EFFECT OF SOIL MOISTURE AND PLANTING METHOD ON GROWTH AND YIELD OF MUNGBEAN

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CERTIFICATE

This is to certify that the thesis entitled **'EFFECT OF SOIL MOISTURE AND PLANTING METHOD ON GROWTH AND YIELD OF MUNGBEAN'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science** in **Agronomy**, embodies the result of a piece of *bonafide* research work carried out by **Md. Nizam Uddin**, Registration number: **09-03523** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
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DEDICATED

TO

MY BELOVED PARENTS

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The Author

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ABSTRACT

The experiment was conducted during the period from March 20, 2014 to June 20, 2014 at Sher-e-Bangla Agricultural University Farm to find out the growth and yield of mungbean (BARI Mung-6) as affected by soil moisture regimes [i) Sm_1-No watering ii) Sm_2-1/2 of field capacity iii) Sm_3-Field capacity] and planting methods [i) Pm_1 - Sowing in furrow without watering ii) Pm_2-Dibbling (30cm×7cm) iii) Pm_3 -Broadcasting iv) Pm_4- Sowing in furrow with watering at the bottom of furrow]. The design of the experiment was split-plot design where soil moisture given in the main plot and planting method in the sub plot with three replications. The highest values of all growth and reproductive parameters were obtained with Sm_3 while the lowest with Sm_1. Similarly the highest values were obtained with Pm_4 while the lowest with Pm_3.The highest values of germination (84.42%), plant height (62.89 cm at 45 DAS), number of branches plant^{-1}(2.83 at 45 DAS), number of leaves plant^{-1} (8.13 at 45 DAS), leaf area plant^{-1} (1093 cm^2 at 45 DAS), number of nodules plant^{-1} (22.54 at 45 DAS), Shoot dry weight plant^{-1} (14.40 g at 45 DAS), 1000-seed weight (57.20 g), number of pods plant^{-1} (22.27), number of seeds pod^{-1} (12.13), yield (1.626 t ha^{-1}) and harvest index (42.30%) were obtained with Sm_3Pm_4.

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CHAPTER -01

INTRODUCTION

Mungbean (*Vigna radiata* L.) is an important legume crop of Bangladesh and a major component of many cropping systems. Mungbean (*Vigna radiata* L.) belonging to family Fabaceae and sub-family Papilionaceae), is composed of more than 150 species originating mainly from Africa and Asia where the Asian tropical regions have the greatest magnitude of genetic diversity (USDA-ARS GRIN, 2012). Mungbean seeds are rich in protein and amino acids, thus serve as a valuable protein source for human consumption. Pods and sprouts of mungbean are also eaten as vegetable and are a source of vitamin and minerals. Moreover, this crop fixes atmospheric nitrogen (Ranawake *et al*., 2011).The mungbean is an important pulse crop in Bangladesh. Its seed contains 24.7% protein, 0.6% fat, 0.9% fiber and 3.7% ash (Potter and Hotchkiss, 1997). It has a short life cycle and therefore widely grown as mixed crop, intercrop or in rotation to improve nitrogen status of soil or to break the diseases or pest cycle. This pulse plays a significant role as supplement of low protein diet of poor people in Bangladesh but its production and acreage is declining day by day with an average yield of 0.69 ton ha^{-1} (BBS, 2008). Mungbean is a warm season crop requiring 60-90 days of frost free conditions from planting to maturity. Adequate rainfall is required from flowering to late pod filling in order to ensure good yield. Mungbean plays a significant role in sustaining crop productivity by adding nitrogen through rhizobial symbiosis and crop residues (Sharma and Behera, 2009). The total production of mungbean in Bangladesh in 2013-14 was 1.81 lac metric tons from an area of 1.73 lac hectares with an average yield 1.04t ha^{-1} (MoA, 2014).

According to FAO (2013) recommendation, a minimum intake of pulse by a human should be 80 g/day, whereas it is 7.92 g in Bangladesh. Mungbean plays an important role to supplement protein in the cereal-based low-protein diet of the people of Bangladesh, but the acreage production of mungbean is gradually declining (BBS, 2012). Mungbean is cultivated with minimum tillage, local varieties with no or minimum fertilizers, pesticides and very early or very late sowing, no practicing of irrigation and drainage facilities etc. with other different stress condition. All these factors are responsible for low yield of mungbean which is incomparable with the yields of developed countries of the world (FAO, 1999). The low yield of mungbean besides other factors may partially be due to lack of knowledge regards to suitable production technology of this crop (Hussain *et al*., 2008).

