_3	6.67	12.81	26.95
D_2S_1	6.97	12.33	28.18
D_2S_2	7.37	12.93	28.60
D_2S_3	7.53	13.49	29.39
D_3S_1	7.27	12.18	26.06
D_3S_2	7.22	12.45	27.83
D_3S_3	7.07	12.38	27.33
LSD (0.05)	**0.68**	**0.45**	**0.76**
CV (%)	6.25	10.45	7.48

D_1 = 2 cm, D_2 = 4 cm, D_3 = 6 cm; S_1 = < 3.2 mm, S_2 = 3.2 to 4 mm, S_3 = > 4 mm

D_1S_1 showed the lowest number of leaflet plant^{-1} (6.33) which, was not significantly differed to D_1S_2, D_1S_3, D_3S_1, D_3S_2 and D_3S_3.

At 30 DAS, D_2S_3 showed the highest number of leaflet plant^{-1} (13.49) which was significantly higher than other treatments. D_1S_1 showed the lowest (12.20) number of leaflet plant^{-1} which, was not significantly differed to D_1S_2, D_1S_3, D_3S_1, D_3S_2 and D_3S_3. Most other treatments showed intermediate values which were in between the values of the highest and lowest and they did not show significant difference among themselves.

At 45 DAS, D_2S_3 showed the highest number of leaflet plant^{-1} (29.39) which was significantly higher than other treatments. The second highest number of leaflet (28.60) was in D_2S_2 which was statistically similar to D_2S_1. D_1S_1 showed the lowest number of leaflet plant^{-1} (25.30) which was similar to D_1S_2, D_1S_3 and D_3S_1.

4.16 Leaf area index

Results of leaf area index was presented in Fig. 30, Fig. 31 and Fig. 32. The leaf area index increased gradually up to harvesting. Irrespective of treatment differences, leaf area index of mungbean ranged from 0.18 - 0.32, 1.02 - 1.65 and 5.21 - 7.70 at 15, 30, and 45 DAS, respectively.

4.16.1 Effect of sowing depth

The sowing depth had a significant effect on leaf area index at 45 DAS (Fig. 30). At all the growth stages, leaf area index increased with the increase of seeding depth up to 4 cm however it decreased at 6 cm. Significantly the highest leaf area index (7.04) was shown by the medium depth (4 cm) that was similar (6.39) with 6 cm depth and the lowest leaf area index (5.72) was shown by 2 cm depth. However at 15 and 30 DAS, there was no significant differences observed among different depths. Islam (2004) also reported that sowing depth had significant effect on leaf area index.

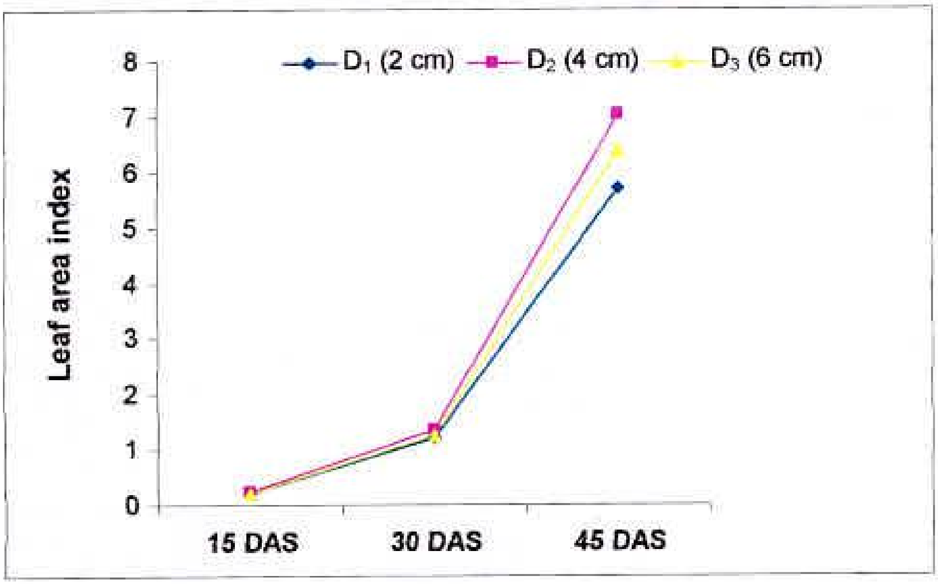

Fig. 30 leaf area index of mungbean as influenced by sowing depth ($LSD_{0.05}$ = NS, NS and 1. 059 at 15, 30 and 45 days, respectively)

4.16.2 Effect of seed size

At all the growth stages leaf area index was found to be increased with the increase of seed size (Fig. 31). The seed size had significant effect on leaf area index at 45 DAS where S_3 showed significantly higher leaf area index (6.76) but S_2 and S_3 showed no variation. At 15 and 30 DAS, no significant differences of was observed for different seed sizes.

Bhardwaj and Bhagsari (1990) also reported that increasing seed size increased LAI. They found the highest LAI of soybeans in large seeds due to more number of leaves and leaf area plant^{-1}. The higher LAI contributed to the higher dry matter production in large seeds, which ultimately led higher seed yield.

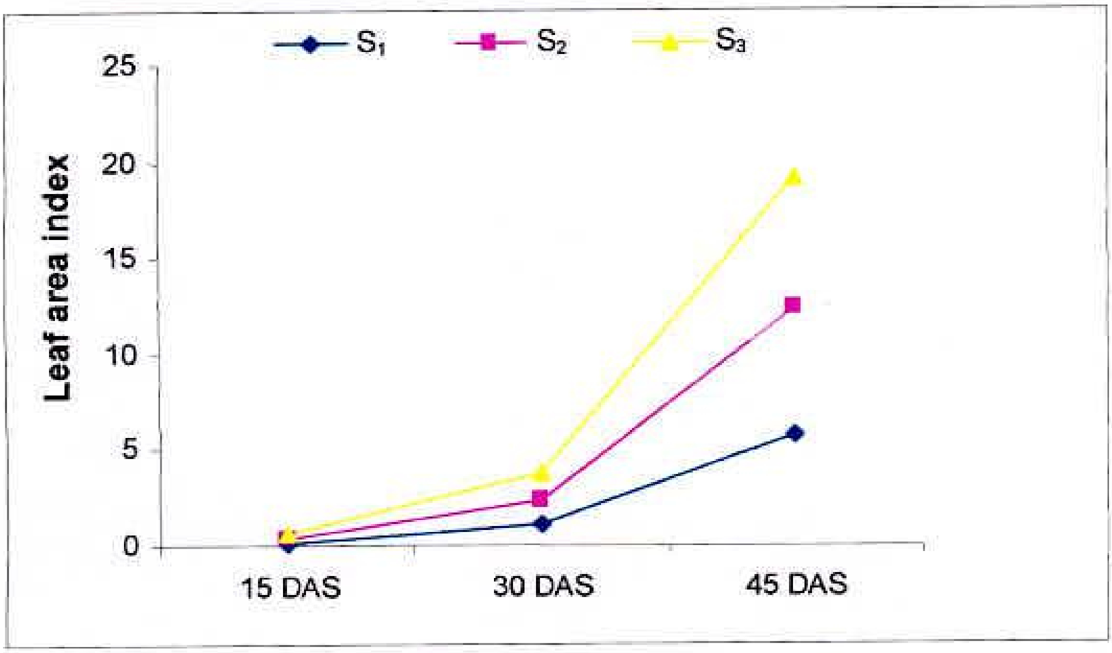

Fig. 31 Leaf area index of mungbean as influenced by seed size ($LSD_{0.05}$ = NS, NS and 0.36 at 15, 30 and 45 days, respectively)

4.16.3 Interaction effect of sowing depth and seed size

The interaction had significant effect on leaf area index (Fig. 32). At all the growth stages, it was observed that at a certain sowing depth, the leaf area index increased with the increase in seed size. However, at the deepest sowing depth (6 cm), the leaf area index increased up the depth of 4 cm and thereafter it decreased.

At 15 DAS, D_2S_3 showed the maximum leaf area index (0.32) which was not significantly differed among the other interaction treatments.

At 30 DAS, D_2S_3 showed the highest leaf area index (1.65) which was significantly higher than other treatments. D_1S_1 showed the lowest (1.02) leaf area index which was not significantly different to D_1S_2, D_2S_1, D_3S_1, D_3S_2 and D_3S_3. Most other treatments showed intermediate values which were in between the values of the highest and lowest and they did not show significant difference among themselves.

At 45 DAS, D_2S_3 showed the highest leaf area index (7.70).The second highest leaf area index was D_2S_2 (7.01) which was similar to D_3S_2 and D_2S_1. D_1S_1 showed the lowest (5.21) leaf area index which was statistically similar to D_1S_2, D_1S_3 and D_3S_1. The other treatments showed leaf area index values which were in between the values of the second highest and the lowest and they did not show significant differences among themselves

Kabir (2000) and Islam (2004) reported that interaction of seed size end sowing depth had significant effect on leaf area index of soybean and mungbean.

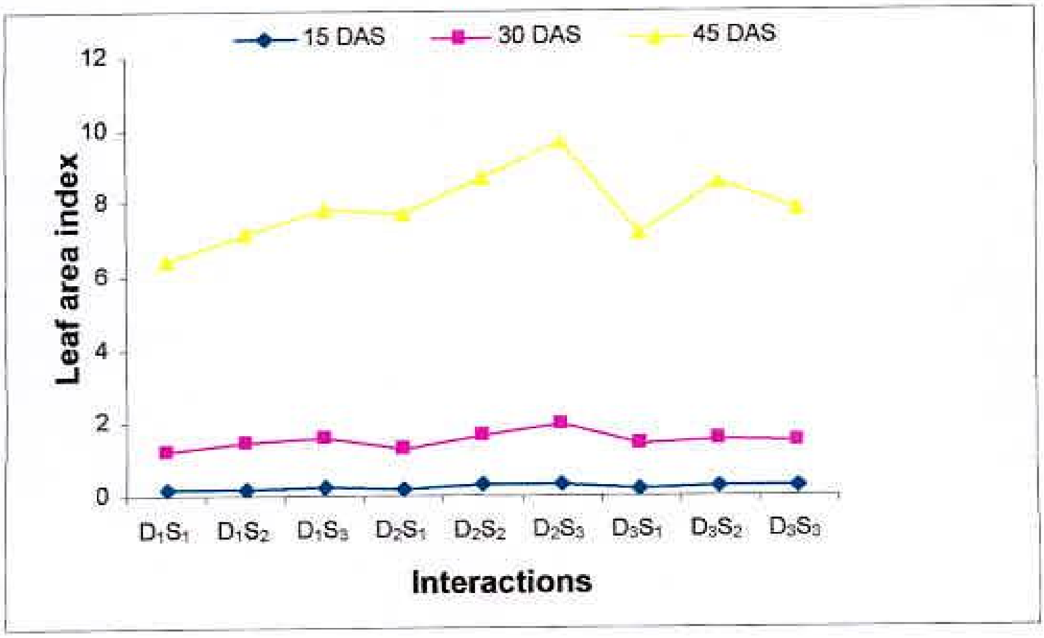

Fig. 32 Interaction effect of sowing depth and seed size on leaf area index of mungbean ($LSD_{0.05}$ = NS, 0.16 and 0.63 at 15, 30 and 45 days, respectively)

4.17 Net assimilation rate (g $m^{-2}day^{-1}$)

Results of net assimilations rate WAS presented in Fig. .33, Fig. 34 and Fig. 35. The net assimilations rate decreased gradually from 30 DAS to 45 DAS. Irrespective of treatment differences, net assimilations rate of mungbean ranged from 5.84-6.88 g m^{-2} day^{-1} and 0.33-1.38 g m^{-2} day^{-1} at 30 and 45 DAS, respectively.

