EFFECT OF SOWING DATE AND SPACING ON GROWTH AND YIELD OF MUNGBEAN

By

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CERTIFICATE

This is to certify that thesis entitled, "EFFECT OF SOWING DATE AND SPACING ON GROWTH AND YIELD OF MUNGBEAN" submitted to the FACULTY OF AGRICULTURE, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (M.S.) in AGRONOMY embodies the result of a piece of bona fide research work carried out by MOHSINA AFREEN registration no. 08-2945 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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ABSTRACT

The experiment was conducted at Sher-e-Bangla Agricultural University farm, during August, 2013 through January, 2014 of *kharif II* season to evaluate the effect of sowing date and spacing on growth and yield of mungbean (*Vigna radiata* L. Wilczek). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The treatments were four sowing dates as S_1 (24 August), S_2 (13 September), S_3 (03 October) and S_4 (23 October), respectively and three spacing as P_1 (20 cm × 10 cm), P_2 (30 cm × 10 cm) and P_3 (40 cm × 10 cm). BARI Mung – 6 was the plant material of the experiment. Data on growth and yield parameters were recorded from vegetative growth to maturity period. The results revealed that all the growth and yield attributes were significantly influenced by different sowing date and spacing and their interaction. Highest plant height (cm), no. of branches plant^{-1}, no. of leaves plant^{-1}, dry weight (gm), no. of pods plant^{-1}, pod length (cm), no. of seeds pod^{-1}, weight of 1000 seed (g), seed yield (t ha^{-1}), stover yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) was observed in S_2 (13 September), where as the minimum was in S_4 (23 October) over different spacing. The highest seed yield (1.53 t ha^{-1}) was obtained from S_2 (13 September) with P_2 (30 cm × 10 cm) treatments and lowest was found in S_4P_3 (sowing on 23 October and spacing at 40 cm × 10 cm). From the results of the experiments, it could be concluded that in *Kharif II* season sowing on 13 September with 30 cm × 10 cm spacing was optimum for obtaining higher grain yields of mungbean. Delay sowing reduced the yield of mungbean due to unfavorable condition for growth and development.

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ABBREVIATED FORM	FULL FORM
%	Percent
AEZ	Agro-ecological Zone
BARI	Bangladesh Agricultural Research Institute
CLS	Cercospora Leaf Spot
cm	Centimeter
CV	Coefficient of Variance
DAS	Days after sowing
DMRT	Duncan's Multiple Range Test
EC	Emulsifiable Concentrate
FAO	Food and Agriculture Organization
g	Gram
ha	Hectare
kg	Kilogram
L	Liter
LAI	Leaf Area Index
LSD	Least Significance Difference
m	Meter
m^2	Square meter
MP	Muriate of Potash
pH	Hydrogen ion concentration
RCBD	Randomized Complete Block Design
SRDI	Soil Resource Development Institute
t	Ton
TSP	Triple Superphosphate
YMV	Yellow Mosaic Virus

Chapter 1

INTRODUCTION

Mungbean (*Vigna radiata* L. Wilczek) is one of the important pulse crops of Bangladesh. It is one of the inter-continental crops but originated in Indian subcontinent. It is an excellent source of vegetable protein (Kaul, 1982), which belongs to the family Fabaceae. The nutritive value of mungbean (grain) contains 1-3% fat, 50.4% carbohydrates, 3.5-4.5% fibers and 4.5-5.5% ash, while calcium and phosphorus are 132 and 367 mg per 100 grams of seed, respectively (Frauque *et al.*, 2000). It is consumed in different ways as dal, halwa, snacks etc. Ascorbic acid (vitamin C) is synthesized in sprouted seeds of mungbean and the amount of riboflavin and thiamine is also increased, which is important for human diet. In combination with cereal, mungbean makes a well-balanced human diet. Hence, on the nutritional point of view, mungbean is perhaps the best of all other pulses (Khan, 1982).

The pulses have the ability to fix atmospheric nitrogen (N_2) in their root nodules in association with specific *Rhizobium/Bradyrhizobium* species. In mungbean nitrogen derived from N_2 fixation is 15-17% and total nitrogen fixed is 9-137 kg/ha (Singh and Sekhon, 2005). The residual effects of preceding pulse crops on cereals yield in terms of fertilizer-N equivalent may vary, these may be 68 kg/ha in case of mungbean (Wani *et al.*, 1995). When mungbean is sown in mungbean-rice rotation it not only increases nitrogen uptake in rice due to N-fixation as well as incorporation of plant residues, but also improves rice grain yield (Rahman *et al.*, 2012). Incorporation of mungbean residue increases the biological activity in soil as measured by dehydrogenase activity and carbon dioxide (CO_2) evolution (Singh and Sekhon, 2005).

Pulse crops can be grown in different cropping systems. When mungbean is grown in a cropping system, its residue incorporation improves soil fertility and crop productivity (Singh *et al.*, 2008). Mungbean is an excellent green manure crop also (Algan and Celen, 2011). It can be used for green manuring after picking pods or threshing grains. The stem and leaves of pulses are used in preparing a concentrate feed called "Bhushi" which is rich in protein. The husks of the seeds are also used as feed of cattle. As a whole pulse crop could be considered as a component of sustainable agriculture.

A good number of high yielding mungbean varieties are available now in Bangladesh. The agro-ecological condition of Bangladesh is favorable for growing mungbean in the winter season although it is cultivated in both summer and winter seasons in many countries of the world (Bose, 1982). Recently, farmers are not much interested in growing pulse crops in winter season. Besides these, increasing area under wheat and irrigated boro rice cultivation has further reduced the area under pulses. Therefore, it has become imperative to shift the cultivation of some of the low yielding pulses from winter to summer seasons. The possibility of growing mungbean in the summer season in Bangladesh has been tried with some success (FAO, 1984).

Mungbean is a short duration crop, it can be well fitted as a cash crop between major cropping seasons. The technology is already tested in the agro-ecological zone of warm humid tropics in mixed rainfed farming systems in northwestern Bangladesh. But the Mungbean cultivation has yet not gained expected popularity among the farmers.

At farmer's level, the average yield of mungbean is very low due to lack of knowledge of selecting and planting the suitable variety and using appropriate agronomic practices. The time of sowing is the most important non-monetary factor for realizing the maximum genetic potential of a cultivar, since it ensures the complete harmony between the vegetative and reproductive phases on one hand, and the climatic rhythm on the other (Singh and Dhingra, 1993; Ram *et al.*, 2011). The date of sowing exerts influence through the effects of various environmental factors, mainly temperature, photoperiod and rainfall that influence the phenological development of mungbean in all growth stages and, therefore, determines the adaptability of mungbean cultivars. The early sown crop suffers due to excessive vegetative growth, whereas, the late sown crop has a constraint of limited growth, resulting in poor pod setting in both cases.

The climate change and global warming has deleterious effects on crop production in terms of period of maturity and yield (Singh *et al.*, 2012b). From the last few years, the change in climate has been observed (Swaminathan and Kesavan, 2012) and it may affect the time of sowing of various varieties of mungbean. Besides optimum sowing time, planting geometry also plays a vital role in influencing plant growth, yield attributes and grain yield of mungbean (Sarkar *et al.*, 2004; Mathur *et al.*, 2007). There was a need to find out optimum spacing of mungbean varieties under different sowing dates.

Another reason of low yield of mungbean is inappropriate plant population. Farmers usually grow mungbean by broadcasting method of sowing which requires higher seed rate and tended to maintain inconsistent plant stand establishment poor growth and difficulty in managing pests and diseases as well as intercultural operations. It is an established fact as reported by many researchers (Khan *et al.*, 2001) that the plant population should be kept optimum to obtain maximum yield.

Bangladesh Agricultural Research Institute (BARI) has developed six high yielding varieties of this legume. Among these varieties, BARI Mung-6 is a yield potential pulse crop. It is well fit growing capacity in all crop rotations in Bangladesh (BARI, 1998). BARI Mung- 6 is well known that short duration and drought tolerant crops. Even mungbean variety shows disease, insect and pest resistance compared to the other mungbean varieties.

So, in recognizing the fact, it is an urgent need for choosing the right variety of mungbean that fits with right date of sowing and appropriate plant density. Therefore, the main focus of this study is given on increasing yield through adoption of improved cultural practices (i.e. choosing sowing date and spacing) of a particular variety of mungbean (BARI Mung- 6) for establishing mungbean as a profitable crop. Proper combination of sowing time and spacing can make the microclimate favorable for mungbean.

In Bangladesh, several studies have been conducted to find out the effects of sowing date and spacing separately but there is a few numbers of findings on the combined effects of these two factors on BARI Mung- 6. Considering the above facts the present study was undertaken with the following specific objectives -

i) to identify the suitable sowing date of BARI Mung- 6 in *kharif-II* season,

ii) to find out the optimum spacing of BARI Mung- 6 and

iii) to assess the yield performance of BARI Mung- 6 with combined effect of sowing date and spacing, thereby finding out the optimum combination of sowing time and spacing.

Chapter 2

REVIEW OF LITERATURE

Mungbean is an important pulse crop in many Asian countries including Bangladesh, where the diet is mostly cereal based. The crop has conventional less concentration by the researchers on various aspects because normally it grows with less care and management practices. For that a very few studies related to growth, yield and development of mungbean have been carried out in our country as well as many other countries of the world. In this chapter, an attempt has been made to review some available literature related to present study under the following headings:

2.1. Effects of sowing date

Sowing time, a non-monetary input, is the single most important factor to obtain optimum yield from mungbean (Samanta *et al.*, 1999). High yielding varieties and suitable sowing time are the most important factors affecting the yield. Too early sowing may not successfully germinate, while yield from too late sown crop may be low due to unfavorable condition for growth and development of mungbean (Hussain *et al.*, 2004). There must be a specific sowing date, especially in the summer season for different varieties to obtain maximum yield.

For improved mungbean production, optimum sowing time may vary from variety to variety and season to season due to variation in agro-ecological conditions as it determines the vegetative, reproductive and maturity periods (Soomro and Khan, 2003). Several research efforts on planting date effects on mungbean performance have already been done in different regions of the world. However, little information is available regarding its effects under rainfed environments as moisture utilization at proper time is necessary for good crop production (Hussain *et al.*, 2004; Miah *et al.*, 2009).

In Bangladesh research has been done on growth, yield attributes and yield of different varieties of mungbean in relation to variation of sowing time (Ahmed *et al.*, 1978; Miah *et al.*, 2009; Nag *et al.* 2000). Different scientists reported that majority of crops can utilize the factors of favourable environment which ultimately influences plant to have more growth and development in mungbean plants (Miah *et al.*, 2009; Quresh and Rahim, 1987; Soomro, 2003; Sarker *et al.*, 2004).

Delayed planting generally shifts reproductive growth into less favorable conditions with shorter days and lower radiation and temperature. Early or late sown crop may not germinate properly followed by lower growth and development producing lower yield (Hussain *et al.*, 2004). Earlier 50% flowering with delayed sowings have been observed in mungbean (Singh *et al.*, 2010).

Rehman *et al.* (2009) conducted a field experiment at Peshawar (Pakistan) to study the effect of sowing dates (30 March, 15 April, 15 May, 15 June and 15 July). They revealed that significant differences were observed among various sowing dates for all the parameters except grains per pod. Sowing date of 30 March took more days to emergence, flowering and physiological maturity. Maximum emergence was recorded for 15 April sowing. The crop attained maximum plant height under 15 May sowing. Highest grain yield was recorded for early planting of 30 March.

Fraz *et al.* (2006), who reported higher number of pods/plant in late sowing (3rd week of July) as compared to early sowing (3rd week of June) at Faisalabad (Pakistan). Sarker *et al.*, (2004) showed that pod length of mungbean was significantly influenced by planting time. Gebolglue *et al.*, (1996) reported higher number of pods per plant in late sowing as compared to early sowing. Sadeghipour (2008) and Sarkar *et al.*, (2004) reported that number of seed per pod affected by sowing date. Early sowing invites a large number of insect pests and diseases, while late sowing fetches lesser grain yield due to short growing season and ultimately lesser accumulation of photosynthates (Quresh & Rahim, 1987).

Farrag (1995) reported in a field study conducted on mungbean (*Vigna radiata*) at El-Mania, Egypt that 1^{st} May sowing gave the earliest maturity and a significant increase in total grain yield, number of pods plant^{-1}, number of grains plant^{-1} and 1000 grain weight compared to 15th March and 15th June sowings. Mungbean crop sown in first week of July produced taller plants, higher yield and yield components (Ramzan *et al.*, 1992). Seed yield, days to emergence and days to maturity of mungbean cultivars decreased with delay in sowing time (Thakar and Dhingra, 1993; Yadav *et al.*, 1995; Rakash *et al.*, 2000) reported that mungbean crop sown on 15th March had higher number of pods plant^{-1}, seeds pod^{-1} and higher grain yield. Raza *et al.*, (1995) revealed that mungbean yield were higher in crop sown in June and July.

There was a linear relationship between appearance of leaves and accumulation of heat in comparison between two mung-bean varieties in different planting dates. Delay in planting date caused decrease in length of main stems, sub stems and the number of pod and as a result, decrease in grain yield. Planting date was effective on seed yield and delayed planting caused the weakness of performance so that the highest on the first planting and the third seeding date had lowest performance.

Singh and Sekhon (2002) reported that at Ludhiana (Punjab), the crop sown on 12 July produced significantly higher grain yield than 2 August sowing due to taller plants, more branches per plant, more pods per plant and higher number of seeds per pod. Late sown crop could not attain proper growth; which resulted in drastic reduction in yield. Soomro and Khan (2003) at Islamabad (Pakistan) found that the early sowing (5 July) showed maximum (9.2 cm) pod length, followed by 15 July sown crop (8.5 cm) and least pod length (5.1 cm) was observed in last sowing (5 August) so it was concluded that first week of July was the ideal time of sowing.

Muhammad *et al.* (2005) conducted a field experiment at Dera Ismail Khan (Pakistan), with seven sowing dates (15 April, 1 May, 15 May, 1 June, 15 June, 1 July and 1 August) of mungbean and found that sowing on 1 May resulted in the highest number of branches per plant, pods per plant, 1000- grain weight and grain yield.

Singh *et al.* (2012b) conducted a field experiment at Ludhiana (Punjab) during *kharif* season for evaluation of date of sowing for mungbean. The crop was sown on two different dates (last week of July and first week of August). The plant height, number of pod per plant, seeds per plant and 100-seed weight was significantly higher when mungbean sown in last week of July as compared to first week of August and resulted higher grain yield.