The yield is very low in comparison with other country production in the world. One of the reasons for lower yield is the scarcity of moisture during growth, development and maturity (Asaduzzaman *et al*., 2008). Drought problems for mungbean are worsening with the rapid expansion of water stressed areas of the world including 3 billion people by 2030 (Postel, 2000). Crop yield of Mungbean is more dependent on an adequate supply of water than on any other single environmental factor (Kramer and Boyer, 1997). Among the favorable characters of growing mungbean short-term growth, nitrogen fixation capability, soil reinforcement and prevention of soil erosion are in top. Mungbean is popular as inter crop, or as mixed crop with cash crops. Soil moisture level is an essential condition which regulates physiological processes of the plant. It is the most important factor which affects the crop production. Moisture stress has been reported to reduce soluble sugar and amino acid (Gupta *et al.*, 2000). In Bangladesh mungbean is cultivated during dry season. Water deficit or unavailable soil moisture is a common occurrence during this time and almost every year, depending on the severity of drought, 10-70% crop yield is lost (BARC, 1990).

Another reason of low yield of mungbean (*Vigna radiata* L. Wilczek) 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. 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 x10 cm plant density always showed highest yield performance.

Keeping in view of these findings, it is important to determine proper soil moisture, seed rate and row spacing for standardization of plant population and moisture content in soil per unit area to achieve increased on mungbean yield.

Considering the above points, the present study was undertaken to evaluate the effects of soil moisture and planting method on the growth and yield of mungbean with the following objectives:

- To examine the effect of soil moisture on seed germination, growth and yield of mungbean.
- To evaluate the effect of planting method on seed germination, growth and yield of mungbean.
- To examine the interaction effect of soil moisture and planting method on seed germination, growth and yield of mungbean.

Chapter 2
Review of literature

CHAPTER 02

REVIEW OF LITERATURE

Mungbean is an important pulse crop in Bangladesh and as well as many countries of the world although the crop has conventional less attention by the researchers on various aspects because basically it grows in fallow land or as intercropped without or minimum care or management practices. Although soil moistures and planting methods play an important role in improving mungbean yield. But research works related to soil moistures and planting methods as a management practices on mungbean are limited and not conclusive in context of Bangladesh. However, some of the important and informative works and research findings related to soil moistures and planting methods in mungbean so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Seed germination (%)

Thahir and Abdel (2011) found that seed germination proceeds under field capacity (0 depletion %) was the best. This treatment surpassed over 25, 50 and 75% depletion of AWC in terms of final germination percentage (2.8, 13.3, 53.2%, respectively), germination energy (10.6, 28.7 and 90.5%, respectively), germination rate (28.6, 49.4 and 124.7.2%, respectively), germination rate : germination percentage ratio (26.5, 13.7 and 52%, respectively), radical length(16.6, 48 and 129.1 %, respectively), plumule length 27.5, 34.8 and 128 %, respectively.

Hosseini *et al.* (2009) reported that at the crop level, the drought stress accounts for most variations in yield. The experiment was laid out in split plot design with soil moisture content as the main treatment and genotype as sub-treatment. Significant differences ($P < 0.001$) as regards plant emergence and early growth were observed among different soil moisture contents (from 100 to 50, then to 25% field capacity). Highly significant differences were also noticed among the genotypes for mean emergence percentage, first day to emergence, plant height, leaf area, total above-ground biomass (plant size) as well as specific leaf area Although the Kabuli types on average germinated faster and produced larger plants as opposed to the Desi types under the limited soil moisture content, but there was no consistency observed among the chickpea genotypes. Susceptibility of the genotypes to limited soil moisture condition was shown through relatively longer delays in time to emergence (lower germination rate) and reduction in seedling parameters as compared to the resistant genotypes. Final average above ground biomass (plant size) and plant height under the limited soil moisture content, as opposed to adequate moisture level (F. C. 25% vs. 100%), were reduced 79-85% in Kabuli and 77-79% in Desi types, respectively.