4.17.1 Effect of sowing depth

The sowing depth had no significant effect on net assimilations rate. At 30 and 45 DAS, net assimilations rate decreased with the increase of seeding depth up to 4 cm however it increased at 6 cm (Fig. 33). At 30 DAS, the maximum net assimilations rate (6.64 g $m^{-2}day^{-1}$) was shown by the lower (2 cm) depth and minimum net assimilations rate (6.35 g m^{-2} day^{-1}) was shown at 4 cm sowing depth. At 45 DAS, the maximum net assimilations rate (0.98 g m^{-2} day^{-1}) was shown by the lower (2 cm) depth and minimum net assimilations rate (0.65 g m^{-2} day^{-1}) was found at 4 cm sowing depth.

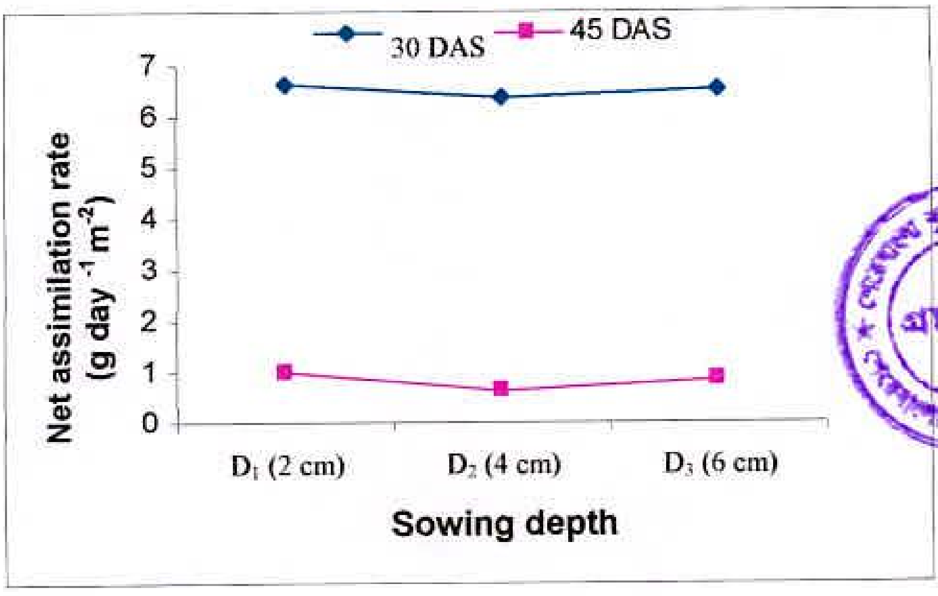

Fig. 33 Net assimilation rate of mungbean as influenced by sowing depth ($LSD_{0.05}$ = NS at both stages)

4.17.2 Effect of seed size

At 30 DAS,. net assimilations rate increased with the increase of seed size up to S_2 however it decreased at S_3 and there was no significant difference among S_1, S_2 and S_3 (Fig. 34).The maximum net assimilations rate (6.83 g $m^{-2}day^{-1}$) was found in S_2 and minimum net assimilations rate(6.33 g $m^{-2}day^{-1}$) in S_1. At 45 DAS, net assimilations rate was found to be decreased with the increase of seed size. There was no significant difference among S_1, S_2 and S_3. Though the maximum net assimilations rate (1.15 g $m^{-2}day^{-1}$) was found in S_1 and minimum net assimilations rate (0.64 g m^{-2} day^{-1}) in S_3

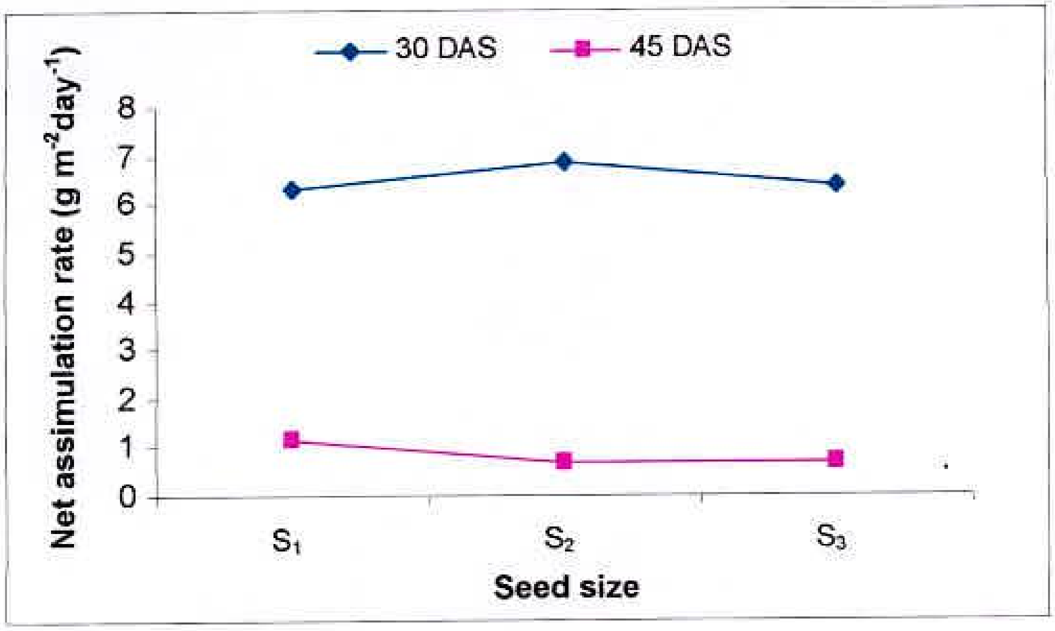

Fig. 34 Net assimilation rate of mungbean as influenced by seed size ($LSD_{0.05}$ = NS at both stages)

4.17.3 Interaction effect of sowing depth and seed size

The treatment had significant effect on net assimilations rate (Fig. 35). At all the growth stages, it was observed that at a certain sowing depth, the net assimilations rate increased with the increase in seed size up to 4 cm but at the deepest sowing depth (6 cm), the net assimilations rate decreased with the increase of seed size.

At 30 DAS, D_2S_2 showed the highest net assimilation rate (6.88 g m^{-2} day^{-1}) which was similar to all other interactions except D_2S_1 that showed the lowest (5.84 g m^{-2} day^{-1}) net assimilations rate.

At 45 DAS, D_1S_1 showed the highest net assimilations rate (1.38 g m^{-2} day^{-1}) which was significantly higher than other treatments. The second highest net assimilations rate was in D_2S_1 (1.16 g m^{-2} day^{-1}) and the lowest net assimilations rate was in D_2S_3 (0.33 g m^{-2} day^{-1}).

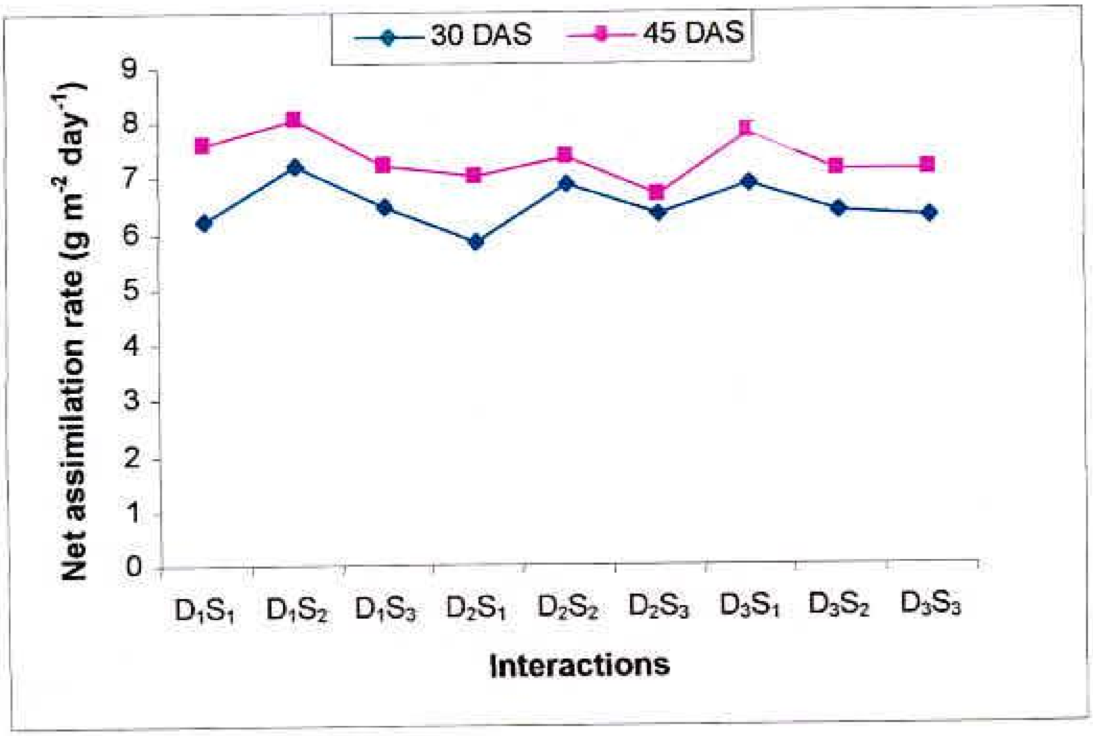

Fig. 35 Interaction effect of sowing depth and seed size on net assimilation rate of mungbean ($LSD_{0.05}$ = 0.89 and 0.13 g m^{-2} day^{-1} at 30 and 45 days respectively)

4.18 Crop Growth Rate (g $m^{-2}day^{-1}$)

Results of crop growth rate were presented in Table 6. The crop growth rate increased gradually up to harvesting. Irrespective of treatment differences, crop growth rate of mungbean ranged from 0.09 - 0.15, 0.36 - 0.62, 1.00 - 1.17 g $m^{-2}day^{-1}$ at 30, 45 DAS and at harvest, respectively.

4.18.1 Effect of sowing depth

The sowing depth had no significant effect on crop growth rate (Table 6). The crop growth rate increased with the increase of seeding depth up to 4 cm and decreased at 6 cm. the maximum crop growth rate was shown by the medium (4 cm) depth and minimum crop growth rate was found in 2 cm sowing depth at all growth stages.

4.18.2 Effect of seed size

At the entire growth stages crop growth rate was found to be increased with the increase of seed size (Table 6). The seed size had no significant effect on the crop growth rate. The maximum crop growth rate was obtained with S_3 and the minimum was in S_1.

4.18.3 Interaction effect of sowing depth and seed size

The treatment had no significant effect on crop growth rate expect at 45 DAS (Table 6). At all the growth stages, it was observed that at a certain sowing depth, the crop growth rate increased with the increase in seed size. However, at the deepest sowing depth (6 cm), the crop growth rate increased up the depth of 4 cm and thereafter decreased. However, such trend was not found at harvest.