Singh *et al.*, (2012a) conducted a field experiment at Varanasi (Uttar Pradesh) which was sown on 1 July, 16 July, 1 August and 16 August. The results revealed the higher disease (Web blight) severity on the crop sown on 1 July (63.3%) and 16 July (56.0%) than that on sown on 16 August (24.8%). However, crop sown on 1 August (683 kg/ha) recorded maximum grain yield compared to those which were sown on 1 July (557 kg/ha) and had comparatively lower disease (48.9%) than crop sown on 16 July (56.0%).

Among the various agronomic practices, planting time is the most important factor influencing the yield of mungbean (Asghar Malik *et al.*, 2006). Patel *et al.*, (1992) reported that the grain yield of two varieties of mungbean was considerably more at the first date of sowing as compared to second date of sowing. Delayed sowing after March and early sowing before February reduce yield of summer mungbean (Chovatia *et al.*, 1993). Yield of non-primed mung bean declined linearly with date of sowing.

Miah *et al.* (2009) who reported that early sowing before 2 March summer mungbean caused a substantial decrease in growth and yield of mungbean. The highest seed yield obtained from 2 March sowing might be due to suitable temperature prevailing accompanied by higher soil moisture content due to sufficient rainfall in April, which enhanced the vegetative as well as reproductive growth of the crop. This findings closely resembles to those reported by Sinha *et al.*, (1989), Poehlman (1991) and Miah *et al.*, (2009) who opined that mungbean being a warm season plant produced higher yield at the optimum mean temperature range of 25-30^{o}C.

Sadeghipour (2008) reported from Tehran (Iran) that crop sown on 29 June gave maximum grain yield because number of pods per plant and 1000-seed weight were increased, while crop sown on 30 May produced minimum grain yield due to decreased number of pods per plant. Singh *et al.* (2010) at Ludhiana tested mungbean sowing on 5, 15, 25 July or 5 August and reported higher grain yield with 15 and 25 July sowings than with 5 July and 5 August sowing dates. Sangakkara (1998) reported from Sri Lanka that late sowing of mungbean produced the lowest yields of low quality seeds.

In a field trial at Gwalior (Madhya Pradesh), Sharma *et al.* (1988) had sown mungbean on 13 July, 23 July, 2 August and 12 August and found that delay in sowing decreased grain yield. In Kwangju (Korea), Choi *et al.*, (1991) tested three sowing dates (21 May, 15 June and 10 July) and reported that 15 June gave the highest number of pods per plant and highest grain yield. At Dharwad (Karnataka), Suresh and Padaganur (1991) evaluated sowing dates of 8 June, 23 June, 8 July and 23 July, and reported that the early sown date had the lowest percentage disease index and highest grain yield. In Chakwal (Pakistan), Ramzan *et al.*, (1992) reported that when mungbean was sown on 4, 14 or 24 July as well as August, sowing on 4 and 14 July gave greater grain yield and yield components and sowing thereafter greatly reduced grain yield.

Singh and Dhingra (1993) conducted an experiment at Bathinda (Punjab) on mungbean which was sown on 1, 10, 20 or 30 July and found that higher grain yield was obtained from the 1 July sown crop which was significantly higher than grain yield obtained from 20 July and 30 July sown crop but was statistically at par with 10 July sowing. The higher grain yield from the early sowing was due to higher number of primary branches per plant, pods per plant, seed per pod or1000-seed weight.

In Hazipur (Bangladesh), Razzaque *et al.* (2005) tested sowing of mungbean from January to May and reported that 15 February gave highest grain yield. Fraz *et at.* (2006) reported maximum grain yield in late sowing date (3rd week of July) as compared to early sowing (3rd week of June and 1st week of July) due to higher number of pods per plant, number of grain per pod, 1000-grainweight and harvest index. This might be due to decreased vegetative growth and increased reproductive growth, which favored these characters.

Farghali and Hussein (1995) in an experiment on 23 accessions of mungbean grown under different sowing time (15 February, 15 May and 15 August) at Assuit, Egypt observed that 15 May sown crop was superior to 15 February and 15 August sowings with respect to number of cluster per plant, number of seeds per pod and 1000-grain weight. The highest number of pods per plant and total grain yield were obtained from the 15 August sowing date.

Chahal (1998) at Ludhiana (Punjab) conducted an experiment with four sowing dates and, the grain yield of the mungbean sown on 25 June, 7 July, 22 July and 6 August was 764, 905, 623 and 481 kg ha^{-1}, respectively. The crop sown on 7 July provided significantly higher grain yield, recording 18, 45 and 88 percent increase as compared to yield under 25 June, 22 July and 6 August sown crops. Total dry matter accumulation, number of pods per plant, number of grains per pod and 1000-grain weight in case of 7 July sown crop were significantly higher than those of other three planting dates tried.

Sekhon *et al.* (2004) conducted a field experiment at Ludhiana (Punjab) with four sowing dates of 8, 16, 24 July and 1 August. They reported that 8 and 16 July sowings gave significantly higher grain yield. In another trial by these researchers 10 and 25 July sowings gave more yield than 10 August sowing. At Peshawar (Pakistan), the effects of sowing date (15 April, 15 May, 15 June, 15 July and 15 August) on performance of mungbean were studied by Hussain *et al.* (2004). They found that 15 April took more number of days to emergence, showed maximum plant height and gave the highest grain yield.

At Ludhiana (Punjab), Singh and Sekhon (2007) reported that in one experiment the mungbean crop sown on 8 July recorded the highest yield (1780 kg/ha), which was significantly higher than the yield recorded with the crop sown on 16 July (1650 kg/ha), 24 July (1426 kg ha^{-1}) and 1 August (1426 kg ha^{-1}) and in another experiment 25 July sowing produced the highest grain yield (1309 kg ha^{-1}), 10 July being at par with it (1293 kg/ha) and both being significantly superior to 10 August sowing (1179 kg ha^{-1}). Lower yield under delayed sowing was the result of reduction in number of pods per plant, 1000-seed weight and the biological yield. Sharma *et al.* (2007) from Ludhiana reported maximum grain yield in early sowing (10 July) as compared to late sowings (26 July and 10 August) due to favourable temperature, which resulted into better plant height, increased number of branches per plant, higher number of pods per plant and higher 100-seed weight. The late planting affected the growth and yield attributing characters.

Monem *et al.* (2012) conducted a field experiment at Varamin (Iran) on mungbean which was sown on 5 May, 20 May and 6 June and found that sowing on 5 May was significantly superior to 20 May and 6 June sowings due to higher number of seeds per pod, harvest index and grain yield. Singh *et al.*,(2003) compared the performance of mungbean under four sowing dates (1 July, 12 July, 24 July and 5 August) and reported the lowest grain yield of 5 August sown crop.

A field experiment was carried out at Dhaka (Bangladesh) to study the effect of time of sowing (15 March, 15 April and 15 May) on the growth and yield of mungbean and found that 15 April sown crop had maximum plant height (68.4 cm), leaves per plant (29.33), total dry matter per plant (17.99 g), branches per plant (8.17), pods per plant (11.33), pod length (8.78 cm), seeds per pod (11.17), 1000-seed weight (46.52 g), grain yield per plant (5.33 g), grain yield per ha (1.77 tonnes) and harvest index (29.58%). The grain yield decreased by 36.8 and 49.9% when the crop was sown early (15 March) or late (15 May) due to production of lower yield components (Jahan and Adam, 2012).

Seijoon *et al.* (2000) also found similar results and opined that the increased harvest index with late sowing could be related to high assimilate use efficiency due to increased sink capacity. Differences in harvest index under different sowing dates of mungbean have also been reported by other researchers (Kabir and Sarkar, 2008, Miah *et al.*, 2009, Jahan and Adam, 2012).

2.2. Effects of spacing

Seed yield and yield components of mungbean are markedly influenced by planting density. The farmers usually grow mungbean without maintaining proper planting density. They hesitate to grow mungbean in rows, although row planting facilitates easy intercultural operations resulting in higher yield (BARI, 1997). Row planting with appropriate planting density can help ensure optimum plant population per unit area of mungbean thereby increasing the yield (BARI, 1998). Mungbean grown at a density of 33 plant m^{-2} produced higher yield (Thakuria and Saharia, 1997). Optimum plant density for higher yield of mungbean was 50 to 60 plants m^{-2}(Mimber, 1993) and 30 to 40 plants m^{-2} (BARI, 1998). The highest yield of mungbean was observed from a density of 33 plants m^{-2} (Haque, 1995).

Planting pattern influences radiation interception and utilization of moisture from soil (Rehman, 2002). Broadcasting is still the principal method of mungbean raising, which is one of the major yield limiting factor. It is well documented that line sowing in appropriate rows is the best strategy for higher production (Ansari *et al.*, 2000). Rajput *et al.*, (1984) reported that number of pods per plant was significantly affected by planting geometry.

Mathur *et al.* (2007) observed that at wider spacing of 45cm seed per pod and 100 seed weight recorded an increase of 11.9 and 15.7 per cent, respectively in comparison to narrow spacing. They attributed it to the fact that comparatively higher wind speed and limited moisture availability during the pre-flowering and flowering stage resulted in more dropping of flowers at wider spacing.

Rajput *et al.* (1993) in Pakistan conducted an experiment to study the performance of mungbean which was sown in row spacing of 20, 30 and 40 cm (with a constant intra-row spacing of 6 cm). The results revealed that effect of row spacing on grain yield was significant. The maximum grain yield was recorded in closest spacing of 20 cm due to high plant population in this treatment and also due to better utilization of inter row-spacing than in the wide row spacing. Inter-plot interference caused a 12%

yield reduction in Oslo in the north–south rows, which was significantly greater than the 7% yield reduction in the east–west row orientation.

Sathyamoorthi *et al.* (2008) at Kumulur (Tamil Nadu) conducted an experiment to study the performance of mungbean which was sown in row spacing of 20, 25 and 30 cm (with a constant intra-row spacing of 10 cm) and found that grain yield was higher under a greater plant density. A field trial was conducted by Kabir and Sarkar (2008) at Mymensingh (Bangladesh) on *kharif* season mungbean to compare three planting geometries (30 cm × 10 cm, 20 cm × 20 cm and 40 cm × 30 cm) and reported higher stover yield and grain yield at 30 cm × 10 cm spacing as compared to other treatments.

An experiment was conducted at Ludhiana (Punjab) on mungbean to compare three planting geometry (20 cm × 10 cm, 25 cm × 10 cm, 30 cm × 10 cm) and revealed that the highest number and dry weight of nodules/plant, branches/plant, pods/plant was obtained at 30 cm × 10 cm spacing, but a planting geometry of 25 cm × 10 cm recorded higher grain yield which was statistically at par with 20 cm × 10 cm and significantly superior to 30 cm × 10 cm spacing. This may be due to higher number of pods and grains per unit area, which resulted in higher grain yield in these treatments.

Singh *et al.* (2012b) at Ludhiana (Punjab) studied the effect of planting geometry on yield and yield components of mungbean which was sown in spacing of 30 cm × 15 cm and 45 cm × 15 cm and showed that the heat units were at par in both the spacing and the higher heat use efficiency was observed in the wider spacing of 45 cm × 15 cm than in closer spacing of 30 cm × 15 cm. The spacing of 30 cm × 15 cm produced significantly higher plant height, number of branches per plant, pods per plant and 100-seed weight as compared to 45 cm × 15 cm.

Mathur *et al.* (2007) observed significant increase in the height due to wider spacing of 45 cm over 30 cm. Sekhon *et al.*, (2002) observed that population density did not affect the plant height while number of branches/plant, LAI and number of pods/plant was significantly affected. They further observed that the plant height remained unaffected by population density yet it tended to increase with increase in population. Singh *et al.*, (2010) observed a linear decline in the plant height with delay in sowing. They further reported that with delay in sowing, the flowering and maturity periods were reduced in all the genotypes. The smallest plants may be due to less plant to plant distance within row, which may have resulted in retarded growth as reported by Singh and Sahu (1998).

Rasul *et al.* (2012) conducted an experiment at Faisalabad (Pakistan) on *kharif* season mungbean to compare three planting geometries (30 cm × 8 cm, 45 cm × 8, 60 cm × 8 cm) and observed that the planting geometry of 30 cm × 8 cm had higher grain yield as compared to other two planting geometries.

A field trial was conducted at Varanasi (Uttar Pradesh) by Singh *et al.*, (2012a) on *kharif* season mungbean to compare five planting geometries (30 cm × 15 cm, 40 cm × 15 cm, 45 cm × 15 cm, 50 cm × 15 cm and 60 cm × 15 cm) and the maximum grain yield (672 kg ha^{-1}) was recorded on 50 cm × 15 cm spacing than the narrow (30 cm × 15 cm, 40 cm × 15 cm), normal (45 cm × 15 cm) and wider (60 cm × 15 cm) spacing. The dense crop canopy (30 cm × 15 cm) exhibited maximum (web blight) disease severity (76.5%) which resulted into reduced grain yield (488 kg ha^{-1}), which may be due to fast spread of disease in closely spaced planting. While in wider spacing (60 cm × 15 cm) although there was a low disease severity (30.9%) but poor grain yield was recorded, this may be due to poor plant stand per unit area.

Quresh and Rahim (1987) found that earlier planting gave significantly higher mean biological yield. The probable reason for this might be the less plant population in early sowing and heavy rains, which adversely affected the mungbean production. Khan *et al.* (2001) found that planting geometry had significant effect on both biological and seed yield. Seijoon *et al.* (2000) also found similar results and suggested that the increased harvest index with late sowing could be related to high assimilate use efficiency due to increased sink capacity. Hussain (2003) found that sowing methods affected the harvest index and maximum harvest index was recorded with bed sowing. In case of varieties and planting geometry the differences with respect to harvest index were found to be non-significant. However, the results are contradictory to the findings of Kabir and Sarkar (2008) who showed significant differences in harvest index under different planting geometries.

Khan *et al.* (2001) at Peshawar (Pakistan) studied the effect of planting geometry on yield and yield components of mungbean which was sown in row spacing of 25 and 50 cm, while plant spacing was 5, 7.5 and 10 cm. The spacing of 50 cm × 10 cm produced the maximum number of pods per plant, grains per pod, 1000-grain weight, biological yield, harvest index and grain yield. Sekhon *et al.* (2002) conducted an experiment at Ludhiana (Punjab) on *kharif* season mungbean to compare three planting geometries (30 cm × 10 cm, 45 cm × 10 cm and 30 cm × 20 cm) and observed that the planting geometries of 30 cm × 10 cm and 45 cm × 10 cm had higher grain yield compared to 30 cm × 20 cm. Younas (1993) viewed that planting patterns have a significant influence on 1000- grain weight. Significant differences in harvest index % value have also been reported by Jan *et al.* (2000) who reported progressive decrease in harvest index % with increasing seed rate.