Table : 6 Effect of sowing depth, seed size and their interaction on crop growth rate (CGR) of mungbean cv. BARI mung 5 at different growth stages

Treatments	Crop growth rate at different days after sowing		
	15	30	45
Sowing depth (D)			
D_1	0.11	0.40	1.04
D_2	0.13	0.51	1.12
D_3	0.12	0.47	1.11
LSD (0.05)	NS	NS	NS
CV (%)	7.89	15.23	16.26
Seed size (S)			
S_1	0.10	0.39	1.12
S_2	0.13	0.47	1.07
S_3	0.13	0.52	1.07
LSD (0.05)	NS	NS	NS
CV (%)	6.35	7.59	10.12
Interaction (S X D)			
D_1S_1	0.09	0.36	1.02
D_1S_2	0.12	0.39	1.00
D_1S_3	0.12	0.46	1.09
D_2S_1	0.09	0.40	1.17
D_2S_2	0.14	0.52	1.11
D_2S_3	0.15	0.62	1.08
D_3S_1	0.12	0.42	1.17
D_3S_2	0.12	0.49	1.10
D_3S_3	0.11	0.49	1.04
LSD (0.05)	NS	**0.24**	NS
CV (%)	6.35	7.59	10.12

D_1 = 2 cm, D_2 = 4 cm, D_3 = 6 cm; S_1 = < 3.2 mm, S_2 = 3.2 to 4 mm, S_3 = > 4 mm

At 30 DAS, D_2S_3 showed the maximum crop growth rate (0.15 g m^{-2} day^{-1}) though there was no significant difference observed among the treatments. D_1S_1 showed the minimum (0.09 g m^{-2} day^{-1}) crop growth rate.

At 45 DAS, D_2S_3 showed the highest crop growth rate (0.62 g m^{-2} day^{-1}) which was statistically similar to other treatments except D_1S_1 that showed the lowest (0.36 g m^{-2} day^{-1}) crop growth rate which, was not significantly differed to other treatments except D_2S_2.

At harvest, D_2S_1 and D_3S_1 showed the maximum crop growth rate (1.17 g $m^{-2}day^{-1}$) which was similar to all other treatments. D_1S_1 showed the minimum (1.00 g $m^{-2}day^{-1}$) crop growth rate.

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

Results of number of branches $plant^{-1}$ have been presented in Fig. 36 and Table 7. From the Figures, it is seen that no of branches $plant^{-1}$ of mungbean ranged from 0.66-1.69 at harvest.

4.19.1 Effect of sowing depth

The sowing depth had a significant effect on number of branches $plant^{-1}$ (Table7). The number of branches $plant^{-1}$ was increased from 2 cm to 4 cm sowing depth and decreased with the increase of seeding depth at 6 cm. The number of branches plant^{-1} ranged from 0.83 – 1.60 significantly highest number of branches plant^{-1} (1.60) was shown by the medium (4 cm) depth but there was no significant difference observed among 2 cm and 4cm sowing depth. lowest number of branches plant^{-1} (0.83) was shown by the large (6 cm) depth that was similar to 2 cm. The result seemed to be close agreement with findings of Kabir (2000) who work on soybean and reported that number to branches plant^{-1} was decreased with increasing the sowing depth.

4.19.2 Effect of seed size

The number of branches plant^{-1}was found to be increased with the increasing rate of seed size (Table7). The seed size had no significant effect on number of branches plant^{-1}. The numerically maximum number of branches plant^{-1} (1.30) was obtained with S_3 and minimum number of branches plant^{-1} (1.28) was obtained from the S_1 and S_2.This finding was supporter by Whitehead *et al* (1980), Kabir (2000) and Islam (2004) who stated that large seeds size produced more branches than the small seeds in soybean and mungbean.

4.19.3 Interaction effect of sowing depth and seed size

The number of branches plant^{-1} was significant by varied due to interaction of seed size and sowing depth(Fig. 36). At a certain sowing depth, the Number of branches plant^{-1} increased with the increase in seed size up to 4 cm sowing depth and there after it decreased when seeds was sown at 6 cm depth. The highest number of branches was found in D_2S_3 (1.69) The second height number of branches plant^{-1} was found in D_2S_2 (1.56) which had no significant difference to D_1S_3 and D_2S_1. The lowest number of branches plant^{-1} was D_3S_3 (0.67). The other interaction treatments showed intermediate values which were in between the values of the second highest and the lowest values.

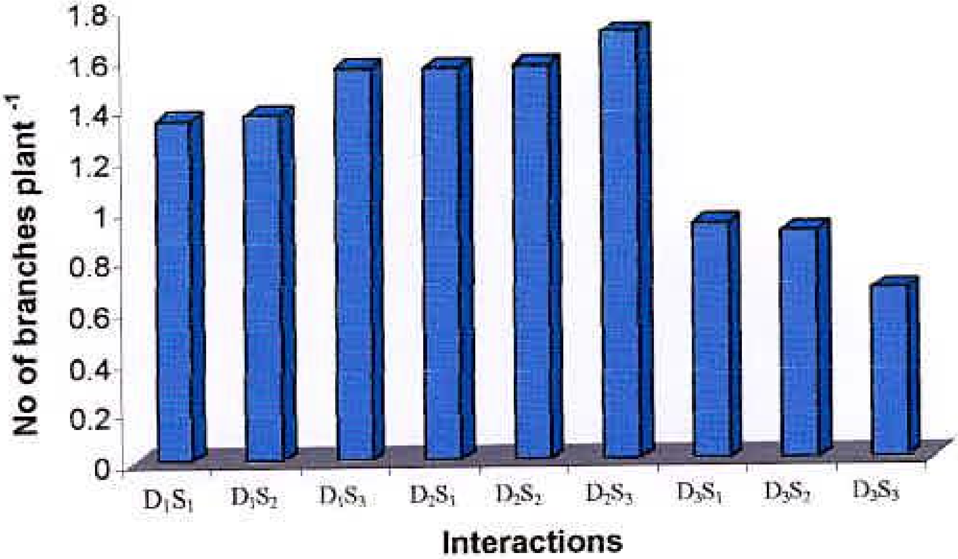

Fig. 36 Interaction effect of sowing depth and seed size on number of branches of mungbean ($LSD_{0.05}$ = 0.10)

4.20 Number of pods plant^{-1}

Results of number of pods plant^{-1} was presented in Fig. 37 and Table 7.The number of pods per plant of mungbean ranged from 11.76-13.28.

4.20.1 Effect of sowing depth

The sowing depth had no significant effect on number of pods plant^{-1} at harvest (Table7). Though it increased numerically with the increase of seeding depth up to 4 cm and it decreased at 6 cm. The number of pods plant^{-1} at harvest ranged from 12.23-13.11.The maximum number of pods plant^{-1} (13.11)was shown by the medium (4 cm) depth and the minimum number of pods plant^{-1} (12.93)was shown by the smallest (2 cm) depth.

4.20.2 Effect of seed size

The number of pods plant^{-1} was found to be increased with the increasing rate of seed size though the seed size had no significant effect on number of pods plant^{-1} (Table7). The numerical maximum number of pod plant^{-1} (12.86) was obtained with S_3 and minimum number of pods plant^{-1} (12.45) was obtained from the S_1. Similar work was done by Martincic *et al.* (1997) on soybean seed size and Islam (2004) on mungbean seed size. They found that number of pods plant^{-1} was higher in large seed size.

4.20.3 Interaction effect of sowing depth and seed size

The number of pods plant^{-1} was significant due to interaction of sowing depth and seed size(Fig. 37). The highest number of pods plant^{-1} was found in D_2S_3 (13.28) which was similar to D_2S_1 , D_2S_1 , D_3S_2 and D_3S_3 treatments. The lowest number of pods plant^{-1} was found in D_1S_1 (11.76) .which was significantly similar to D_1S_2 and D_3S_1. The other interaction treatments showed the values between the highest and the lowest and they did not show significant difference among themselves.

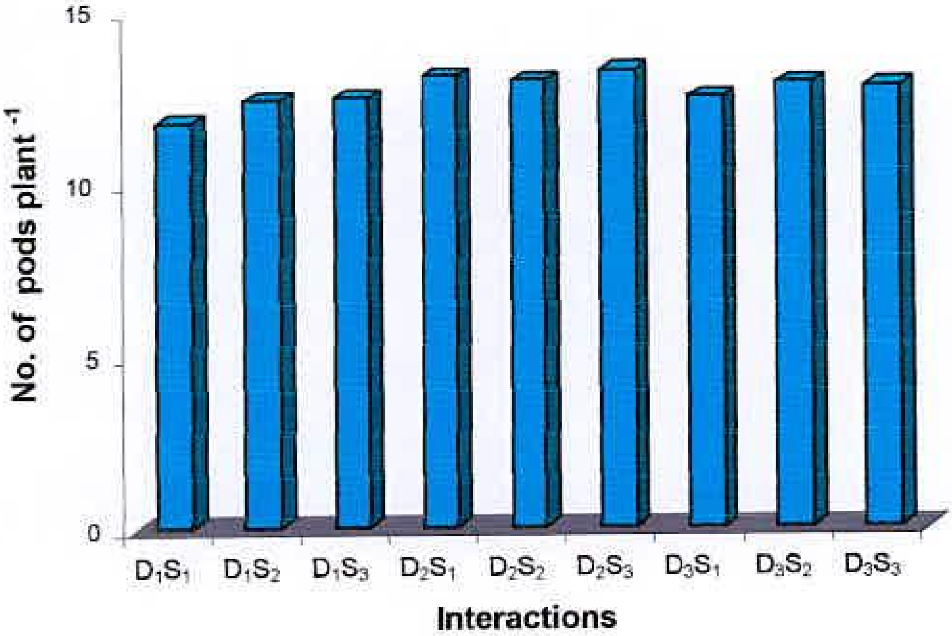

Fig. 37 Interaction effect of sowing depth and seed size on number of pods plant^{-1} of mungbean ($LSD_{0.05}$ = 0.73)

4.21 Pod length

Results of pod length was presented in Fig. 38 and Table 7. The pod length of mungbean ranged from 8.84-10.93 at harvesting

4.21.1 Effect of sowing depth

The sowing depth had no significant effect pod length at harvest (Table7). Though the pod length was increased with the increase of seeding depth up to 4 cm and thereafter decreased at 6 cm. The maximum pod length (10.14 cm) was shown by the medium (4 cm) depth which was statistically similar to 2 cm and 6 cm sowing depth.

4.21.2 Effect of seed size

The pod length was found to be increased with the increasing of seed size (Table7). The seed size had significant effect on pod length. The highest pod length (10.15 cm) was obtained with S_3 which was significantly higher than S_1 and S_2. The lowest pod length (9.25 cm) was found in the S_1 which was significantly lower than S_2 and S_3.

4.21.3 Interaction effect of sowing depth and seed size

The difference of pod length among the treatments was significant due to interaction of sowing depth and seed size(Fig. 38). It was observed that at a certain sowing depth, the pod length increased with the increase in seed size but at 6 cm depth, the largest seed size showed slightly lower value in pod length than that by the medium seed size. The highest pod length (10.93) was found in D_2S_3 which was significantly higher than other treatments. The lowest pod length was found in D_3S_1 (8.84 cm) which was similar to D_1S_1, D_2S_1, D_3S_2 and D_3S_3 treatments. The other interaction treatments showed the intermediate pod length.

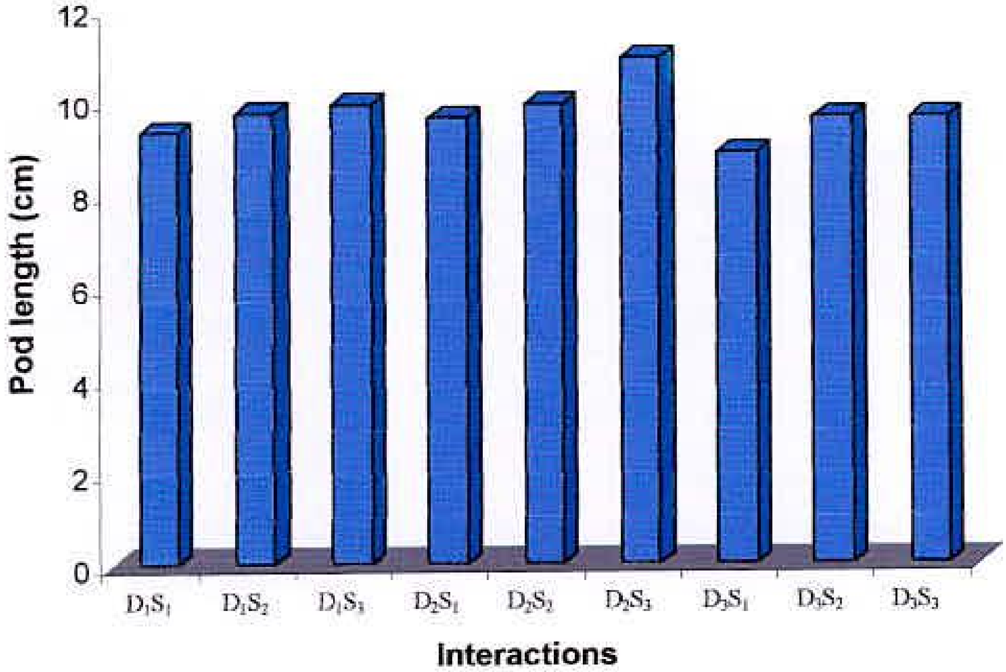

Fig. 38 Interaction effect of sowing depth and seed size on pod length of mungbean ($LSD_{0.05}$ = 0.78)

4.22 Number of seeds per pod

Results of number of seeds per pod have been presented in Fig. 39 and Table 7. The number of seeds per pod of mungbean ranged from 9.41-10.24.

4.22.1 Effect of sowing depth

The sowing depth had no significant effect on number of seeds per pod at harvest (Table7) though the number of seeds per pod increased with the increase of seeding depth up to 4 cm however it decreased at 6 cm. The number of seeds per pod at harvest ranged from 9.74 - 9.97 .The maximum number of seeds per pod (9.99) was shown by the medium (4 cm) depth and the minimum was shown by the smallest (2 cm) depth.

4.22.2 Effect of seed size

The number of seeds per pod was found to be increased with the increasing rate of seed size (Table7). Though the seed size had no significant effect on number of seeds per pod. The maximum number of seeds per pod (9.99) was obtained with S_3 and the minimum number of seeds per pod (9.66) was obtained from the S_1. The result seemed to be close agreement with the findings of Saka *et al* (1996) who reported that the number of seed per pod were not significantly affected by the seed size .It was also in agreement with the findings of Reddy *et al.* (1989) and Whitehead *et al.* (1980).

4.22.3 Interaction effect of sowing depth and seed size

The number of seeds per pod was significant due to interaction of sowing depth and seed size(Fig. 39). It was observed that at a certain sowing depth, the number of seeds per pod increased with the increase in seed size. The highest number (10.24) was found in D_2S_3 which was significantly higher than other interactions. The second highest number of seeds was found in D_1S_3 and it was statistically similar to D_1S_2, D_2S_1, D_2S_2 D_3S_1 D_3S_2 and D_3S_3. The lowest number of seeds per pod (9.41) was found in D_1S_1. The result seemed to be close agreement with the findings of Kabir (2000) who reported that the number of seeds per pod were significantly affected by the seed size and depth of soybean seed sowing. He again stated that large and medium seeds produced the higher seeds per pod with different depth of sowing whereas and the small seeds produced the lowest seeds per pod.

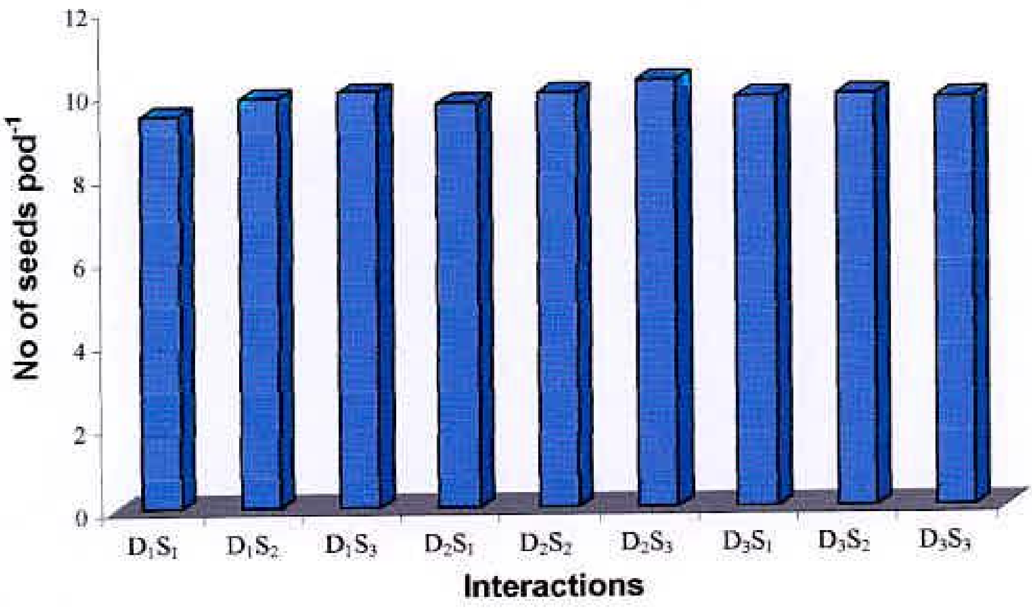

Fig. 39 Interaction effect of sowing depth and seed size on number of seeds/pod of mungbean ($LSD_{0.05}$ = 0.75)

4.23 1000 Seed weight

Results of 1000 seed weight was presented in Fig. 40, Table 7. The 1000 seed weight of mungbean ranged from 37.21- 44.09.

4.23.1 Effect of sowing depth

The sowing depth had a significant effect on 1000 seed weight. At that stage, 1000 seed weight was significantly increased with the increase of seeding depth up to 4 cm however it decreased at 6 cm depth. The highest 1000 seed weight (43.45 g) was shown by the medium (4 cm) depth which was significantly higher than 2cm and 6 cm depth. Significantly the lowest 1000 seed weight (39.45 g) was shown by the smallest (2 cm) depth.

4.23.2 Effect of seed size

The 1000 seed weight was found to be increased with the increasing of seed size . The seed size had significant effect on 1000 seed weight. The highest 1000 seed weight (42.67 g) was obtained from S_3 which was significantly higher than S_1 and S_2. The lowest 1000 seed weight (40.47 g) was obtained from the S_1 which was significantly lower than S_3 but similar to S_2. The result seemed to be close agreement with the findings of Kabir (2000) and Islam (2004) who reported that1000 seed weight were affected by the seed size .They reported that larger seed size produced higher 1000 seed weight than medium and small seeds size of soybean.

Table: 7 Effect of different sowing depth and seed size on yield and other crop characters of mungbean cv. BARI mung 5

Treatments	No.of bran-ches plant^{-1}	No. of pods plant^{-1}	Pod length (cm)	No. of seeds pod^{-1}	1000 seed weigh t (g)	Seed yield (t ha^{-1})	Shell-ing per-centage	Har-vest index (%)
Sowing depth (D)								
D_1	1.42	12.23	9.66	9.74	39.45	1.33	31.68	24.24
D_2	1.60	13.11	10.14	9.97	43.45	1.45	31.77	25.44
D_3	0.83	12.73	9.36	9.84	41.14	1.43	30.72	24.47
LSD (0.05)	NS	NS	**1.13**	NS	**1.23**	**0.04**	NS	**0.519**
CV (%)	3.25	4.21	5.32	2.31	7.23	2.31	8.32	9.56
Seed size (S)								
S_1	1.28	12.45	9.25	9.66	40.47	1.36	31.30	24.08
S_2	1.28	12.76	9.75	9.90	40.90	1.41	31.22	24.80
S_3	1.30	12.86	10.15	9.99	42.67	1.45	31.65	25.27
LSD (0.05)	**0.61**	**0.42**	**0.45**	**0.43**	**0.66**	**0.01**	**0.53**	**1.34**
CV (%)	3.62	2.35	8.36	4.52	6.63	5.45	6.32	7.45

D_1 = 2 cm, D_2 = 4 cm, D_3 = 6 cm; S_1 = < 3.2 mm, S_2 = 3.2 to 4 mm, S_3 = > 4 mm

4.23.3 Interaction effect of sowing depth and seed size

The 1000 seed weight was differed among the interactions due to interaction of sowing depth and seed size (Fig. 40). It was observed that at a certain sowing depth, 1000 seed weight increased with the increase in seed size but at 6 cm depth, the largest seed size showed slightly lower 1000 seed weight than that of medium seed size. The highest 1000 seed weight (44.09 g) was found in D_2 S_3 which was not significantly differed to D_1S_3, D_2S_1 and D_2S_2

treatments .The next highest 1000 seed weight was D_3S_2 (41.61 g) but it was not significantly differed to D_3S_3. The lowest 1000 seed weight was found in D_1S_1 (37.21 g) which was similar to D_1S_2 . Similar findings was obtained by Kabir (2000) reported that the highest1000 seed weight was obtained from using the large sized seeds when sown in 4 cm depth of soybean crop.

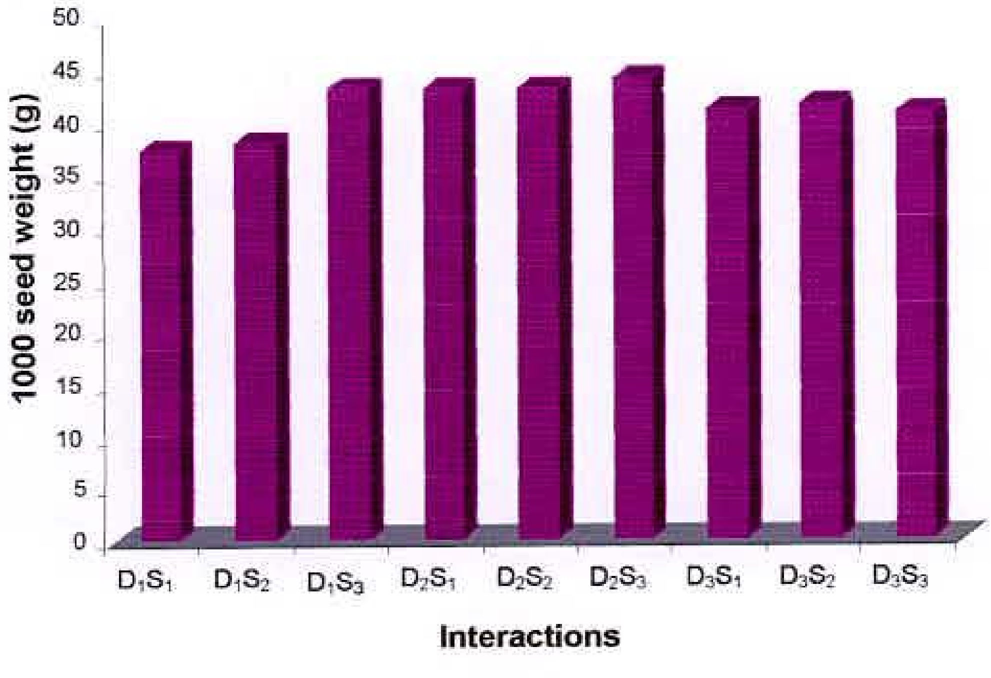

Fig. 40 Interaction effect of sowing depth and seed size on 1000 seeds weight of mungbean ($LSD_{0.05}$ = 1.13)

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

Results of seed yield were presented in Fig. 41, and Table 1. The seed yield of mungbean ranged from 1.28 -1.515 ton per hectare.