For obtaining high yields, optimum seed rate should be used for planting in an appropriate planting geometry. Extensive studies in India showed that 20 cm × 10 cm spacing was superior to 30 cm × 10 cm in summer season while in Kharif (rainy season) 30 cm × 10 cm spacing was optimum for obtaining higher grain yields of mungbean (PAU,1998; Ahlawat and Rana, 2002). In Bangladesh, planting density of 30 cm × 10 cm gave higher yield of mungbean than 20 cm × 20 cm or 40 cm × 30 cm planting density (Sarkar *et al.,* 2004). High variation has been reported in mungbean with respect to growth, phenology, yield attributes and grain yield (Yimram *et al.,* 2009).

The importance of using optimum seed rate and plant spacing has been recognized by the researchers. There has been found a significant difference in the mean seed yield of adopters and non-adopters of mungbean's appropriate seed rate (Dolli and Swamy, 1997). Both over and under plant densities result in significant yield decrease, however, medium plant density is required to harvest maximum seed yield (Ashour *et* *al.*, 1995). Sarkar *et al.* (2004) in an experiment studied the effect of plant density on the yield and yield attributes of mungbean and observed that 30 × 10 cm plant density always showed highest yield performance.

From the above reviewed literature it can be conceptualized that there is significant effects of sowing date and spacing on productivity and growth of different varieties of mungbean in different cultivation environment. So, it revealed that there is a scope of study on BARI Mung- 6 relating to sowing date and spacing in our rainfed environmental condition and crop rotation.

Chapter 3

MATERIALS AND METHODS

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka during August, 2013 to January, 2014 of *kharif II* season to study the effect of sowing date and spacing on growth and yield of mungbean. The details of materials used and methodologies followed in the experimental period are presented in this chapter under the following headings:

3.1. Description of the experimental site

3.1.1. Site and soil

The experimental site is located between $23^{\circ}77'$ N latitude and $90^{\circ}33'$ E longitude at an altitude of 8.6 m above sea level. The soil belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ- 28) and the general soil type is shallow red brown terrace soils. The land topography is medium high and soil texture is silty clay with pH 5.6. The characteristics of the soil under the experimental area were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka and presented in Appendix I.

3.1.2. Climate

The climate of the experimental site is subtropical which is characterized by high temperature and heavy rainfall during *kharif* season (March-September) and scanty rainfall during *Rabi* season (October-March) associated with moderately low temperature. The prevailing weather conditions during the period of experiment was collected from the Bangladesh Meteorological Department (Climate and Weather Division), Sher-e-Bangla Nagar and presented in Appendix II.

3.2. Planting materials

The seed of BARI Mung- 6, a modern mungbean variety was used as experimental material. BARI Mung- 6 was innovated by Bangladesh Agricultural Research Institute (BARI) in 2003. BARI Mung- 6 is a short duration, disease (YMV & CLS) resistant, photo insensitive, synchronous maturity and late potential mungbean variety. It was characterized as of 40-45 cm in height and life cycle lasts for 55-60 days. The plants are erect, stiff and less branched. Each plant contains 15-20 pods. Each pod is approximately 10 cm long and contains 8-10 seeds (5 to 6 gram per 100 seeds). Seeds are green in color and drum shaped. The seed yield of BARI Mung-6 ranges from 1.5-1.6 tons ha^{-1}.

3.3. Treatment

The experiment was consisted of two factors:

A. Sowing Date: 4

1. Sowing on 24 August (S_1)

2. Sowing on 13 September (S_2)

3. Sowing on 03 October (S_3)

4. Sowing on 23 October (S_4)

B. Plant Spacing: 3

1. 20 cm × 10 cm (P_1)

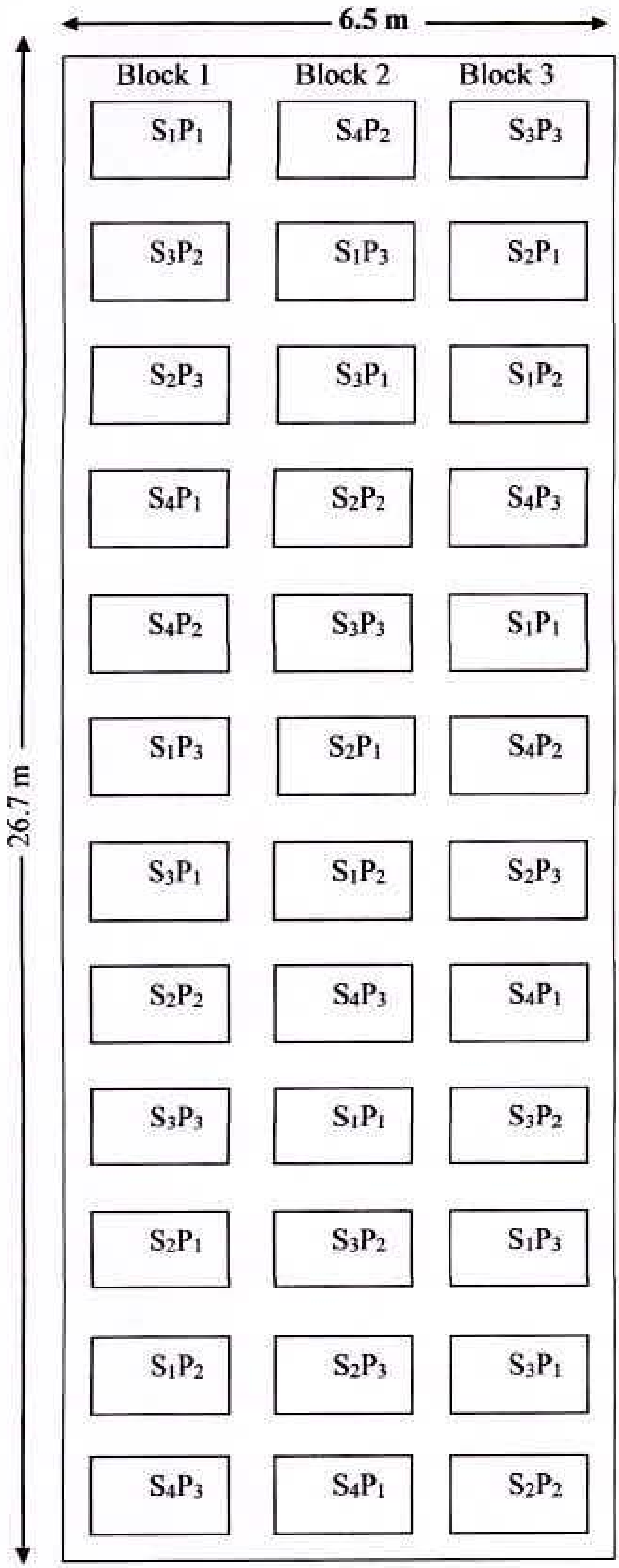
2. 30 cm × 10 cm (P_2)

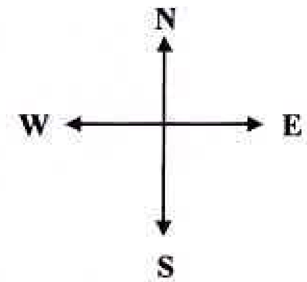
3. 40 cm × 10 cm (P_3)

There were on the whole 12 treatment combinations such as S_1P_1, S_1P_2, S_1P_3, S_2P_1, S_2P_2, S_2P_3, S_3P_1, S_3P_2, S_3P_3, S_4P_1, S_4P_2 and S_4P_3.

3.4. Experimental design and layout

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental area was divided into three equal blocks. Each block was divided into 12 plots, where 12 treatment combinations were allocated at random. There were 36 unit plots altogether in the experiment. The size of the each unit plot was 4 m^2. The distance maintained between two blocks and two plots was 0.25 m. The layout of the experiment is shown in figure 1.





Plot size: 2.0 m × 2.0 m
Plot to plot: 0.25 m
Replication to replication: 0.25 m

Factor A:
S_1 : Sowing on 24 August
S_2 : Sowing on 13 September
S_3 : Sowing on 03 October
S_4 : Sowing on 23 October

Factor B:
P_1 : Spacing at 20 cm × 10 cm
P_2 : Spacing at 30 cm × 10 cm
P_3 : Spacing at 40 cm × 10 cm

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

3.5. Land preparation

The land was irrigated before ploughing. After having zoe condition the land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 3 operations of ploughing, harrowing and laddering. The stubbles and weeds were removed. Land preparation was completed on 21 August, 2013. Experimental land was divided into unit plots following the design of experiment and spaded one day before planting.

3.6. Fertilizer application

Recommended doses of fertilizers - urea, Triple Superphosphate (TSP) and Muriate of Potash (MP) were at the rate of 45, 100 and 58 kg ha^{-1} respectively. The fertilizers were applied as basal dose before sowing of seeds.

3.7. Sowing of seeds

The seeds of BARI Mung-6 were sown as per the sowing date of treatment i.e. August 24, September 13, October 03 and October 23, 2013. The seeds were sown in the furrows having 3 cm depth at spacing of 20 cm × 10 cm, 30 cm × 10 cm and 40 cm × 10 cm and the furrows were covered with the soils soon after seeding.

3.8. Intercultural operations

3.8.1. Thinning and weeding

Seeds were germinated four days after sowing (DAS). Thinning was done twice; first thinning was done at 10 days after sowing and second was done at18 days after sowing to maintain 10 cm distance between plants to obtain proper plant population in each plot. Two hand weeding were done at 20 and 35 days after sowing (DAS).

3.8.2. Irrigation and drainage

The crop was cultivated under residual soil moisture condition without irrigation. But two irrigations were given as plants required. First irrigation was given after third sowing and second irrigation were applied after fourth sowing. After first sowing, there was heavy rainfall for several times. So it was essential to remove the excess water from the field.

3.8.3. Insect and pest control

At early stage of growth few hairy caterpillar and virus vectors (jassid) attacked the young plants and at later stage of growth pod borer attacked the plant. Hairy caterpillar and pod borer were successfully controlled by the application of Diazinon 50 EC and Ripcord @ 1 L ha^{-1} on the time of 50% pod formation stage.

3.9. Plant sampling and collection

Three plants from each treatment were randomly marked outside the central row of each plot with sample card. Plant heights, branches per plant were recorded 5 times from selected plant at an interval of 10 days.

3.10. Determination of maturity

At the time when 90% of the pods turned brown color, the crop was assessed to attain maturity.

3.11. Harvesting and processing

The crop was harvested as per experimental specification. Before harvesting three sample plants from each plot was marked outside and harvested for recording the different data of different yield contributing characters. The rest of the plants of prefixed $1m^2$ areas were harvested plot wise and were bundled separately, tagged and brought to the threshing floor. The harvesting was done by picking pods from central rows for avoiding the border effects. The collected pods were sun dried, threshed and weighed to a control moisture level. The seed weight of three harvesting per plot was added and converted per hectare basis.

3.12. Outline of data recording

The following data were recorded from the each treatment.

A. Growth Parameters

i. Days to seedling emergence

ii. Days to first flowering

iii. Plant height at 10 days interval

iv. Number of branches per plant at 10 days interval

v. Number of leaves per plant at 10 days interval

vi. Dry weight per plant at 10 days interval

B. Yield contributing parameters

i. Number of pods per plant

ii. Pod length

iii. Number of seeds per pod

iv. 1000 seeds weight

C. Yield and harvest index

i. Seed yield

ii. Stover yield

iii. Biological yield

iv. Harvest index

3.13. Recording of data

A. Growth Parameters

i. Days to seedling emergence

Days to seedling emergence were recorded by counting the number of days required to start germination of seeds.

ii. Plant height

The heights of three randomly pre-selected plants from each plot was measured with a meter scale from the ground level to the tip of the leaf apex and mean height was expressed in cm. Data were recorded from the inner rows of each plot at 10 days interval.

iii. Number of branches plant^{-1}

Number of branches plant^{-1} was counted from each selected plant sample and the mean values were determined.

iv. Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted from each selected plant sample and the mean values were determined.

v. Dry weight plant^{-1}

Three plants were randomly selected at 10 DAS to harvest and different plant parts were separated. After that the separated plant parts were oven dried and weighed.

vi. Days to first flowering

Days to first flowering were recorded by counting the number of days required to start initiation of flower in each plot.

B. Yield contributing parameters

i. Number of pods plant^{-1}

The total number of pods of three selected plants per plot was counted and the average values were recorded.

ii. Pod length

Ten pods were randomly selected from the three plants and the average lengths of pods were calculated.

iii. Number of seeds pod^{-1}

Number of seeds pod^{-1}was counted from ten randomly selected pods of three selected plants and then the average seed number was calculated.

iv. 1000 seed weight

1000 cleaned dried seeds were counted randomly from each harvest sample weighed by using a digital electric balance and weight was expressed in gram (g). Data were recorded as the average of three selected plants from the inner rows.

C. Yield and harvest index

i. Seed yield

Seeds obtained from $1m^2$ area of each unit plot were dried in sun and weighed out. The seed weight was then converted as t ha^{-1}. Seed yield was adjusted to 12% moisture content.

ii. Stover yield

After threshing the plants and the fruits walls were sun dried for several days to a constant weight to record the stover yield. The stover yield $plot^{-1}$ was converted to t ha^{-1}.

iii. Biological yield

Biological yield was calculated by using the following formula:
Biological yield = Seed yield + Stover yield.

iv. Harvest index

Harvest index was calculated with the help of following formula and it was calculated on dry weight basis.
Harvest index (HI %) = Seed yield/ (Biological yield × 100)

3.14. Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and the mean differences were adjusted by Least Significance Difference (LSD) test (Gomez and Gomez, 1984).

Chapter 4

RESULTS AND DISCUSSION

The results of the experiment were presented and discussed in this chapter. For the convenience of easy understanding results have been discussed and possible interpretations given under the following subheading and data were presented in Table or Graph.

4.1. Effects of sowing date and spacing and their interactions on growth characters of mungbean

4.1.1. Days to 80% seedling emergence

A statistically significant variation was recorded for days to 80% seedling emergence due to different sowing date (Figure 1). The minimum days (4.44 days) required for 80% seedling emergence was recorded on S_1 (24 August) and S_2 (13 September), while the maximum days (7.56 days) was found on S_4 (23 October) treated plots. S_3 (03 October) treated plots required 6.44 days to emerge. The result was almost similar with the findings of Hussain *et al.* (2004) who reported that too early sowing may not successfully germinate.