4.24.1 Effect of sowing depth

The sowing depth had a significant effect on seed yield. The seed yield was significantly increased with the increase of seeding depth up to 4 cm but decreased at 6 cm depth. The seed yield ranged from 1.33-1.45 t ha^{-1}. The highest seed yield (1.45 t ha^{-1}) was shown by the medium (4 cm) depth which was significantly higher than 2 cm depth but similar to 6 cm depth. Significantly the lower seed yield (1.33 t ha^{-1}) was shown by the smallest (2 cm) depth. Similar findings were obtained by Himmel *et al.* (1981) who reported that yield was generally decreased at the deeper sowing depth.

4.24.2 Effect of seed size

The seed yield was found to be increased with the increasing of seed size. The seed size had significant effect on seed yield. The highest seed yield (1.45 t ha^{-1}) was obtained from S_3 which was significantly higher than S_1 and S_2 treatments. lowest grain weight (1.36 t ha^{-1}) was obtained from the S_1 which was significantly lower than S_2. The highest seed yields by largest seeds might be due to contribution of the cumulative favorable effect of the yield and yield components. These result was in conformity with the finding of Kler and Dhillon (1983) who also indicated variation of yield in soybean due to different seed size.

The result also seemed to be close agreement with the findings of Kabir (2000) and Islam (2004) who reported that grain weight were significantly affected by the seed size. They reported that larger seed produced higher grain weight than medium and small sized seed.

4.24.3 Interaction effect of sowing depth and seed size

The differences of seed yield among the treatments were significant by varied due to interaction of sowing depth and seed size (Fig. 41). It was observed that at a certain sowing depth, grain weight increased with the increase in seed size but at 6 cm depth, the largest seed size showed slightly lower value in grain weight than that by the medium seed size. The highest grain weight (1.52 t ha^{-1}) was found in D_2S_3 which was similar D_3S_2.The next highest seed yield was in D_3S_2 (1.47 t ha^{-1}) that was similar to D_3S_3. The lowest seed yield was found in D_1S_1 (1.29 t ha^{-1}) which was not significantly differed to D_1S_2.The other treatments showed intermediate seed yield. Similar findings were obtained by Kabir (2000) who reported that the highest grain weight was obtained by using the large size seeds when sown in 4 cm depth.

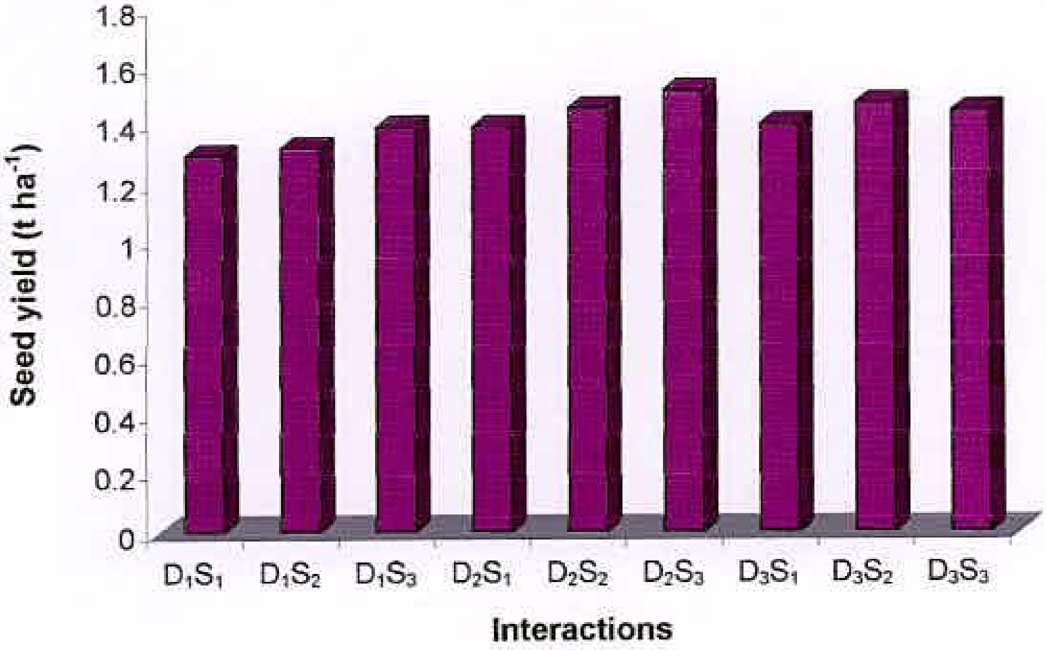

Fig. 41 Interaction effect of sowing depth and seed size on seed yield of mungbean ($LSD_{0.05}$ = 0.04)

4.25 Shelling percentage

Results of shelling percentage was presented in Fig. 42 and Table 7. It was seen that shelling percentage of mungbean ranged from 30.30 - 32.55 at the time of harvest.

4.25.1 Effect of sowing depth

The sowing depth had no significant effect no shelling percentage (Table 7).At that stage, shelling percentage increased with the increase of seeding depth up to 4 cm however it decreased at 6 cm depth. The shelling percentage at harvest ranged from 30.72-31.77. The maximum shelling percentage (31.77) was shown by the medium (4 cm) depth and the minimum shelling percentage (30.72) was shown by the largest (6 cm) depth.

4.25.2 Effect of seed size

The shelling percentage was found to be increased numerically with the increase of seed size (Table 7). The seed size had no significant effect on shelling percentage though the maximum shelling percentage (31.65) was obtained from S_3 and the minimum shelling percentage (31.22) was obtained from the S_2.

4.25.3 Interaction effect of sowing depth and seed size

The difference of shelling percentage among the treatments was significant due to interaction of sowing depth and seed size (Fig. 42). It was observed that at a certain sowing depth, shelling percentage increased with the increase in seed size, but at 6 cm depth, the largest seed size showed slightly lower value in shelling percentage than that by the medium seed size. The highest shelling percentage (32.55) was found in D_2S_3 which was similar to D_1S_2, D_1S_3. The lowest shelling percentage (30.30) was found in D_3S_2 which was not significantly differed to D_1S_1. D_1S_1, D_3S1, D_3S_2 and D_3S_3 interaction treatments.

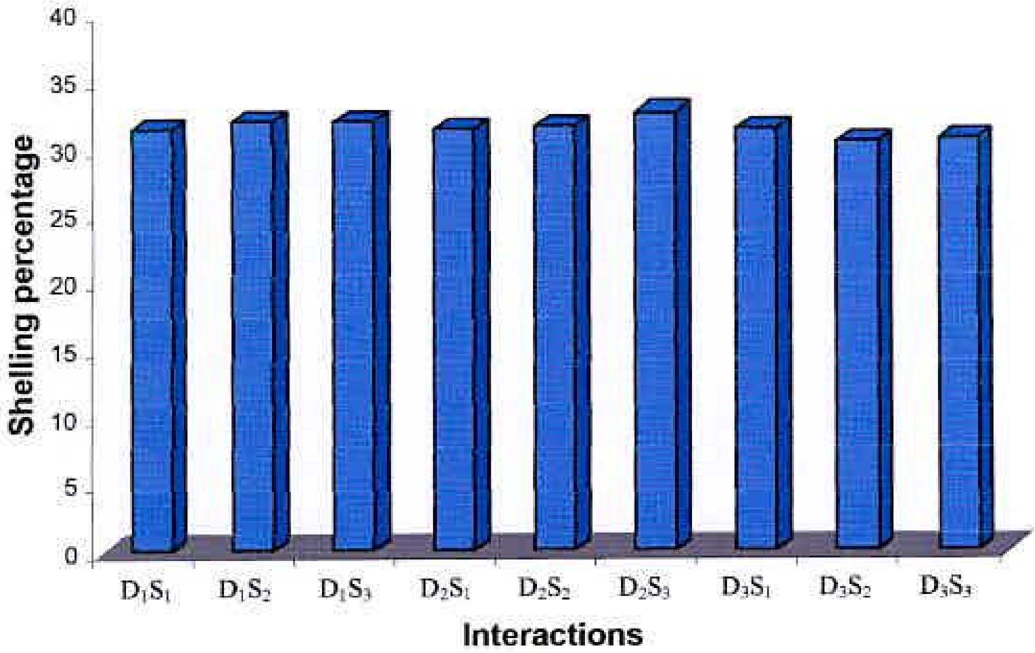

Fig. 42 Interaction effect of sowing depth and seed size on shelling percentage of mungbean ($LSD_{0.05}$ = 0.91 %)

4.26 Harvest index

Results of harvest index was presented in Fig. 43 and Table 7. It was seen that harvest index of mungbean ranged from 22.21 - 25.73 at the time of harvest.

4.26.1 Effect of sowing depth

The sowing depth had no significant effect on harvest index (Table 7). But it increased with the increase of seeding depth up to 4 cm however it decreased at 6 cm depth. The highest harvest index (25.44) was shown by the medium (4 cm) depth. Significantly the minimum harvest index (24.24) was shown by the smallest (2 cm) depth that was similar to 6 cm depth (24.47).

4.26.2 Effect of seed size

The seed size had significant effect on harvest index. Numerically the higher harvest index (25.27) was obtained from S_3.The minimum harvest index (24.08) was obtained from the S_1. This result was in conformity with the finding of Kabir (2000) and Islam (2004) found that harvest index increased with increasing the seed size. Bhardwaj and Bhagsari (1989) and Reddy *et al.* (1989) also reported that harvest index was not significantly affected by seed size.

4.26.3 Interaction effect of sowing depth and seed size

The difference of harvest index among the treatments was significant due to interaction of sowing depth and seed size (Fig. 43). It was observed that at 2 cm sowing depth, harvest index increased with the increase in seed size but at 4 cm depth, similar harvest index was found irrespective of seed size but at 6 cm sowing depth the harvest index increased up to 4 cm and decreased thereafter. The highest harvest index (25.73) was found in D_2S_3which was similar to D_1S_2, D_1S_3, D_2S_1, D_2S_2 and D_3S_1 D_3S_2 and D_3S_3.The lowest harvest index (22.21) was found in D_1S_1 which was not significantly differed to D_3S_1 and D_3S_3 treatments.

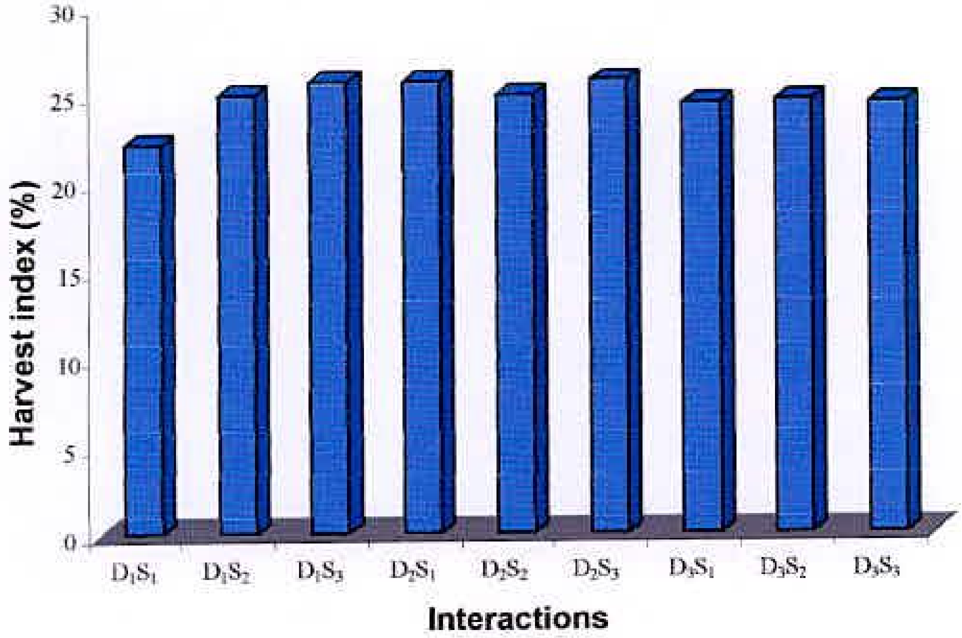

Fig. 43 Interaction effect of sowing depth and seed size on harvest index of mungbean ($LSD_{0.05}$ = 2.32)

Chapter 5

Summary and conclusion

CHAPTER 5

SUMMARY

A field experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from March 2007 to June 2007 to study the influence of varying sowing depth and seed size on growth and yield of mungbean. The experimental site was under Modhupur Tract (AEZ-28). The experiment was consisted of three sowing depths (2 cm = D_1, 4 cm = D_2 and 6 cm = D_3) three and seed sizes (small = S_1, Medium = S_2 and large = S_3). The experiment was laid out in a split-plot design with three replications having depth in the main plots and seed size in the sub-plots. The unit plot size was 4 m × 2.4m). The land was fertilized with Urea, TSP and MP applied as basal at the rate of 45 – 100 – 55 N, P_2O_5 and K_2O, respectively. The seeds were sown on 27th March 2007. Intercultural operations such as weeding, water management and pest management were done as and when necessary.

Before setting the experiment in the field, percentage of germination and vigour of three size seeds were determined by performing a standard germination test in petridishes. Likewise, the percent and trend of emergence and the seedling growth were also monitored by simulating the experiment in polybags. Data of different parameters of the seedlings were monitored at 15 DAS.

From the field experiment, data on crop growth parameters like plant height, number of branches per plant, leaf area index and dry matter were recorded at different growth stages. Yield parameters like number of pods per plant, pod length, number of seeds pod^{-1}, 1000 seed weight, seed and stover yield were recorded after harvest.

Data were analyzed using IRRISTAT package. The mean differences among the treatments were compared by least significant difference (LSD) test at 5% level of significance.

Results from the germination experiment showed that seed size had significant effect on percent germination and vigour index. S_1 showed significantly the highest germination percentage and vigour index. Whereas, S_3 showed the lowest values in these respect.

From the results of the emergence experiment in polybag, it was seen that the seedlings under the treatment D_1 started emerging from 7 days after sowing and those under D_2 and D_3 from 9 days. Sowing depth had significant effect on the emergence. At 7 DAS, the emergence occurred only with D_1. At 8 and 9 DAS, emergence of seedlings occurred under D_2 and D_3, respectively. At all the days, the percentage of emergence was significantly higher at 2 cm depth (D_1) and the lowest at D_3 (6 cm).

Unlike with sowing depth, seedlings from all of seed sizes were found to start emerging from 7 DAS. After the start, seedlings emerged almost linearly up to 12 DAS and thereafter the emergence was ceased. From 8 DAS and onwards, the smallest seeds (S_1) emerged significantly faster and had higher emergence values than S_2 and S_3. Similar trend was also observed up to the 15 DAS. At all the counts significantly the lower emergence was shown by S_3.

Interaction effect of seed size and sowing depth was found significant in respect of the seedling emergence. D_1 S_1 showed the highest emergence whereas, the D_3 S_3 showed the lowest emergence of seedlings.

The seed size had significant effect on epicotyle length. Significantly the highest epicotyle length (4.94 cm) was obtained from S_3 which was significantly higher than S_1 and S_2 treatments. The lowest epicotyle length (4.25 cm) was obtained from the S_1 seed which was significantly lower than S_2 and S_3 treatments.

Significant effect of seed size was noticed on hypocotyle length due to the difference in seed size. The hypocotyle length was found to be increased with the increase of seed size. Significantly the highest hypocotyle length (7.34cm) was obtained from S_3 wherereas, the lowest (6.34cm) from S_1.

The sowing depth had significant effect on hypocotyle length of seedlings. Significantly the highest values of these two parameters were shown by D_3 whereas, the lowest by D_1. Unlike with epicotyle length, the sowing depth had significant effect on hypocotyle length. Significantly the maximum hypocotyle length was shown by the highest (6 cm) depth. The seed size had significant effect on hypocotyle length.

The differences in epicotyle and hypocotyle length were significant due to the interaction of seed size and sowing depth. The highest epicotyle length was found in D_1 S_3 whereas, the lowest in D_3 S_1. Significantly the highest hypocotyle length was found in D_3 S_3 whereas, the lowest in D_1 S_1.

The sowing depth had significant effect on seedling root length. The seedling root length decreased with the increase of seeding depth. Significantly the highest seedling root length was shown by D_1 whereas, the lowest by D_3. The seed size had also significant effect on seedling root length. The highest seedling root length was obtained from S_2 and the lowest from S_1.

The seedling root length was significant due to interaction of sowing depth and seed size. At a certain sowing depth, seedling root length increased with the increase in seed size but at 6 cm depth, the largest seed size showed the lowest value. The highest seedling root length (14.19 cm) was found in D_1 S_3 whereas, the lowest in D_3 S_1 (9.98 cm).

The sowing depth had significant effect on root and shoot fresh weight. These two parameters increased with the increase of seeding depth. Significantly the highest root and fresh weight were obtained with D_3 whereas, the lowest with D_1. The seed size had significant effect on the fresh weight of seedlings. Significantly the highest root and shoot fresh weight were obtained with S_3 whereas, the lowest values of these two parameter were shown by S_1.

In respect of the interaction effect, it was observed that at a certain sowing depth, shoot fresh weight increased with the increase in seed size at 6 cm depth. The highest total fresh weight (0.48 g\plant) was found in D_3 S_3. The lowest total fresh weight was found in D_1 S_1 (0.28 gm).

From the field experiment data it was seen that the sowing depth had a significant effect on plant height, leaf, stem, root, inflorescence and total dry weight, number of leaflet, leaf area index and number of branches/plant. At all the growth stages, significantly the highest values of these parameters were found with medium depth of 4 cm (D_2). At the sowing depth of 6 cm (D_3), the values were found to be significantly decreased.

The growth parameters were also significantly affected by the seed sizes. At all the growth stages, significantly the highest plant height; leaf, stem, root, inflorescence and total dry weight, number of leaflet, leaf area index and number of branches/plant was shown by the largest seed size (S_3) whereas, the minimum with the smallest (S_1).

The interaction effect of sowing depth and seed size was also significant on different growth parameters. The treatment D_2 S_3 showed significantly the highest value of plant height, leaf dry matter, stem dry matter, inflorescence dry matter and total dry matter whereas, in most cases D_1 S_1 showed the lowest values almost at all the growth stages. The interaction effect on root dry matter was not significant at 15, 30 and 45 DAS, but the effect was significant at harvest. The highest root dry matter was recorded in D_1 S_3 and the lowest in D_1 S_1.

Both the sowing depth and seed size had also significant effect on net assimilation rate and crop growth rate. Significantly higher NAR was obtained with D_1 and D_2. Likewise, significantly the highest NAR was obtained with S_2. Among the interaction treatments, D_1 S_2 and D_3S_1 showed significantly the higher NAR values.

Significantly the highest CGR was obtained with D_2 the lowest with D_1. Seed size did not have significant impact on CGR at 15 DAS, the effect was significant at 30 and 45 DAS. At 45 DAS, S_3, whereas, at 45 DAS S_1 showed significantly the highest CGR. Among the interaction treatments, D_2 S_1 and D_3 S_1 showed significantly the highest CGR value.

The sowing depth had a significant effect on different reproductive parameters such as number of pods plant^{-1}, number of seeds pod^{-1}, pod length, 1000 grain weight, seed yield ha^{-1} and harvest index. Significantly the highest values of all these parameters were observed with seeding depth of 4 cm (D_2) and with further increase in depth of 6 cm (D_3). In all the cases, significantly the lowest values were obtained with 2 cm sowing depth (D_1).

Seed size also did not have significant effect on number of branches, number of pods plant^{-1}, number of seeds pod^{-1} although these parameters were found to be increased with the increasing rate of the seed size. In all the cases, the highest values were obtained with S_3 and lowest with S_1. However, the pod length, 1000 grain weight, seed yield were significantly increased with the increase of seed size. Significantly the highest pod length (10.15 cm), 1000 grain weight (42.67 gm) and seed yield (1.44 t ha^{-1}) were obtained with S_3 which was significantly higher than S_1 and S_2. The effect of seed size on harvest index was not significant.

Interaction effect of seed size and sowing depth was found significant for plant height, number of pods plant^{-1}, number of seeds pod^{-1}, pod length, 1000 seed weight, seed yield and harvest index. Among sowing depth treatments, D_2S_3 showed significantly higher plant height, number of pods plant^{-1}, number of seeds pod^{-1}, pod length, 1000 seed weight, seed yield and harvest index. The interaction of D_1S_1 showed the lowest values in these respect.

CONCLUSION

Based on the above summary, following conclusions may be drawn;

The smallest seeds (S_1) showed significantly the highest germination percentage, vigour index and emergence. Significantly the highest epicotyle and hypocotyle length, root, shoot and total fresh weight were obtained with S_3. Results of the field experiment showed that the significantly the highest pod length, 1000 grain weight and seed yield were obtained with S_3.

The percentage of emergence was significantly highest at 2 cm depth. The significantly highest hypocotyle length, root, shoot and total fresh weight were shown by D_3. From the field experiment, it was seen that significantly the highest values of number of pods plant^{-1}, number of seeds pod^{-1}, pod length, 1000 grain weight, seed yield and harvest index were observed in D_2.

Results of interaction effect of seed size and sowing depth showed that highest hypocotyle length and fresh weight of root, shoot and total plant of the seedling were found with D_3 S_3. In the field, it was observed that the treatment D_2 S_3 showed significantly the highest value of plant height, leaf dry matter, stem dry matter, inflorescence dry matter and total dry matter. Significantly higher NAR was obtained with D_2 S_2 at 30 DAS however, D_1 S_1 at 45 DAS. The interaction of D_2S_3 showed significantly higher plant height, number of pods plant^{-1}, number of seeds pod^{-1}, pod length, 1000 seed weight, seed yield and harvest index.