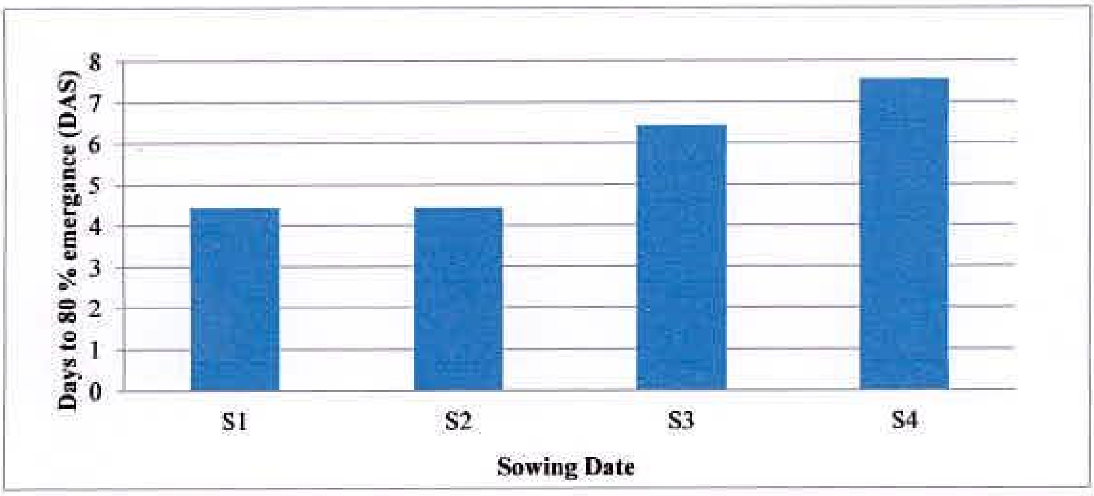


Figure 1. Effect of sowing date on days to 80% seedling emergence of mungbean [LSD $_{(0.05)}$ = 0.41]

Here, S_1= 24 August, S2= 13 September, S3= 03 October, S4= 23 October

There was no significant variation among the P_1 (20 cm × 10 cm), P_2 (30 cm × 10 cm) and P_3 (40 cm × 10 cm) treated plots during seedling emergence (Figure 2). The maximum days (5.92 days) was recorded at P_3 (40 cm × 10 cm) treated plots and minimum days (5.58 days) was observed at P_1 (20 cm × 10 cm).

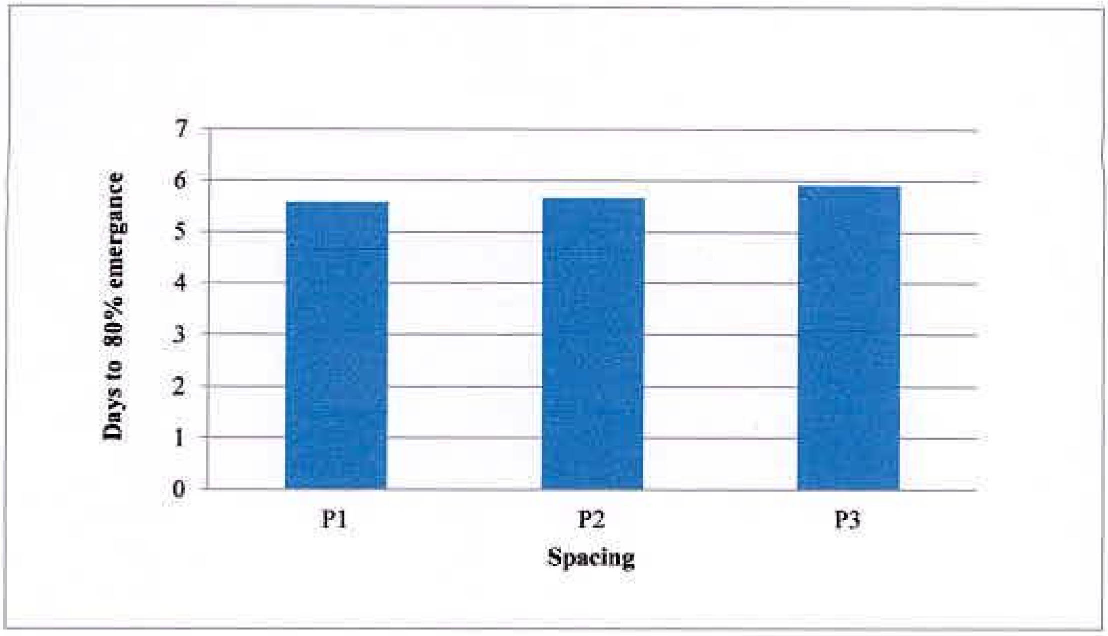


Figure 2. Effect of spacing on days to 80% seedling emergence of mungbean [LSD (0.05) = 0.36]

Here, P_1= 20 cm × 10 cm, P2= 30 cm × 10 cm, P_3= 40 cm × 10 cm

Interaction effects between sowing dates and spacing had significant changes on days to 80% seedling emergence (Figure. 03). The maximum days (8.00 days) to seedling emergence was found on S_4P_1 (sowing on 23 October and spacing at 20 cm × 10 cm) interaction, which was followed by S_4P_2 (sowing on 23 October and spacing at 30 cm × 10 cm) (7.67 days) and S_4P_3 (sowing on 23 October and spacing at 40 cm × 10 cm) (7.00 days). The minimum days (4.00 days) was observed on S_1P_1 (sowing on 24 August and spacing at 20 cm x 10 cm) and S_2P_1 (sowing on 13 September and spacing at 20 cm x 10 cm).

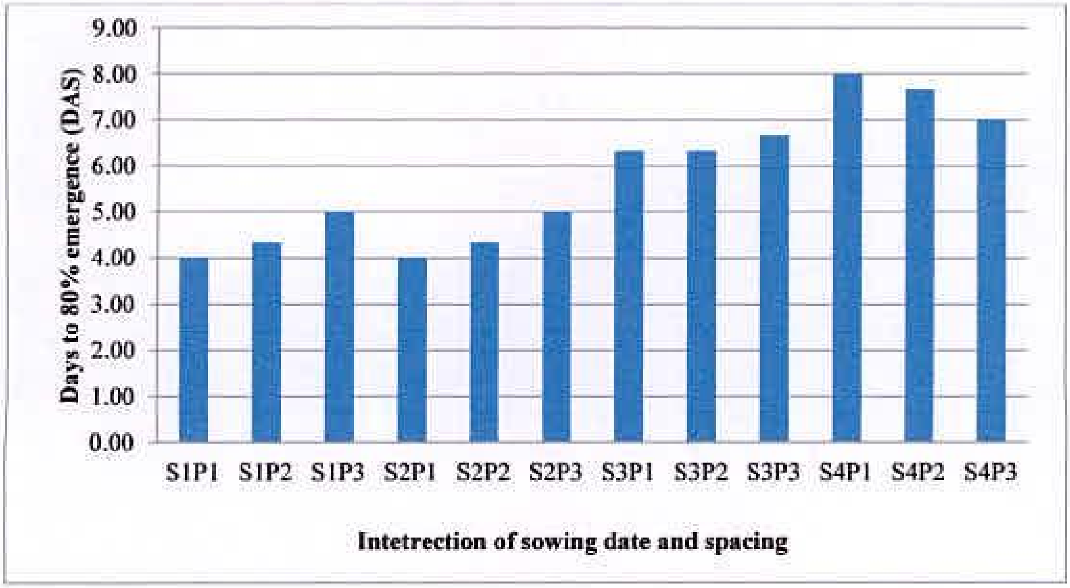


Figure 3. Interaction effects of sowing date and spacing on days to 80% seedling emergence of mungbean [LSD (0.05) = 0.72]

Here,	S_1= Sowing on 24 August	P_1= 20 cm × 10 cm
	S_2= Sowing on 13 September	P_2= 30 cm × 10 cm
	S_3= Sowing on 03 October	P_3= 40 cm × 10 cm
	S_4= Sowing on 23 October	

4.1.2. Plant height

The results showed that the effect of sowing date on plant height was significant at 30, 40 and 50 DAS (Figure. 04). Plant height was increased on S_1 (24 August), S_2 (13 September) and S_3 (03 October) for all the growth stages. At 40 and 50 DAS on S_2 (13 September) showed the highest plant height 60.26 cm and 62.29 cm, respectively identical with S_1 (24 August) obtaining 58.64 cm and 61.68 cm, respectively. The lowest height (20.02 cm) was obtained from S_4 (23 October) for all the growth stages. The result was in agreement with the findings of Rehman *et al.* (2009) who reported that the plant height differed among various sowing dates. S_2 (13 September) showed the highest plant height due to favorable environmental condition which was the optimum sowing time of BARI mung-6. Lowest plant height was obtained from S_4 (23 October) due to delay sowing. Delay planting generally shifts vegetative growth to reproductive growth into less favorable conditions with shorter days and lower radiation and temperature.

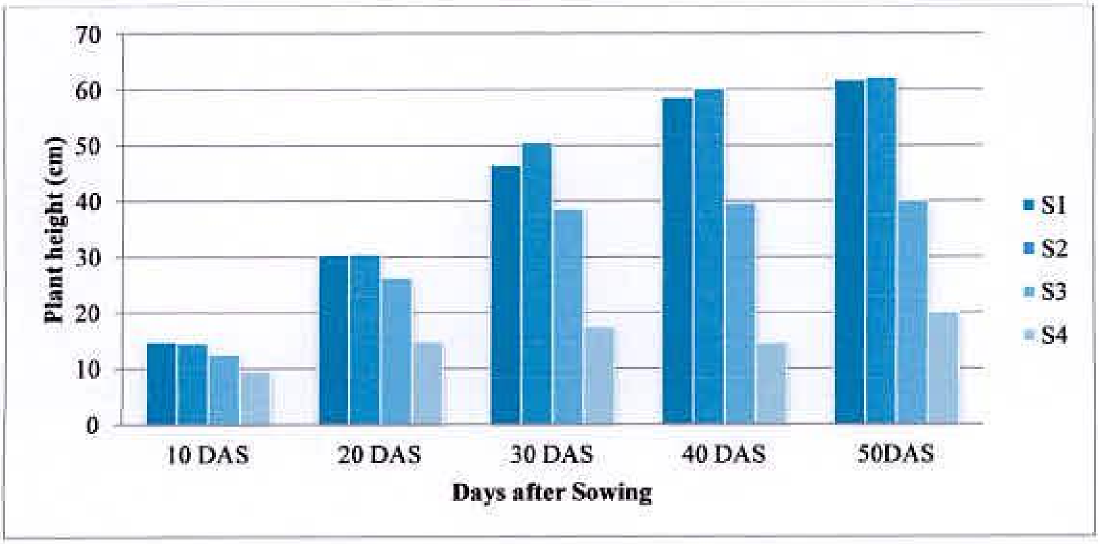


Figure 4: Effect of sowing date on plant height at different days after sowing (DAS) [LSD $_{(0.05)}$ for 10 DAS = 0.97, 20 DAS = 3.47, 30 DAS = 3.54, 40 DAS = 4.09, 50 DAS = 3.79]

Here, S_1= 24 August, S2= 13 September, S3= 03 October, S4= 23

The plant height was not significantly affected by spacing at 40 and 50 DAS. At 50 DAS, the highest height (47.31 cm) was recorded at P_1 (20 cm × 10 cm) treated plots followed by obtaining 45.49 cm and lowest (45.22 cm) was at P_3 (40 cm × 10 cm) (Figure. 05) which is almost similar to the result of Singh *et al.,* (2012b). The pattern of plant height at 40 DAS was similar as observed in 50 DAS. Highest plant height was recorded at P_1 (20 cm × 10 cm). At P_1 (20 cm × 10 cm), the plant height remained unaffected by population density yet it tended to increase with increase in population. A linear decline was observed in plant height with delay in sowing, although it was not significant.

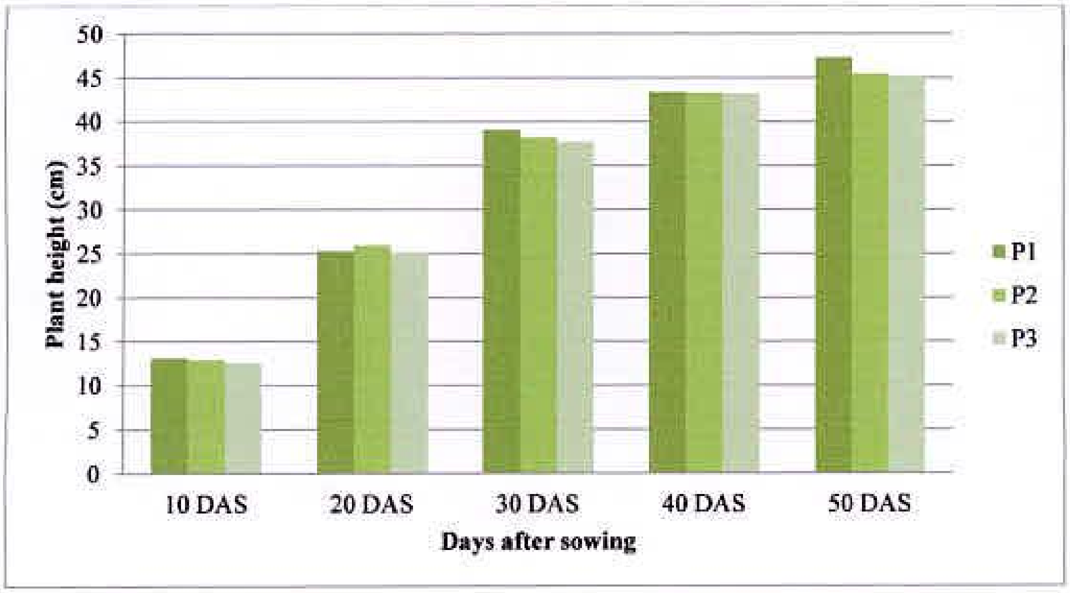


Figure 5: Effect of spacing on plant height at different days after sowing (DAS) [LSD $_{(0.05)}$ for 10 DAS = 0.84, 20 DAS = 3.00, 30 DAS = 3.07, 40 DAS = 3.54, 50 DAS = 8.42]

Here, P_1= 20 cm × 10 cm, P2= 30 cm × 10 cm, P_3= 40 cm × 10 cm

Interaction of sowing date and spacing exerted non-significant variation among the treatments (Table. 1). The tallest plants of 65.33 cm were observed in the S_2P_2 (sowing on 13 September and spacing at 30 cm x 10 cm) interaction at 50 DAS, followed by S_2P_1 (63.60 cm), S_1P_3 (62.68 cm), S_2P_1 (60.02 cm) and S_1P_1 (60.60 cm) treatments. The shortest plants of 18.78 cm were observed in S_4P_1 (sowing on 23 October and spacing at 20 cm x 10 cm) interaction.