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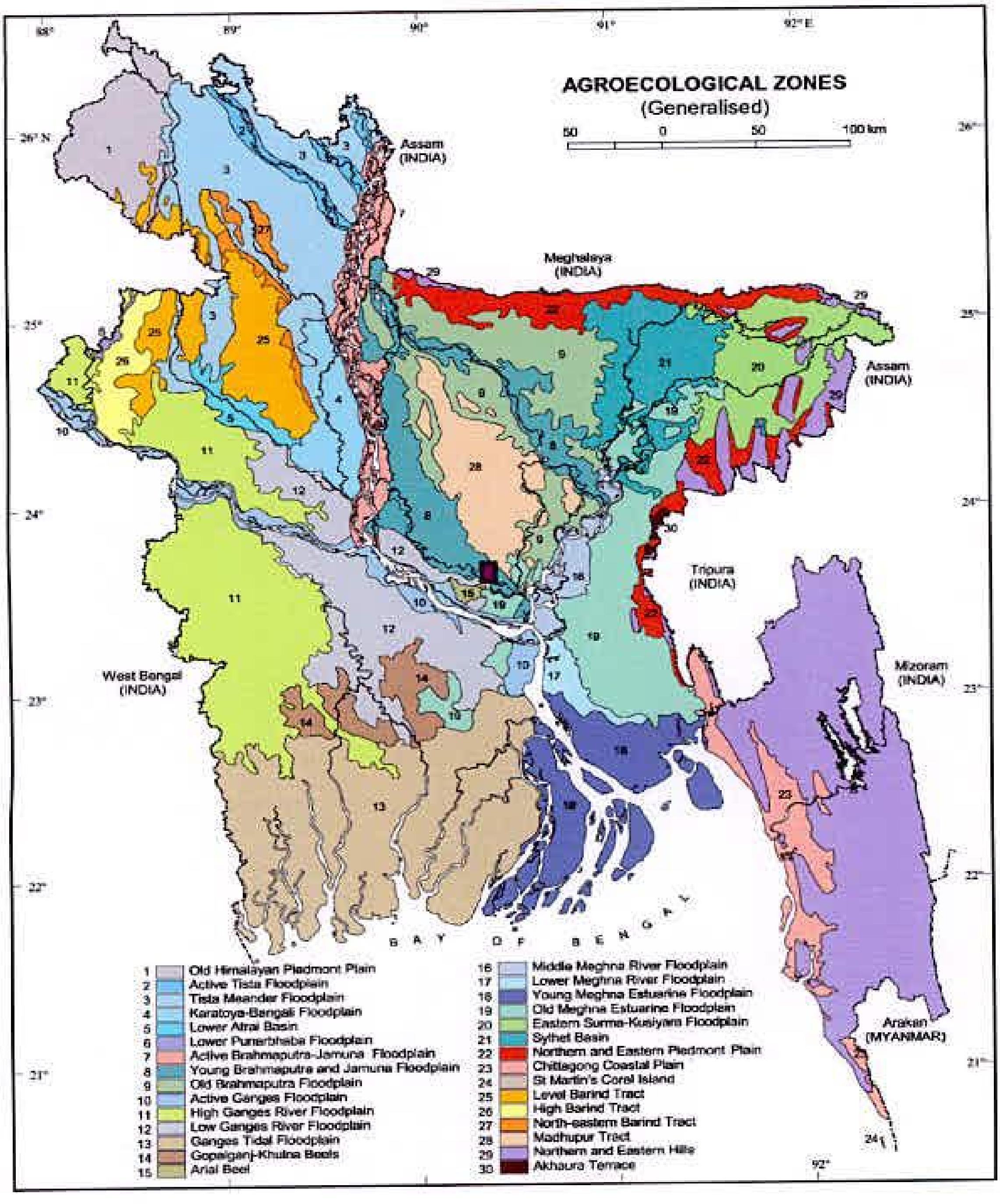
APPENDICES

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 experimentation (0 - 15 cm depth).

Mechanical composition:

Particle size constitution

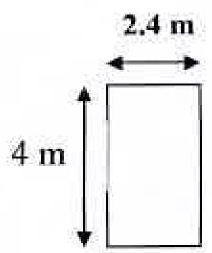
Sand	:	26%
Silt	:	45%
Clay	:	29%
Texture	:	Silty clay

Chemical composition:

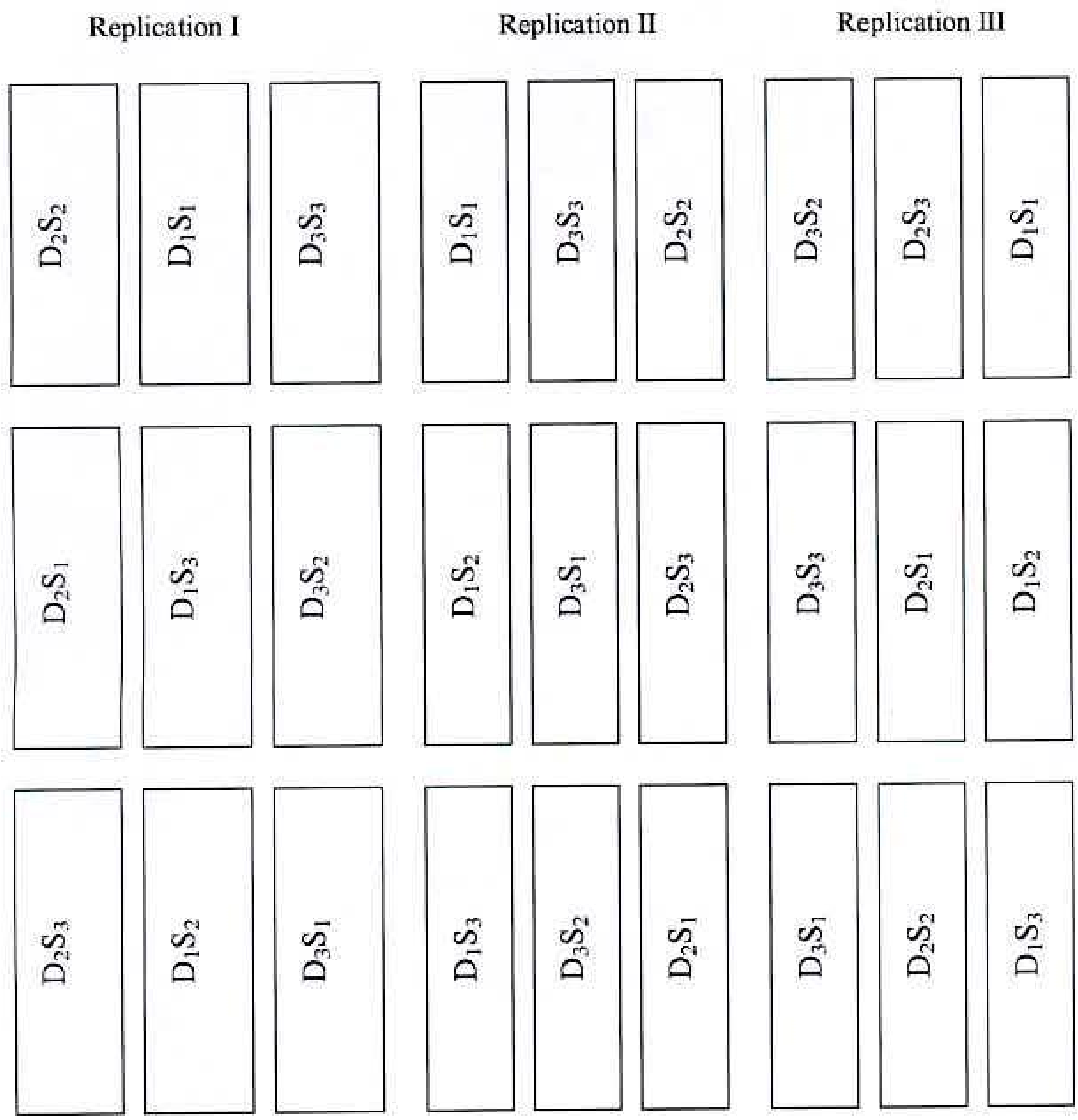
Soil characters	Value
pH	7.1
Organic matter	1.08%
Total Nitrogen	0.054 %
Potassium	0.27 meq/100 g soil
Calcium	3.5 meq/100 g soil
Magnesium	0.46 meq/100 g soil
Phosphorus	10.46 ppm
Sulphur	18 ppm
Boron	0.4 ppm
Copper	1.6 ppm
Iron	14 ppm
Manganese	36.8 ppm
Zinc	1.84 ppm

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

Appendix III. Experimental layout



Plot size: 4 m×2.4 m
Between Plot: 0.5m
Between replication: 1 m



Appendix IV : Analysis of variance on emergence of mungbean

Sources of variation	DF	Mean square Emergence						
		7 day	8day	9day	10day	11day	12day	13day
Replication	2	1.20	20.30	0.28	2.87	15.68	25.05	2.46
Factor A (sowing depth)	2	131.26^{NS}	93.240**	1200.00**	5222.74**	4215.73**	967.322**	346.903**
Error 1	4	4.224	1.872	0.673	3.437	10.225	4.186	4.661
Factor B (seed size)	2	88.854^{NS}	12.231**	0.623*	21.795**	236.488**	630.923**	292.330**
Interaction A*B	4	5.572^{NS}	8.961**	0.115*	12.537**	59.123**	68.250**	19.158**
Error 11	12	3.615	2.643	0.438	0.648	3.506	2.960	3.847
Total	26							

** = Significant at 1 % level; * = Significant at 5 % level; NS = Not Significant
DF =Degrees of freedom

Appendix V: Analysis of variance on epicotyle length hypocotyls length and root length of mungbean

Sources of variation	DF	Mean square		
		Epicotyls length	Hypocotyls length	Root length
Replication	2	0.191	0.693	0.104
Factor A (sowing depth)	2	0.611^{NS}	4.090**	11.659**
Error 1	4	0.501	0.270	2.014
Factor B (seed size)	2	1.071**	2.518**	13.515**
Interaction A*B	4	0.382**	0.393*	8.077**
Error 11	12	0.412	0.735	0.608
Total	26			

** = Significant at 1 % level; * = Significant at 5 % level; NS = Not Significant
DF =Degrees of freedom

Appendix VI: Analysis of variance on shoot and root fresh weight of mungbean

Sources of variation	DF	Mean square		
		Shoot fresh weight (gm)	Root fresh weight(gm)	Total fresh weight(gm)
Replication	2	0.0002*	0.0002*	0.001
Factor A (sowing depth)	2	0.0002**	0.0001**	0.0004**
Error 1	4	0.004	0.0002	0.005
Factor B (seed size)	2	0.0006**	0.0001**	0.0001**
Interaction A*B	4	0.0004**	0.0004**	0.0009**
Error 11	12	0.0004	0.0002	0.0003
Total	26			

Appendix VII : Analysis of variance on plant height of mungbean

Sources of variation	DF	Mean square Plant height (cm)			
		15DAS	30DAS	45DAS	At harvest
Replication	2	0.286	0.230	0.525	0.625
Factor A (sowing depth)	2	1.639*	8.925*	53.368*	18.580*
Error 1	4	0.267	0.382	0.245	0.967
Factor B (seed size)	2	5.779*	13.587*	5.159*	1.962*
Interaction A*B	4	0.669*	1.945*	2.794**	16.332*
Error 11	12	0.386	0.423	0.791	0.670
Total	26				

** = Significant at 1 % level; * = Significant at 5 % level; NS = Not Significant
DF =Degrees of freedom

Appendix VIII: Analysis of variance on leaf dry matter of mungbean

Sources of variation	DF	Mean square Leaf dry matter (gm)			
		15DAS	30DAS	45DAS	At harvest
Replication	2	0.703	0.151	0.283	0.281
Factor A (sowing depth)	2	0.159 ^{NS}	0.994 ^{NS}	1.573*	0.993*
Error 1	4	0.593	0.951	0.625	0.267
Factor B (seed size)	2	0.120*	0.309 ^{NS}	3.269*	0.157*
Interaction A*B	4	0.126*	0.822*	0.270*	0.560 ^{NS}
Error 11	12	0.140	0.778	0.369	0.299
Total	26				

** = Significant at 1 % level; * = Significant at 5 % level; NS = Not Significant
DF =Degrees of freedom

Appendix IX: Analysis of variance on stem dry matter of mungbean

Sources of variation	DF	Mean square Stem dry matter (gm)			
		15DAS	30DAS	45DAS	At harvest
Replication	2	0.470	0.968	0.287	0.424
Factor A (sowing depth)	2	0.727 ^{NS}	0.112 ^{NS}	0.633 ^{NS}	0.128 ^{NS}
Error 1	4	0.204	0.331	0.260	0.327
Factor B (seed size)	2	0.109 ^{NS}	0.379 ^{NS}	1.031 ^{NS}	0.460*
Interaction A*B	4	0.981 ^{NS}	0.230 ^{NS}	0.230*	0.697*
Error 11	12	0.131	0.204	0.844	0.322
Total	26				

** = Significant at 1 % level; * = Significant at 5 % level; NS = Not Significant
DF =Degrees of freedom

Appendix X: Analysis of variance on root dry matter of mungbean

Sources of variation	DF	Mean square Root dry matter (gm) 15 DAS	30 DAS	45 DAS	At harvest
Replication	2	0.593	0.122	0.319	0.297
Factor A (sowing depth)	2	0.316 NS	0.271 NS	0.904 NS	0.748 NS
Error 1	4	0.648	0.108	0.191	0.193
Factor B (seed size)	2	0.127 NS	0.559 NS	0.290 NS	0.112*
Interaction A*B	4	0.626 NS	0.344 NS	0.464 NS	0.505*
Error 11	12	0.180	0.251	0.151	0.121
Total	26				

** = Significant at 1 % level; * = Significant at 5 % level; NS = Not Significant
DF =Degrees of freedom

Appendix XI: Analysis of variance on total dry matter of mungbean

Sources of variation	DF	Mean square Total dry matter (gm) 15DAS	30DAS	45DAS	At harvest
Replication	2	0.521	0.124	0.576	0.676
Factor A (sowing depth)	2	0.697 NS	0.199 NS	6.213**	19.876**
Error 1	4	0.429	0.128	0.107	0.640
Factor B (seed size)	2	0.203 NS	0.680 NS	9.280**	3.932**
Interaction A*B	4	0.182 NS	0.202*	1.352**	3.629**
Error 11	12	0.694	0.941	0.398	0.588
Total	26				

** = Significant at 1 % level; * = Significant at 5 % level; NS = Not Significant
DF =Degrees of freedom

Appendix XII: Analysis of Variance on Number of leaf of mungbean

Sources of variation	DF	Mean square Number of leaves plant^{-1}		
		15DAS	30DAS	45 DAS
Replication	2	0.678	0.123	0.765
Factor A (sowing depth)	2	1.541 ^{NS}	0.796 ^{NS}	14.539*
Error I	4	0.671	0.696	0.234
Factor B (seed size)	2	0.141 ^{NS}	0.991*	4.779*
Interaction A*B	4	0.116 ^{NS}	0.184*	0.485*
Error 11	12	0.144	0.634	0.181
Total	26			

** = Significant at 1 % level; * = Significant at 5 % level; NS = Not Significant
DF =Degrees of freedom

Appendix XIII: Analysis of variance on leaf area index of mungbean

Sources of variation	DF	Mean square Leaf area index		
		15 DAS	30 DAS	45 DAS
Replication	2	0.189	0.474	0.197
Factor A (sowing depth)	2	0.103 ^{NS}	0.685 ^{NS}	3.934*
Error 1	4	0.397	0.344	0.654
Factor B (seed size)	2	0.869 ^{NS}	0.263 ^{NS}	2.310*
Interaction A*B	4	0.258 ^{NS}	0.466*	0.397*
Error 11	12	0.690	0.793	0.124
Total	26			

** = Significant at 1 % level; * = Significant at 5 % level; NS = Not Significant
DF =Degrees of freedom

Appendix XIV: Analysis of variance on leaf area index of mungbean

Sources of variation	DF	Mean square Crop growth rate 30 DAS	45 DAS	At harvest
Replication	2	0.584	0.242	0.356
Factor A (sowing depth)	2	0.782^{NS}	0.270^{NS}	0.178^{NS}
Error 1	4	0.624	0.479	0.234
Factor B (seed size)	2	0.271^{NS}	0.399^{NS}	0.742^{NS}
Interaction A*B	4	0.881^{NS}	0.578*	0.980^{NS}
Error 11	12	0.423	0.178	0.197
Total	26			

]

Appendix XV: Analysis of variance on yield attributes of mungbean

Sources of variation	**DF**	**Mean square** **Yield and other crop character** **No. of branches/plant**	**No. of pods/plant**	**Pod length**	**No. of seeds/pod**	**1000 seed weight (g)**	**Grain weight tons/ha**	**Shelling percentage (%)**	**Harvest index (%)**
Replication	2	0.28	0.28	0.18	0.61	0.91	1.53	0.20	3.042
Factor A (sowing depth)	2	1.46**	1.77^{NS}	1.41^{NS}	0.11^{NS}	36.1**	3.78**	3.21^{NS}	5.046*
Error 1	4	0.33	0.78	0.84	0.83	0.88	4.32	0.94	0.158
Factor B (seed size)	2	0.17^{NS}	0.42^{NS}	1.83*	0.25^{NS}	12.2**	1.82**	0.39^{NS}	6.046*
Interaction A*B	4	0.57**	0.14*	0.27*	0.116*	10.6**	2.78**	0.99*	3.135*
Error 11	12	0.36	0.17	0.19	0.180	0.40	7.48	0.26	1.71
Total	26								

** = Significant at 1 % level; * = Significant at 5 % level; NS = Not Significant

DF =Degrees of freedom

PLATES

Plate 1 Seedling emergence of mungbean at 8 days after emergence when different sized seeds were sown at 2 cm depth.

Plate 2 Seedling emergence of mungbean at 8 days after emergence when small sized seeds were sown at different depths.

Plate 3 Seedling emergence of mungbean at 10 days after emergence when small sized seeds were sown at different depths.

Plate 4 Seedling emergence of mungbean at 10 days after emergence when different sized seeds were sown at 2 cm depth.

Plate 5 Seedling emergence of mungbean at 10 days after emergence when different sized seeds were sown at 6 cm depth

Plate 6 Seedling emergence of mungbean at 12 days after emergence when small sized seeds were sown at different depths

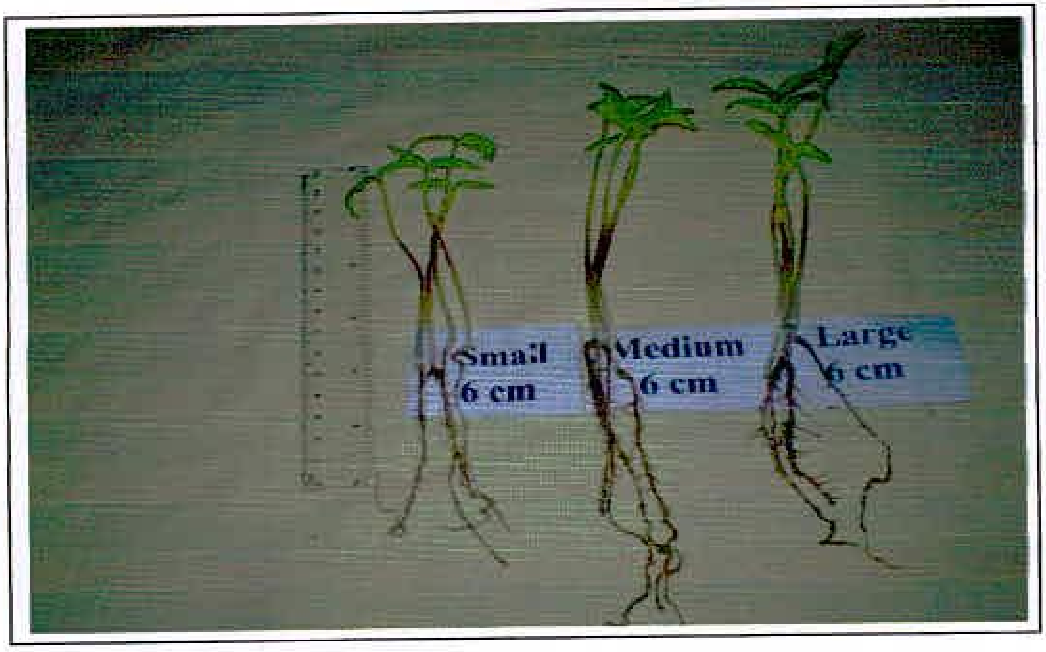


Plate 7 Seedling emergence of mungbean at 12 days after emergence when different sized seeds were sown at 6 cm depth

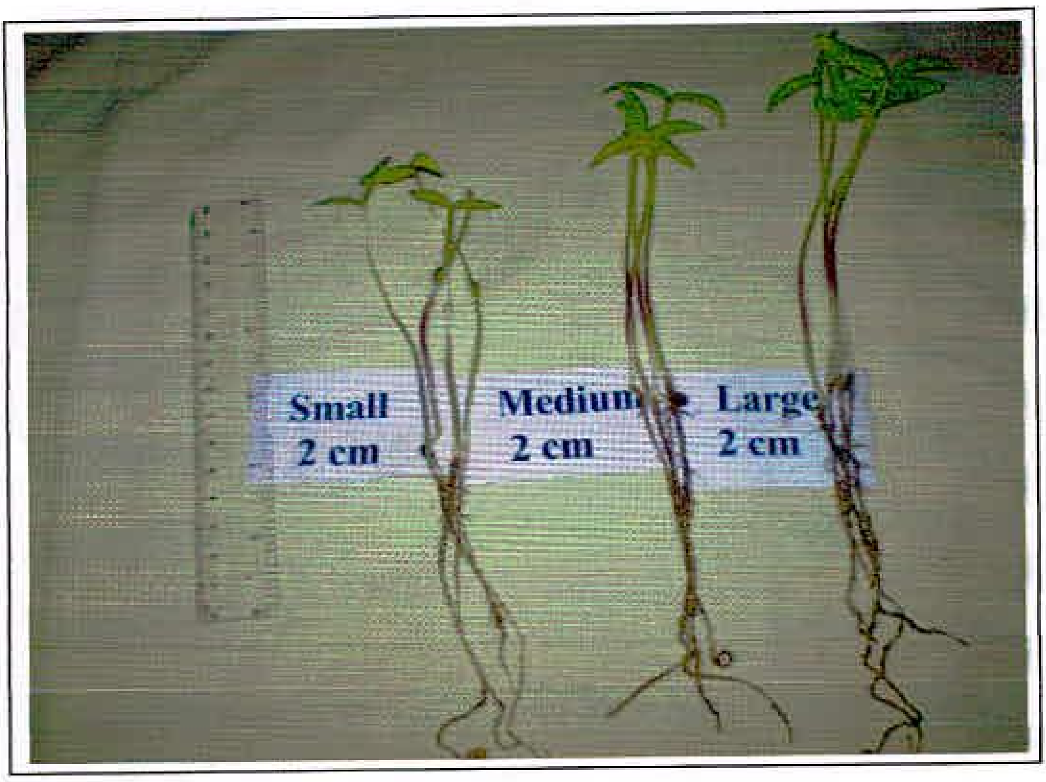


Plate 8 Seedling emergence of mungbean at 12 days after emergence when different sized seeds were sown at 2 cm depth