Table 1: Interaction effects of sowing date and spacing on plant height at different days after sowing (DAS)

Treatment	Plant height (cm)				
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS
S_1P_1	15.09 a	30.87 a	50.74 ab	58.77 a	60.60 a
S_1P_2	14.89 a	30.62 a	51.53 a	61.29 a	63.60 a
S_1P_3	14.40 ab	29.66 a	49.62 ab	60.71 a	62.68 a
S_2P_1	14.33 a-c	31.16 a	48.61 ab	58.00 a	60.02 a
S_2P_2	15.09 a	30.86 a	45.84 ab	58.37 a	65.33 a
S_2P_3	14.14 a-c	29.39 ab	45.28 bc	59.56 a	59.69 a
S3P1	12.72 b-d	23.47 b	39.42 cd	42.67 b	42.56 b
S_3P_2	12.67 cd	14.83 c	38.35 d	37.72 b	39.25 b
S_3P_3	12.28 d	26.92 ab	38.14 d	38.50 b	38.30 b
S_4P_1	10.27 e	15.72 c	17.50 e	13.61 c	18.78 c
S_4P_2	9.00 e	13.72 c	17.12 e	15.39 c	21.06 c
S_4P_3	9.32 e	28.56 ab	17.81 e	14.61 c	20.22 c
$LSD_{(0.05)}$	1.69	6.00	6.13	7.09	6.56
CV (%)	7.75	13.91	9.44	9.67	8.42

Here, S_1= Sowing on 24 August; S_2= Sowing on 13 September; S_3= Sowing on 03 October; S_4= Sowing on 23 October

P_1= 20 cm × 10 cm; P_2= 30 cm × 10 cm; P_3= 40 cm × 10 cm

4.1.3. Number of branches plant^{-1}

At 30, 40 and 50 DAS of the growth stages was significantly affected due to sowing date in respect of number of branches plant^{-1} (Figure 06) but at 20 DAS, there was no significant variation on different sowing dates. Numerically, S_2 (13 September) produced the maximum number of branches plant^{-1} (3.15) at 50 DAS and the lowest (1.59) as on S_4 (23 October) at 50 DAS. The result was in agreement with the findings of Singh and Sekhon (2002). Maximum number of branches per plant was recorded in early sowing as compared to late sowings due to favorable temperature. The late planting retarded the vegetative growth of plant.

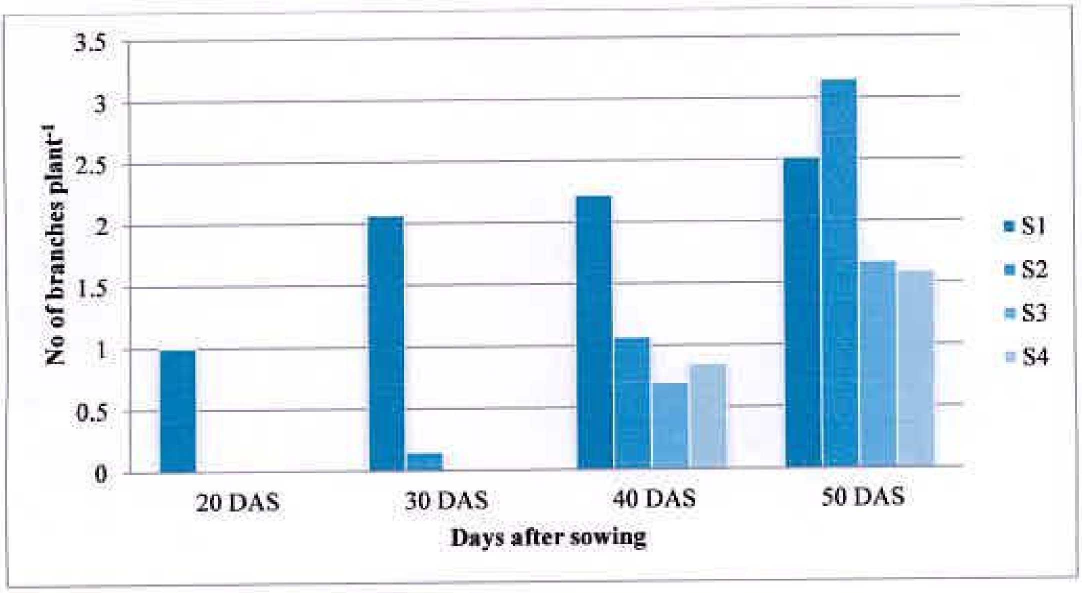


Figure 6. Effect of sowing date on number of branches plant^{-1} at different days after sowing (DAS) [LSD $_{(0.05)}$ for 20 DAS = 0.03, 30 DAS = 0.28, 40 DAS = 0.45, 50 DAS = 0.44]

Here, S_1= 24 August, S2= 13 September, S3= 03 October, S4= 23 October

Spacing exerted no significant difference in branch number of plant (Figure 07). Numerically, the maximum branches plant^{-1} (2.28) was obtained at 50 DAS with P_2 (30 cm × 10 cm) treatment. Minimum number of branches plant^{-1} (2.20) was observed at 50 DAS with P_1 (20 cm × 10 cm) treatment. P_3 (4 0 cm × 10 cm) treatment produced intermediate level (2.22) of branch plant^{-1}.The result was in agreement with the findings of Singh *et al.* (2007) who reported that the spacing of 30 cm × 15 cm produced significantly produced maximum number of branches per plant. Number of branches/plant was significantly affected by plant population density. Wider spacing produce more branches but more plant to plant distance between rows creates weed infestation which compete with the crops for nutrient, light, air, water and more space. In narrow spacing crops maintain soil moisture percentage and suppress weed through covering the soil surface with dense crop canopy.

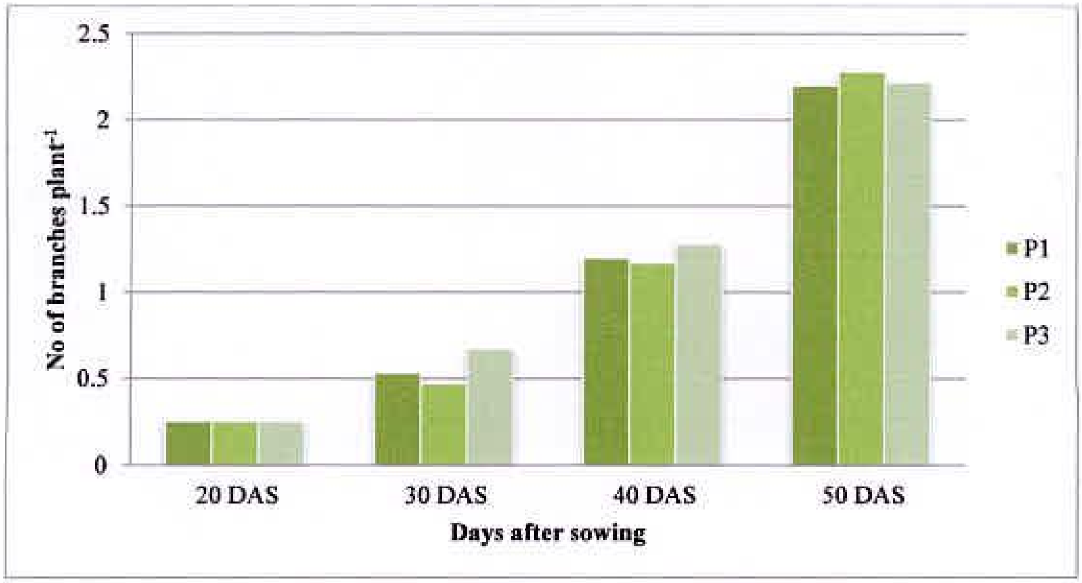


Figure 7. Effect of spacing on number of branches plant^{-1} at different days after sowing (DAS) [LSD $_{(0.05)}$ for 20 DAS = 0.27, 30 DAS = 0.24, 40 DAS = 0.39, 50 DAS = 0.38]

Here, P_1= 20 cm × 10 cm, P2= 30 cm × 10 cm, P_3= 40 cm × 10 cm

Interaction effect of sowing date and spacing on number of branches plant^{-1} was significant at 20, 30 and 40 DAS (Table. 2) but it was significant at 50 DAS. The maximum branches plant^{-1} (4.00) was obtained at 50 DAS on S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm). The lowest number of branches plant^{-1} (1.11) was found at same day with S_4P_1 (sowing on 23 October and spacing at 20 cm ×10 cm) treatment.

Table 2. Interaction effects of sowing date and spacing on number of branches plant^{-1} at different days after sowing (DAS)

Treatment	Number of branches plant^{-1}			
	20 DAS	30 DAS	40 DAS	50 DAS
S_1P_1	1.00 a	1.89 b	1.20 c	2.56 b
S_1P_2	1.00 a	2.44 a	1.28 c	2.78 b
S_1P_3	1.00 a	1.89 b	1.17 c	2.22 b
S_2P_1	0.00 b	0.22 c	0.13 d	2.67 b
S_2P_2	0.00 b	0.22 c	2.45 a	4.00 a
S_2P_3	0.00 b	0.00 c	2.11 ab	2.78 b
S_3P_1	0.00 b	0.00 c	0.67 cd	2.45 b
S_3P_2	0.00 b	0.00 c	0.78 cd	1.11 c
S_3P_3	0.00 b	0.00 c	0.67 cd	1.45 c
S_4P_1	0.00 b	0.00 c	1.44 bc	1.11 c
S_4P_2	0.00 b	0.00 c	0.78 cd	2.22 b
S_4P_3	0.00 b	0.00 c	0.99 c	1.44 c
$LSD_{(0.05)}$	0.05	0.48	0.78	0.76
CV (%)	0.001	50.98	37.86	20.15

Here,
S_1= Sowing on 24 August
S_2= Sowing on 13 September
S_3= Sowing on 03 October
S_4= Sowing on 23 October
P_1= 20 cm × 10 cm
P_2= 30 cm × 10 cm
P_3= 40 cm × 10 cm

4.1.4. Number of leaves plant^{-1}

Number of leaves plant^{-1} was significant at all the growth stages. On S_2 (13 September) produced the highest (14.41) number of leaves plant^{-1} at 50 DAS and S_4 (23 October) had the lowest (3.63) number of leaves plant^{-1} at 50 DAS (Figure 08). There was a linear relationship on appearance of leaves in different planting dates. Delay sowing retarded vegetative growth where as early sowing produced highest number of leaves plant^{-1}.

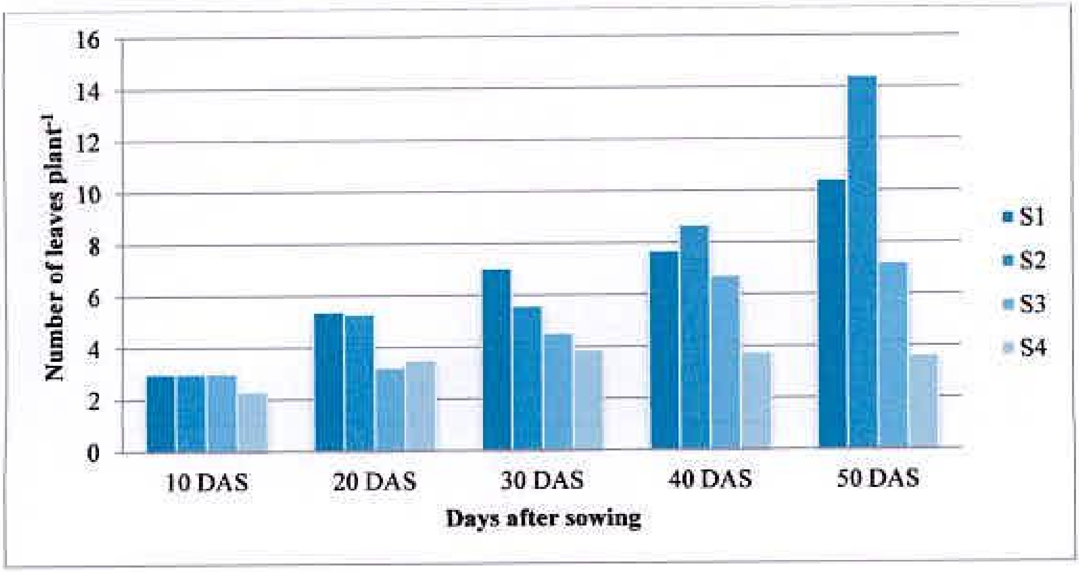


Figure 8. Effect of sowing date on number of leaves plant^{-1} at different days after sowing (DAS) [LSD $_{(0.05)}$ for 10 DAS=0.18, 20 DAS = 0.68, 30 DAS = 0.43, 40 DAS = 0.74, 50 DAS = 2.38]

Here, S_1= 24 August, S2= 13 September, S3= 03 October, S4= 23 October

Spacing had significant effect on number of leaves plant^{-1} at all the stages of crop growth. Plots treated with P_3 (40 cm × 10 cm) produced the highest number of leaves plant^{-1} (14.41 and 8.67) at 40 and 50 DAS respectively (Figure 09). At P_2 (30 cm × 10 cm) showed the lowest (6.67 and 9.03) number of leaves plant^{-1} at same DAS. Wider spacing increase leafy area between rows and conserve soil moisture. So, optimum plant population increase vegetative growth and produce higher grain yield.

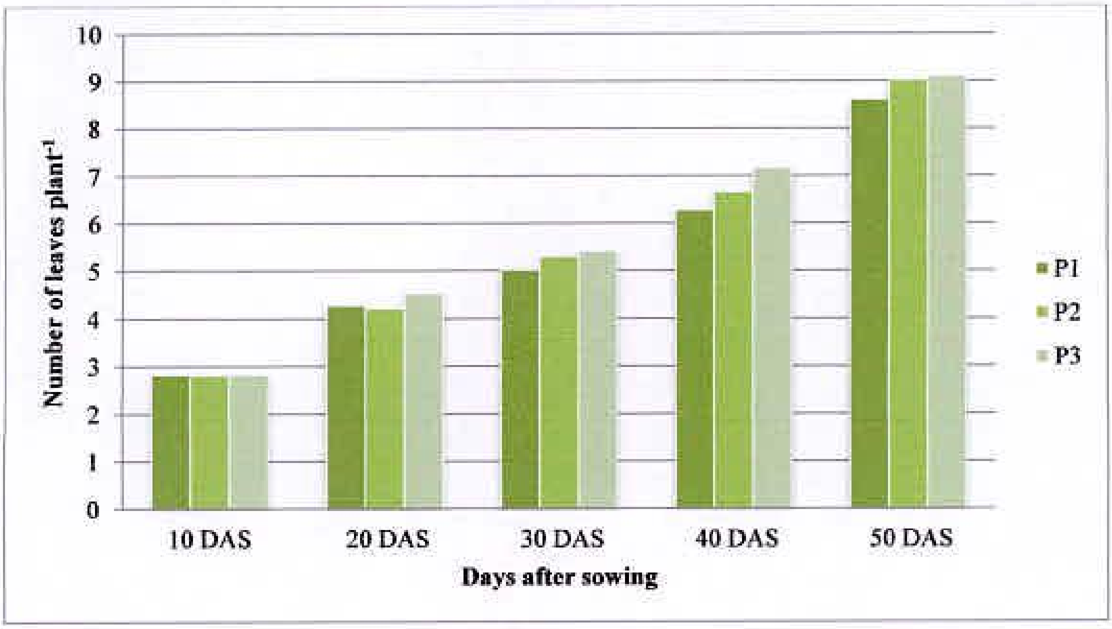


Figure 9. Effect of spacing on number of leaves plant^{-1} at different days after sowing (DAS) [LSD $_{(0.05)}$ for 10 DAS=0.15, 20 DAS = 0.59, 30 DAS = 0.38, 40 DAS = 0.64, 50 DAS = 2.07]

Here, P_1= 20 cm × 10 cm, P2= 30 cm × 10 cm, P_3= 40 cm × 10 cm

Interaction effects on sowing date and spacing exerted significant effect on number of leaves plant^{-1} at 50 DAS but it showed no significant effect at 20 and 30 DAS. The highest number of leaves (17.56) at 50 DAS was observed in S_2P_3 (sowing on 13 September and spacing at 40 cm × 10 cm) and S_4P_1 (sowing on 23 October and spacing at 20 cm × 10 cm) showed the minimum number of leaves (3.22) at same stage (Table 3).

Table 3. Interaction effects of sowing date and spacing on number of leaves plant^{-1} at different days after sowing (DAS)

Treatment	Number of leaves plant^{-1}				
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS
S_1P_1	3.00 a	5.11 a	6.22 c	6.56 d	8.34 c-f
S_1P_2	3.00 a	5.11 a	7.00 b	8.11 c	10.44 b-e
S_1P_3	3.00 a	5.89 a	7.89 a	8.44 bc	12.45 bc
S_2P_1	3.00 a	5.22 a	5.67 c	6.78 d	6.99 e-g
S_2P_2	3.00 a	5.11 a	5.56 c	6.56 d	11.78 b-d
S_2P_3	3.00 a	5.55 a	5.56 c	10.00 a	17.56 a
S_3P_1	3.00 a	3.45 b	4.55 d	6.78 d	6.67 e-g
S_3P_2	3.00 a	3.56 b	4.55 d	6.33 d	8.00 d-f
S_3P_3	3.00 a	3.45 b	4.45 de	9.67 ab	13.89 ab
S_4P_1	2.33 b	3.33 b	3.67 f	3.34 e	3.22 g
S_4P_2	2.22 b	3.11 b	4.11 d-f	4.11 e	4.22 fg
S_4P_3	2.33 b	3.22 b	3.78 ef	3.78 e	3.44 g
$LSD_{(0.05)}$	0.31	1.18	0.75	1.29	4.14
CV (%)	6.42	16.01	8.43	11.34	27.41

Here,
S_1= Sowing on 24 August
S_2= Sowing on 13 September
S_3= Sowing on 03 October
S_4= Sowing on 23 October

P_1= 20 cm × 10 cm
P_2= 30 cm × 10 cm
P_3= 40 cm × 10 cm

4.1.5. Dry weight plant^{-1}

Sowing date had significant effect on dry weight plant^{-1} at 10, 20 and 30 DAS, but it differed significantly at 40 and 50 DAS (Figure 10). S_2 (13 September) showed the highest dry weight (6.18 gm) at 50 DAS where as S_4 (23 October) showed the lowest dry weight (0.66 gm) (Figure 10). The result was in agreement with the findings of Chahal (1998) who reported that total dry matter accumulation were significantly higher at second sowing date than those of other three planting dates. Delay sowing decrease the dry matter content of plant.

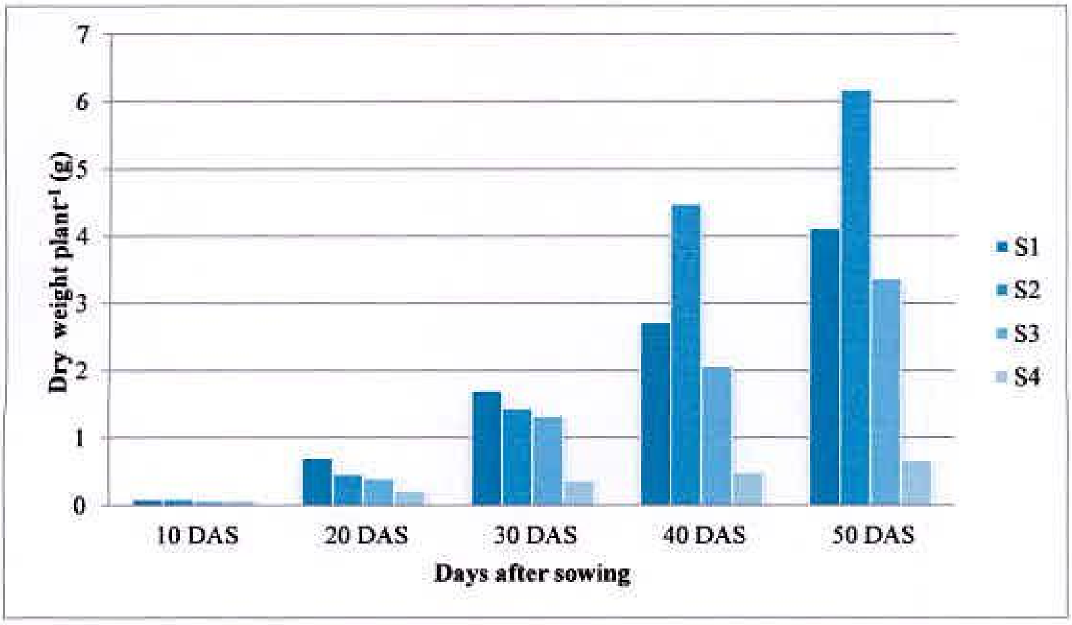


Figure 10. Effect of sowing date on dry weight plant^{-1} at different days after sowing (DAS) [LSD $_{(0.05)}$ for 10 DAS=0.03, 20 DAS = 0.10, 30 DAS = 0.30, 40 DAS = 0.62, 50 DAS = 1.16]

Here, S_1= 24 August, S2= 13 September, S3= 03 October, S4= 23 October

Treatment spacing exerted significant effect on dry weight plant^{-1} at 10, 20, 30, 40 and 50 DAS. The highest dry weight (3.87 gm) was found in P_1 (20 cm × 10 cm) treated plot. The lowest dry weight plant^{-1}(3.18 gm) was found at P_3 (40 cm × 10 cm) treated plot (Figure 11). Plants dry matter weight significantly increased with the increasing plant population.

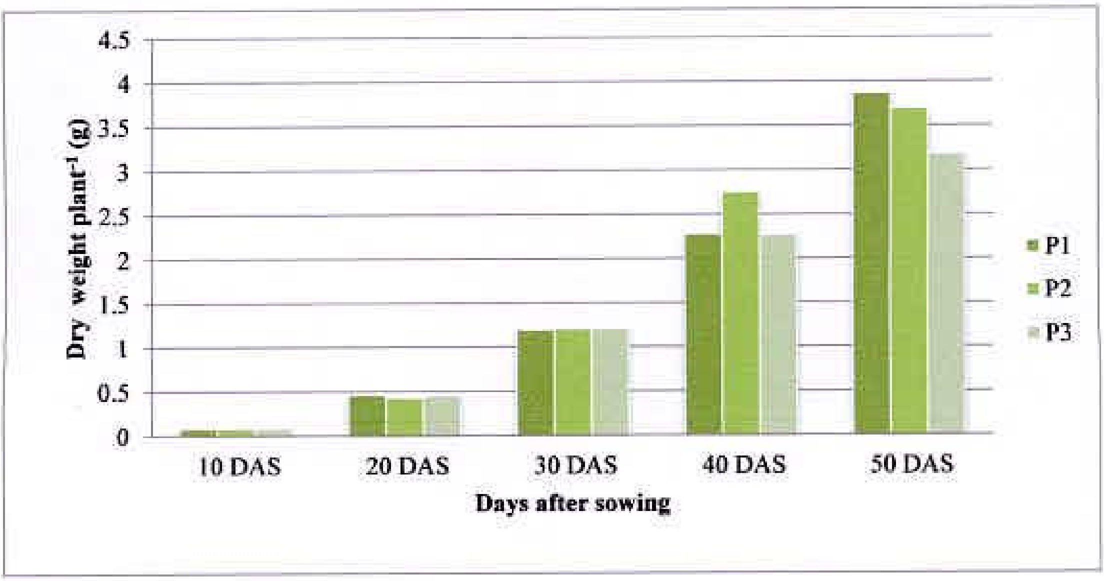


Figure 11. Effect of spacing on dry weight plant^{-1} at different days after sowing (DAS) [LSD $_{(0.05)}$ for 10 DAS=0.03, 20 DAS = 0.08, 30 DAS = 0.26, 40 DAS = 0.54, 50 DAS = 1.00]

Here, P_1= 20 cm × 10 cm, P2= 30 cm × 10 cm, P_3= 40 cm × 10 cm

Interaction of sowing date and spacing had significant difference on dry weight plant^{-1} at all the growth stages. At 50 DAS, S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm) interaction showed the highest dry weight (6.59 gm) which was identical with S_1P_2 (6.45) and S_1P_1 (5.49). The lowest value (0.58 gm) was found on S_4 (23 October) when it was treated with P_3 (40 cm × 10 cm) treatment (Table 4).

Table 4. Interaction effects of sowing date and spacing on dry weight plant^{-1} at different days after sowing (DAS)

Treatment	Dry weight plant^{-1}(g)				
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS
S_1P_1	0.09 a	0.74 a	1.60 ab	4.38 ab	5.49 ab
S_1P_2	0.09 a	0.70 a	1.89 a	5.44 a	6.45 a
S_1P_3	0.08 a	0.78 a	1.60 ab	2.51 de	3.07 c
S_2P_1	0.09 a	0.49 b	1.43 ab	3.61 bc	6.59 a
S_2P_2	0.09 a	0.46 b	1.22 b	3.00 cd	4.69 a-c
S_2P_3	0.08 a	0.42 b	1.67 ab	2.63 c-e	4.59 a-c
S_3P_1	0.07 a	0.36 bc	1.43 ab	1.75 e	3.55 bc
S_3P_2	0.06 a	0.40 bc	1.33 b	1.99 de	2.94 c
S_3P_3	0.07 a	0.45 b	1.19 b	2.44 de	3.61 bc
S_4P_1	0.09 a	0.25 cd	0.34 c	0.43 f	0.62 d
S_4P_2	0.07 a	0.16 d	0.39 c	0.58 f	0.79 d
S_4P_3	0.09 a	0.25 cd	0.35 c	0.45 f	0.58 d
$LSD_{(0.05)}$	0.05	0.17	0.51	1.08	2.01
CV (%)	12.95	21.89	25.19	26.07	33.10

Here,
S_1= Sowing on 24 August
S_2= Sowing on 13 September
S_3= Sowing on 03 October
S_4= Sowing on 23 October
P_1= 20 cm × 10 cm
P_2= 30 cm × 10 cm
P_3= 40 cm × 10 cm

4.2. Effects of sowing date and spacing and their interaction on yield contributing parameters of mungbean

4.2.1. Days to 1st flowering

Days to 50% flowering of mungbean showed significant variation due to different sowing date. The minimum days to 50% flowering (30.00 days) recorded from S_4 (23 October), while the maximum days to 50% flowering (35.00 days) was found on S_2 (13 September) which was statistically similar to S_1 (24 August) (34.67 days) and S_3 (03 October) (32.33 days) (Table 5). Early sowing takes more days to flowering due to increasing vegetative growth. Earlier 50% flowering in delay sowing occurs due to decrease in vegetative growth and increase in reproductive growth. Earlier 50% flowering with delayed sowings have been observed in mungbean (Singh *et al.*, 2010).

Days to 50% flowering was not significantly affected by spacing. The minimum days (32.58 days) to 50% flowering was observed at P_3 (40 cm × 10 cm), which was statistically identical to P_1 (20 cm × 10 cm) (33.08 days), while the maximum days to 50% flowering (33.33 days) was found at P_2 (30 cm × 10 cm) treated plot (Table 6). At wider spacing higher wind speed and limited moisture availability during the pre-flowering and flowering stage resulted in more dropping of flowers in comparison to narrow spacing.

No significant variation was recorded for interaction effect of sowing date and spacing in terms of days required for 50% flowering. The minimum days (29.00 days) required for 50% flowering was obtained in S_4P_1 (sowing on 23 October and spacing at 20 cm × 10 cm) and the maximum days (35.33 days) was found in S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm), which was statistically similar with S_1P_2 (sowing on 24 August and spacing at 30 cm × 10 cm) (35.00 days), S_2P_1 (sowing on 13 September and spacing at 20 cm × 10 cm) (35.00 days), S_1P_3 (sowing on 24 August and spacing at 40 cm × 10 cm) (34.67 days), S_1P_1 (sowing on 24 August and spacing at 20 cm × 10 cm) (34.67 days) and S_2P_3 (sowing on 13 September and spacing at 40 cm × 10 cm) (34.33 days). Other treatment produced intermediate level of days to flowering (Table 7).

4.2.2. Number of pods plant^{-1}

Sowing date showed significant variation in pod numbers per plant. S_2 (13 September) produced the highest number of pods plant^{-1} (22.92) at 3 times harvesting; followed by S_1 (15.96) treatment. S_4 (23 October) produced the lowest number of pods plant^{-1} (1.78) (Table. 5). The results were in conformity with the findings of Choi *et al.*, (1991) who tested three sowing dates and reported that 2nd sowing date gave the highest number of pods per plant and highest grain yield. On 2nd sowing crops may have utilized the factors of favorable environment which ultimately influences plant to have more growth and development.

Spacing showed non-significant difference in producing number of pods plant^{-1} (Table. 6). Significantly maximum number of pods plant^{-1} (12.56) was found at P_2 (30 cm × 10 cm) treated plot and the minimum (10.25) was in P_1 (20 cm × 10 cm) treatment. P_3 (40 cm × 10 cm) produced intermediate level (11.00) of number of pods plant^{-1}. The result was similar with the result documented by Singh *et al.*, (2007) who conducted an experiment on mungbean to compare three planting geometry (20 cm × 10 cm, 25 cm × 10 cm, 30 cm × 10 cm) and revealed that the highest number pods plant^{-1} was obtained at 30 cm × 10 cm spacing.

Interaction of sowing date and spacing exerted non-significant effect on number of pods plant^{-1} at harvesting time (Table. 7). The highest number of pods plant^{-1} (27.55) was found on S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm) treated plot followed by S_2P_3 (sowing on 13 September and spacing at 40 cm × 10 cm) (21.67), S_1P_1 (sowing on 24 August and spacing at 20 cm × 10 cm) (19.55) and S_1P_3 (sowing on 24 August and spacing at 40 cm × 10 cm) (17.78) treatment at harvesting period. And the lowest value (0.89) was observed in S_4P_1 (sowing on 23 October and spacing at 20 cm × 10 cm) interaction treatment at same harvest.

4.2.3. Pod length

The difference in pod length due to sowing date was statistically highly significant (Table 5). The longest pod (8.91 cm) was produced on S_2 (13 September) treated plots and the shortest pod (1.54 cm) was on S_4 (23 October) treated plots. The result was similar with the result of Soomro and Khan (2003) who found that the early sowing showed the highest length (9.2 cm) of pod and least (5.1 cm) was observed in last sowing.

Spacing showed highly significant difference in pod length (Table 6). Longer pod length (9.28 cm) was observed at P_2 (30 cm × 10 cm) treatment followed by P_1 (20 cm × 10 cm) (7.88 cm) and shorter (4.55 cm) was at P_3 (40 cm × 10 cm) treatment.

The combined effect of sowing date and spacing was significant on pod length (Table7). The longest pod length (9.20 cm) was recorded in S_2P_2 (sowing on 13

September and spacing at 30 cm × 10 cm) treatment followed by S_2P_1 (sowing on 13 September and spacing at 20 cm × 10 cm) (9.15 cm) and shortest (2.06 cm) was found in S_4P_1 (sowing on 23 October and spacing at 20 cm × 10 cm) treatment.

4.2.4. Number of seeds pod^{-1}

Sowing date had significant effect in respect of number of seeds pod^{-1}. However, S_2 (13 September) produced the highest number of seeds pod^{-1} (11.59) followed by S_1 (24 August) (11.28). S_4 (23 October) had the lowest number of seeds pod^{-1} (2.31) (Table 5). S_3 (03 October) produced intermediate level (6.37) of number of seeds pod^{-1}. This result was consistent with the findings of Sadeghipour (2008) and Sarkar *et al.* (2004) who reported that number of seeds per pod affected by sowing date. Maximum number of seeds pod^{-1} was recorded on 2nd sowing probably due to prevailing favorable condition for growth and development of mungbean.

Spacing significantly affected the number of seeds pod^{-1}. P_2 (30 cm × 10 cm) treated plants produced the highest (10.31) number of seeds pod^{-1} followed by P_1 (20 cm × 10 cm) (8.99) treated plant and the lowest (7.63) in P_3 (40 cm × 10 cm) treatment (Table. 6). Similar trend was also reported by Khan *et al.*, (2001) who studied the effect of planting geometry on yield and yield components of mungbean which produced the maximum number of seeds pod^{-1}.

Interaction effects of sowing date and spacing on seeds pod^{-1} were significant. The maximum number of seeds pod^{-1} (11.90) was produced by S_2P_1 (sowing on 13 September and spacing at 20 cm × 10 cm) interaction followed by S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm) (11.47), S_1P_2 (sowing on 24 August and spacing at 30 cm × 10 cm) (11.23), S_1P_1 (sowing on 24 August and spacing at 20 cm × 10 cm) (10.80) and S_1P_3 (sowing on 24 August and spacing at 40 cm × 10 cm) (9.80). The minimum (1.23) was in S_4P_2 (sowing on 23 October and spacing at 30 cm × 10 cm) interaction treatment (Table 7).

4.2.5. 1000 seed weight

1000 seed weight of BARI Mung-6 differed significantly due to sowing date. Maximum weight (40.77 gm) of 1000-seed was obtained from S_1 (24 August) (Table. 5). S_4 (23 October) had minimum 1000 seed weight (3.95 gm). S_2 (13 September) gave the second highest (38.60 gm) 1000 seed weight. The result corroborates with the findings of Farghali and Hussein (1995). They observed that mungbean grown under different sowing time, 2nd sown crop was superior to 1st and 3rd sowings with respect to number of cluster per plant, number of seeds per pod and 1000 grain weight. Optimum sowing time gave the earliest maturity and a significant increase in number of pods plant^{-1}, number of grains plant^{-1} and 1000 grain weight compared to early and late sowing.

Spacing non-significantly affected the 1000 seeds weight. Data presented in (Table. 6) showed that 1000 seed weight was maximum (27.17 gm) in P_2 (30 cm × 10 cm) treated plants, which was similar (27.03 gm) with P_1 (20 cm × 10 cm) treated plants. The lowest weight of 1000 seed (26.87 gm) was found in P_3 (40 cm × 10 cm). Similar result was reported by Younas (1993) who viewed that planting patterns have a significant influence on 1000 grain weight. At wider spacing of 40cm, 1000 seed weight was recorded an increase in comparison to narrow spacing. The optimum spacing of 30 cm × 10 cm produced significantly maximum 1000 seed weight as compared to 40 cm × 10 cm.

The combined effect of sowing date and spacing was statistically significant in respect of 1000 seed weight. 1000 seed weight was the highest (41.67 gm) in S_2P_1 (sowing on 13 September and spacing at 20 cm × 10 cm) treatments followed by S_1P_1 (sowing on 24 August and spacing at 20 cm × 10 cm) (11.47) (41.43 gm), S_1P_2 (sowing on 24 August and spacing at 30 cm × 10 cm) (39.36 gm) and S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm) (39.20 gm). It was the lowest (3.21 gm) in S_4P_1 (sowing on 23 October and spacing at 20 cm × 10 cm) (Table 7).

Table 5. Effect of sowing date on yield contributing parameters of mungbean

Sowing Date	Days to 50% flowering	Number of pods plant^{-1}	Pod length (cm)	Number of Seeds pod^{-1}	1000 seed weight (g)
S_1	34.67 a	15.96 b	7.88 a	11.28 a	40.77 a
S_2	35.00 a	22.92 a	8.91 a	11.59 a	38.60 b
S_3	32.33 b	4.41 c	4.55 b	6.37 b	28.73 c
S_4	30.00 c	1.78 c	1.54 c	2.31 c	3.95 d
$LSD_{(0.05)}$	0.97	3.16	0.66	1.08	1.98
CV (%)	3.00	28.70	13.20	15.08	7.50

Table 6. Effect of spacing on yield contributing parameters of mungbean

Spacing	Days to 50% flowering	Number of pods plant^{-1}	Pod length (cm)	Number of Seeds pod^{-1}	1000 seed weight (g)
P_1	33.08 a	10.25 a	7.88 a	8.99 a	27.03 a
P_2	33.33 a	12.56 a	9.28 a	10.31 a	27.17 a
P_3	32.58 a	11.00 a	4.55 a	7.63 a	26.87 a
$LSD_{(0.05)}$	0.84	2.74	0.57	0.93	1.72
CV (%)	3.00	28.70	13.20	15.08	7.50

Table 7. Interaction effects of sowing date and spacing on yield contributing parameters of mungbean

Treatment	Days to 50% flowering	Number of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}	1000 seed weight(g)
S_1P_1	34.33 ab	19.55 bc	8.60 a	10.80 a	41.43 a
S_1P_2	35.00 a	15.33 c	8.15 a	11.23 a	39.36 ab
S_1P_3	34.67 ab	17.78 bc	7.89 a	9.80 a	37.95 b
S_2P_1	35.00 a	14.78 c	9.15a	11.90 a	41.67 a
S_2P_2	35.33 a	27.55 a	9.20 a	11.47 a	39.20 ab
S_2P_3	34.33 ab	21.67 b	7.94 a	9.40 a	38.48 ab
S_3P_1	32.00 cd	4.22 d	4.08 b	5.77 b	27.33 c
S_3P_2	33.00 bc	5.00 d	4.77 b	6.53 b	29.06 c
S_3P_3	32.00 cd	4.00 d	4.81 b	6.80 b	29.80 c
S_4P_1	29.00 e	0.89 d	2.06 c	1.56 c	3.21 d
S_4P_2	30.33 de	2.78 d	2.55 c	1.23 c	3.56 d
S_4P_3	30.67 de	1.67 d	3.00 c	1.34 c	4.62 d
$LSD_{(0.05)}$	1.67	5.48	1.14	1.87	3.43
CV (%)	3.00	28.70	13.20	15.08	7.50

Here,

S_1= Sowing on 24 August
S_2= Sowing on 13 September
S_3= Sowing on 03 October
S_4= Sowing on 23 October

P_1= 20 cm × 10 cm
P_2= 30 cm × 10 cm
P_3= 40 cm × 10 cm

4.3. Effects of sowing date and spacing and their interaction on yield parameters of mungbean

4.3.1. Seed yield

Effect of sowing date on seed yield was statistically significant (Table 8). Among the four sowing date, S_2 (13 September) produced the highest seed yield (1.56 t ha^{-1}) while the lowest (0.37 t ha^{-1}) was in S_4 (23 October) and S_1 (24 August) produced intermediate level of seed yield (1.42 t ha^{-1}). This findings closely resembles to those reported by Sinha *et al.* (1989), Poehlman (1991) and Miah *et al.* (2009) who opined that mungbean being a warm season plant produced higher yield at the optimum mean temperature range of 25-30°C. The highest seed yield obtained due to suitable temperature prevailing accompanied by higher soil moisture content due to sufficient rainfall, which enhanced the vegetative as well as reproductive growth of the crop and the lowest yields of low quality seeds are produced in late sowing of mungbean. Late sown crop could not attain proper growth; which resulted in drastic reduction in yield.

Effect of spacing on seed yield was significant (Table 9). The highest seed yield (1.13 t ha^{-1}) was obtained from P_2 (30 cm × 10 cm) treated plots and the lowest (1.02 t ha^{-1}) was in P_3 (40 cm × 10 cm). P_1 (20 cm × 10 cm) produced intermediate level of seed yield (1.06 t ha^{-1}). This result was closely related to the findings of Rasul *et al.*, (2012) who conducted an experiment on mungbean at Faisalabad (Pakistan) in *kharif* season to compare three planting geometries (30 cm × 8 cm, 45 cm × 8 cm, 60 cm × 8 cm) and observed that the planting geometry of 30 cm × 8 cm had higher grain yield as compared to other two planting geometries. The effect of row spacing on grain yield was significant. The maximum grain yield was recorded in closest spacing due to high plant population and better utilization of inter row-spacing than in the wide row spacing.

The interaction effect of sowing date and spacing was found significant in respect of seed yield (Table 10). The highest seed yield (1.53 t ha^{-1}) was obtained from S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm) interaction treatments followed by S_2P_1 (sowing on 13 September and spacing at 20 cm × 10 cm) (1.52 t ha^{-1}). The lowest seed yield (0.33 t ha-1) was recorded from S_4P_3 (sowing on 23 October and spacing at 40 cm × 10 cm).

4.3.2. Stover yield

Sowing date showed significant differences in stover production (Table 8). S_2 (13 September) produced the highest stover yield (1.78 t ha^{-1}) followed by S_1 (24 August) (1.59 t ha^{-1}) and lowest in S_4 (23 October) (0.25 t ha^{-1}). The highest yield was found on optimum sowing date and in late planting it affected the yield and yield attributing characters of crop.

Different spacing showed significant differences in stover production (Table 9). Stover production differed among different spacing. It was higher (1.18 t ha^{-1}) at P_2 (30 cm × 10 cm) treated plots compared to P_1 (20 cm × 10 cm) (1.09 t ha^{-1}) treated plots. This result was consistent with the findings of Kabir and Sarkar (2008) who conducted an experiment on *kharif* season mungbean to compare three planting geometries (30 cm × 10 cm, 20 cm ×20 cm and 40 cm × 30 cm) and reported higher stover yield and grain yield at 30 cm ×10 cm spacing as compared to other treatments.

Sowing date and spacing interaction effect on stover yield were significant (Table 10). The highest stover yield (1.76 t ha^{-1}) was observed in S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm) while the lowest was (0.23 t ha^{-1}) in S_4P_1 (sowing on 23 October and spacing at 20 cm × 10 cm).

Table 8. Effect of sowing date on yield parameters of mungbean

Sowing date	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_1	1.42 b	1.59 b	3.01 b	50.33 b
S_2	1.56 a	1.78 a	3.25 a	57.84 a
S_3	0.92 c	0.92 c	1.84 c	48.03 b
S_4	0.37 d	0.25 d	0.62 d	47.26 b
$LSD_{(0.05)}$	0.07	0.08	0.10	5.62
CV (%)	6.66	6.98	4.73	11.31

Table 9. Effect of spacing on yield parameters of mungbean

Spacing	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
P_1	1.06 b	1.09 b	2.15 b	50.88 a
P_2	1.13 a	1.18 a	2.31 a	52.62 a
P_3	1.02 b	1.14 ab	2.16 b	49.09 a
$LSD_{(0.05)}$	0.06	0.07	0.16	4.87
CV (%)	6.66	6.98	4.73	11.31

Table 10. Interaction effects of sowing date and spacing on yield parameters of mungbean

Treatment	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_1P_1	1.39 c	1.46 d	2.85 d	49.01 a-e
S_1P_2	1.49 bc	1.60 bc	3.19 ab	56.87 a-c
S_1P_3	1.39 c	1.50 c	2.99 cd	48.62 b-e
S_2P_1	1.52 ab	1.60 c	3.13 bc	58.23 ab
S_2P_2	1.53 a	1.76 a	3.32 a	58.43 a
S_2P_3	1.43 ab	1.68 b	3.29 ab	56.34 a-d
S_3P_1	0.96 d	1.07 e	2.04 e	47.74 c-e
S_3P_2	0.96 d	0.75 f	1.71 f	48.95 a-e
S_3P_3	0.83 e	0.94 e	1.77 f	46.72 de
S_4P_1	0.35 f	0.23 g	0.57 g	46.43 e
S_4P_2	0.42 f	0.29 g	0.72 g	46.91 de
S_4P_3	0.33 f	0.24 g	0.58 g	46.13 e
$LSD_{(0.05)}$	0.1197	0.1312	0.1776	9.738
CV (%)	6.66	6.98	4.73	11.31

Here, S_1= Sowing on 24 August; S_2= Sowing on 13 September; S_3= Sowing on 03 October; S_4= Sowing on 23 October

P_1= 20 cm × 10 cm; P_2= 30 cm × 10 cm; P_3= 40 cm × 10 cm

4.3.3 Biological yield

The biological yield of mungbean varied significantly among the sowing date. S_2 (13 September) had highest biological yield (3.25 t ha^{-1}) and the lowest (0.62 t ha^{-1}) on S_4 (23 October). S_1 (24 August) (3.01 t ha^{-1}) produced intermediate level of biological yield (Table 8). Suitable sowing time is the most important factors affecting the yield. Majority of crops can utilize the factors of favorable environment which ultimately influences plant to have more growth and development. Lower yield under delayed sowing was the result of reduction in biological yield.

Different spacing exerted significant effects on biological yield of mungbean (Table 9). P_2 (30 cm × 10 cm) gave the highest biological yield (2.24 t ha^{-1}), which was statistically similar with P_3 (40 cm × 10 cm) (2.16 t ha^{-1}). The lowest biological yield (2.15 t ha^{-1}) was observed in P_1 (20 cm × 10 cm). The result was similar with the findings of Khan *et al.*, (2001) who found that planting geometry had significant effect on biological yield.

Interaction of sowing date and spacing had significant effect on biological yield. S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm) interaction showed the highest biological yield (3.32 t ha^{-1}), which was statistically similar with S_2P_3 (sowing on 13 September and spacing at 40 cm × 10 cm) (3.29 t ha^{-1}) interaction. The lowest (0.57 t ha^{-1}) biological yield was recorded in S_4P_1 (sowing on 23 October and spacing at 20 cm × 10 cm) interaction treatments (Table 10). Quresh and Rahim (1987) found that earlier planting gave significantly higher mean biological yield. The probable reason for this might be the less plant population in early sowing and heavy rains, which adversely affected the mungbean production.

4.3.4. Harvest index

Sowing date showed significant differences on harvest index (Table 8). The highest harvest index (57.84 %) was recorded in S_2 (13 September) and the lowest harvest index (47.26 %) in S_4 (23 October). S_1 (24 August) showed 50.33 % harvest index, which was statistically similar to S_3 (03 October). The similar result was reported by Sejjon *et al.* (2000) who found that the increased harvest index with late sowing could be related to high assimilate use efficiency due to increased sink capacity.

Although harvest index differed significantly among the different spacing but the values were closer to each other (Table 9). These might be due to closer variation with in the treatment for seed yield and stover yield. P_2 (30 cm × 10 cm) treatment showed the highest harvest index (52.62%), which was similar with P_1 (20 cm × 10 cm) (50.88%) treatment. The lowest harvest index (49.09%) was observed in P_3 (30 cm × 10 cm) treatment.

The interaction between sowing date and spacing was significant in respect of harvest index (Table 10). The highest harvest index (58.43%) was observed in S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm) interaction treatment, which was similar with S_2P_1 (sowing on 13 September and spacing at 20 cm × 10 cm) (58.23%) interactions. The lowest harvest index (46.13%) was observed in S_4P_3 (sowing on 23 October and spacing at 40 cm × 10 cm) interaction treatment. The results are similar to the findings of Kabir and Sarkar (2008) who showed significant differences in harvest index under different planting geometries. Hussain (2003) found that sowing methods affected the harvest index and maximum harvest index was recorded with bed sowing.

Chapter 5

SUMMARY AND CONCLUSION

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka, during August, 2013 to January, 2014 of *kharif II* season to study the effect of sowing date and spacing on growth and yield of mungbean. The experiment was consisted of four sowing date viz., S_1 (24 August), S_2 (13 September), S_3 (03 October) and S_4 (23 October), respectively and three spacing viz., P_1 (20 cm × 10 cm), P_2 (30 cm × 10 cm) and P_3 (40 cm × 10 cm). Randomized Complete Block Design (RCBD) was laid out to determine this experiment with three replications. The unit plot size was 2.0 m × 2.0 m. Chemical fertilizers- urea, TSP and MP were applied as per its recommended dose. Data on growth and yield parameters were recorded from vegetative growth to maturity period. All the collected data were statistically analyzed and the mean differences among the treatments were adjusted by Least Significance Difference (LSD) test.

Results showed that sowing date had significant effect on plant height at 50 DAS. At 40 and 50 DAS on S_2 (13 September) showed the highest plant height 60.26 cm and 62.29 cm, respectively and the lowest height (20.02 cm) was obtained from S_4 (23 October) for all the growth stages. Spacing had no significant effect on plant height. At 50 DAS, the highest height (47.31 cm) was recorded at P_1 (20 cm × 10 cm) treated plots and lowest (45.22 cm) was at P_3 (40 cm × 10 cm) treated plot. In case of interaction treatment the tallest plants of 65.33 cm were observed in the S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm) at 50 DAS than other treatments.

Number of branches plant^{-1} was significantly affected due to sowing. Numerically, S_2 (13 September) produced the maximum number of branches plant^{-1} (3.15) at 50 DAS and the lowest (1.59) as on S_4 (23 October) at 50 DAS. Spacing exerted no significant difference in branch number of plant. The maximum branches plant^{-1} (2.28) was obtained at 50 DAS with P_2 (30 cm × 10 cm) treatment and minimum number of branches plant^{-1} (2.20) was observed at 50 DAS with P_1 (20 cm × 10 cm) treatment.

Interaction effect was significant at 50 DAS (4.00) on S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm).

Number of leaves plant^{-1} was significant on S_2 (13 September), which produced the highest (14.41) number of leaves plant^{-1} and S_4 (23 October) had the lowest (3.63) number of leaves plant^{-1} at 50 DAS. Spacing had significant effect on number of leaves plant^{-1} at all the stages of crop growth. Plots treated with P_3 (40 cm × 10 cm) produced the highest number of leaves plant^{-1} (14.41 and 8.67) and P_2 (30 cm × 10 cm) showed the lowest (6.67 and 9.03) number of leaves plant^{-1} at 40 and 50 DAS respectively. Interaction exerted significant effect on number of leaves plant^{-1} at 50 DAS (17.56) no was observed in S_2P_3 (sowing on 13 September and spacing at 40 cm × 10 cm).

Sowing date differed significantly in producing plant dry wt. at 40 and 50 DAS. S_2 (13 September) showed the highest dry weight (6.18 gm) at 50 DAS where as S_4 (23 October) showed the lowest dry weight (0.66 gm). Treatment spacing exerted no significant effect on dry weight plant^{-1}. The highest dry weight (3.87 gm) was found in P_1 (20 cm × 10 cm) and the lowest dry weight plant^{-1} (3.18 gm) was found at P_3 (40 cm × 10 cm) treated plot. Interaction of sowing date and spacing had non-significant difference in S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm) (6.59 gm) at 50 DAS.

Yield components of mungbean are markedly influenced by sowing date and spacing. Interaction exert non-significant effect on number of pods plant^{-1} in S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm) (27.55) treated plot. The combined effect of sowing date and spacing was significant on pod length in S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm) (9.20 cm) treatment. The significant effects of sowing date and spacing on seeds pod^{-1} was recorded in S_2P_1 (sowing on 13 September and spacing at 20 cm × 10 cm) (11.90) interaction. 1000 seed weight of BARI mung-6 differed significantly due to sowing date. Maximum weight (40.77 gm) was obtained from S_1 (24 August) and minimum 1000 seed weight (3.95 gm) was S_4 (23 October). Spacing non-significantly affected the 1000 seed weight and was recorded maximum (27.17 gm) in P_2 (30 cm × 10 cm) treated plants and minimum (26.87 gm) in P_3 (40 cm × 10 cm). The combined effect of sowing date and spacing was statistically significant in respect of 1000 seed weight in S_2P_1 (sowing on 13 September and spacing at 20 cm × 10 cm) treatments.

Planting time and planting geometry is the most important factors influencing the yield of mungbean. Effect of sowing date on seed yield was statistically significant on S_2 (13 September), which produced the highest seed yield (1.56 t ha^{-1}) while the lowest (0.37 t ha^{-1}) was in S_4 (23 October). Sowing date showed significant differences in stover production on S_2 (13 September), that produced the highest stover yield (1.78 t ha^{-1}) and lowest in S_4 (23 October) (0.25 t ha^{-1}). Effect of spacing on seed yield was significant and was highest (1.13 t ha^{-1}) at P_2 (30 cm × 10 cm) and the lowest (1.02 t ha^{-1}) was in P_3 (40 cm × 10 cm). Stover production differed among different spacing. It was higher (1.18 t ha^{-1}) at P_2 (30 cm × 10 cm) treated plots compared to P_1 (20 cm × 10 cm) (1.09 t ha^{-1}) treated plots. The interaction effect of sowing date and spacing was found significant in respect of seed yield. The highest seed yield (1.53 t ha^{-1}) was obtained from S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm) interaction. Sowing date and spacing interaction effect on stover yield were significant. The highest stover yield (1.76 t ha^{-1}) also observed in S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm).

Interaction of sowing date and spacing had significant effect on biological yield. S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm) interaction showed the highest biological yield (3.32 t ha^{-1}), which was statistically similar with S_2P_3 (sowing on 13 September and spacing at 40 cm × 10 cm) (3.29 t ha^{-1}) interaction. Significant differences in harvest index % value had also recorded. The highest harvest index (58.43%) was observed in S_2P_2 (sowing on 13 September and spacing at 30 cm × 10 cm) interaction treatment which was similar with S_2P_1 (sowing on 13 September and spacing at 20 cm × 10 cm) (58.23%) interactions.

From the present study it may be concluded that in *Kharif II* season mungbean differed significantly in their yield performance due to sowing date and spacing. Among the four sowing dates S_2 (13 September) with the combination of P_2 (30 cm ×

10 cm), was the best optimum time of sowing with appropriate spacing to obtain higher yield. But sowing in S_1 (24 August) may be other options for obtaining higher yield since S_2P_2 combinations produced statistically identical yield of BARI Mung- 6. So, farmers can get benefit to understand their target level if planting is completed up to 13 September because there was drastic reduction in yield after this date and researcher can identify the growth and yield attribute of mungbean in an appropriate planting geometry.

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APPENDICES

Appendix I. Characteristics of Agronomy Farm soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	Medium high land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Fallow-Mungbean

B. Physical and chemical properties of the initial soils

Characteristics	Value
Sand (%)	27
Silt (%)	43
Clay (%)	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (mel 1 00 g soil)	0.10
Available S (ppm)	45

Source : SRDI (2013)

Appendix II. Monthly record of air temperature, rainfall, relative humidity, soil temperature and Sunshine of the experimental site during the period from August 2013 to January 2014

Month	Average air temperature (°C)			Average relative humidity (%)	Total rainfall (mm)	Total Sunshine per day (hrs)
	Maximum	Minimum	Mean			
August, 2013	36.0	23.6	29.8	81	319	4.0
September, 2013	34.8	24.4	29.6	81	279	4.4
October, 2013	34.8	18.0	26.4	77	227	5.8
November, 2013	29.7	20.1	24.9	65	5	6.4
December, 2013	26.9	15.8	21.35	68	0	7.0
January, 2014	24.6	12.5	18.7	66	0	5.5

Source: Bangladesh Meteorological Department (Climate & weather division), Agargaon, Dhaka – 1212

Appendix III. Analysis of variance of the data on seedling emergence and plant height of mungbean as influenced by different sowing date, spacing and their interaction.

Source of variance	Degrees of freedom	Mean square					
		Days to 80% seedling emergence	Plant height (cm)				
			10 DAS	20 DAS	30 DAS	40 DAS	50 DAS
Replication	2	0.03	2.23	2.25	26.56	36.54	54.47
Factor A (sowing date)	3	21.44*	53.07*	493.68*	1962.73*	4091.04*	3665.57*
Factor B (spacing)	2	0.36	1	1.94	5.63	0.07	15.48
AB (interaction)	6	0.69*	0.54	8.41	2.82	10.26	13.53
Error	22	0.18	0.99	12.57	13.10	17.51	15.01

* Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on branch plant^{-1} as influenced by different sowing date, spacing and their interaction.

Source of variance	Degrees of freedom	Mean Square			
		No. of branch plant^{-1}			
		20 DAS	30 DAS	40 DAS	50 DAS
Replication	2	0.001	0.20	0.02	0.15
Factor A (sowing date)	3	2.25	9.27*	4.29*	4.94*
Factor B (spacing)	2	0.001	0.12	0.04	0.02
AB (interaction)	6	0.001	0.08	0.22	1.43*
Error	22	0.001	0.08	0.21	0.20

* Significant at 0.05 level of probability

Appendix V. Analysis of variance of the no. of leaves plant^{-1} of mungbean as influenced by different sowing date, spacing and their interaction

Source of variance	Degrees of freedom	Mean square				
		No. of leaves plant^{-1}				
		10 DAS	20 DAS	30 DAS	40 DAS	50 DAS
Replication	2	0.01	0.10	0.20	0.95	0.29
Factor A (sowing date)	3	1.11*	11.87*	17.37*	40.85*	189.66*
Factor B (spacing)	2	0.003	0.32	0.4847	2.38*	0.86
AB (interaction)	6	0.003	0.16	0.60*	4.50*	13.25*
Error	22	0.003	0.48	0.20	0.58	5.97

* Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the dry wt. plant^{-1} of mungbean as influenced by different sowing date, spacing and their interaction

Source of variance	Degrees of freedom	Mean Square				
		Dry wt. of plant^{-1} (gm)				
		10 DAS	20 DAS	30 DAS	40 DAS	50 DAS
Replication	2	0	0.03	0.09	0.41	0.47
Factor A (sowing date)	3	0.001*	0.36*	3.07*	24.57*	46.74*
Factor B (spacing)	2	0	0.003	0.001	0.91	1.52
AB (interaction)	6	0	0.01	0.10	0.74	0.83
Error	22	0.001	0.01	0.09	0.40	1.41

* Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the yield contributing parameters of mungbean as influenced by different sowing date, spacing and their interaction

Source of variance	Degrees of freedom	Mean square			
		Days to 50% flowering	Number of pods plant^{-1}	Pod length (cm)	Number of Seeds pod^{-1}
Replication	2	0.58	40.863	0.06	0.46
Factor A (sowing date)	3	48.67*	885.04*	125.87*	265.13*
Factor B (spacing)	2	1.75	16.60	0.68*	1.20*
AB (interaction)	6	0.97	15.38	0.45*	1.22*
Error	22	0.98	10.46	0.12	0.21

* Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the yield parameters of mungbean as influenced by different sowing date, spacing and their interaction

Source of variance	Degrees of freedom	Mean square				
		1000-seed weight (gm)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	2.59	0.03	0.01	0.04	84.45
Factor A (sowing date)	3	3168.17*	2.64*	4.33*	13.12*	210.06*
Factor B (spacing)	2	0.27	0.04*	0.02*	0.03*	37.53*
AB (interaction)	6	3.88*	0.06*	0.07*	0.07*	33.07*
Error	22	1.21	0.01	0.01	0.01	9.28

* Significant at 0.05 level of probability