Ullah (2006) carried out an experiment at Sher-e-Bangla Agricultural University during July, 2000.In experiment 2, seeds were soaked in water for 12, 24, 36, 48, 60 and 72 hours and then were sown in soil of polythene bags to evaluate seedling emergence. In experiment, 3 seeds were sown in soils of earthen pots and then the pots along with soil were drowned in water for 12, 24, 36 and 48 hours. The results showed that water logging over 24 hours delayed germination significantly. Water logging over 48 hours reduced the germination significantly and that over 60 hours reduced germination drastically. Water logging over 72 hours caused failure in germination. Water logging over 12 hours delayed seedling emergence significantly. But, water logging up to 48 hours significantly improved the emergence percentage of seedlings and that over 48 hours caused drastic reduction in seedling emergence. In experiment 3, it was seen that significantly lower values of almost all the physiological parameters were found with successive increase in duration of water logging over 12 hours.

Cook *et al.* (1995) found that manual furrow sowing was more effective when the soil was relatively wetter, whereas manual dibbling was more effective when the soil was relatively drier. This was because of the greater water conservation and the absence of a hard cap which develops on closing the dibble in wet soil. In a comparison based on the cost of the seeder and labor, and the seed spacing, no-till manual furrow seeding and manual dibble sowing were found to be equally effective management options for establishment of mungbean after rice.

Woodhead (1994) reported that emergence for mung bean was 65± 5% and 26± 5% and for soybean 34± 3% and 0% for the mechanical relay seeder and broadcast seeding, respectively. Lack of emergence of the broadcast soybean seeds was due to inadequate imbibition of seeds for germination.

2.2 Effect of soil moisture on growth and yield of mungbean:

2.2.1 Plant height

Uddin *et al.* (2013) conducted the trial which comprised of seven treatments of irrigation in different growth stages. The effect of irrigation on plant height was significant at 60 DAS, 75 DAS and 90 DAS. At 60 DAS highest plant height (36.51cm) was obtained from T_6 where two irrigations were applied at flowering to pod dry matter and maturity and the lowest (30.08 cm) was obtained from T_1. Similar results were found at 75 and 90 DAS.

Ranawake *et al.* (2011) revealed that plant height, number of leaves, number of floral buds dry matter weight of shoot system, number of lateral roots, length of tap root, number of root nodules, and dry matter weight of root system were measured after one week recovery period in stressed plants at three different growth stages and in relevant control plants. Water stress significantly effects on them.

Adnan (2005) found that plant height and number of leaves plant-1 was the highest in 80% FC and gradually decreased with gradual decrease in field capacity levels.

In mungbean, Hutami and Achlan (1992) observed that there were interactions between water stress condition and mungbean variety/line on plant height, number of pods / plant and number of seeds / plant.

In an experiment with mungbean, Villegas (1981) found that under greenhouse conditions moisture stress significantly reduced plant height.

Parjol *et al.* (1971) stated that water deficit reduced plant height in vegetative growth phase of mungbean.

2.2.2 Number of leaves and number of branches per plant

Uddin *et al.* (2013) reported that the effect of irrigation on the number of branches plant^{-1} and number of leaves plant^{-1} was significant at 30 DAS, 60 DAS and 90 DAS and 30 DAS, 75 DAS and 90 DAS, respectively .The highest number of branches plant^{-1} was found in T_4 where one irrigation was at pod setting to maturity (P-M) and the lowest was observed in T_1 with no irrigation condition.

Kulathunga *et al.* (2008) carried out a field study to evaluate different irrigation schedules to ascertain the impact of soil moisture on growth, yield and nodulation of mungbean. Growth, yield and nodulation were higher in flat beds than in ridge and furrow systems of land preparation.

Adnan (2005) found that the soil moisture levels had significant at I% level of significance influences on number of leaves plant-1 and the number of secondary branches plant-1 at 50 DAS and 60 DAS The highest number of secondary branches plant" 4.44 at 50 DAS and 4.11 at 60 DAS were obtained from 80% FC followed by 60% FC.

Arjunan *et al.* (1992) observed higher number of functional leaves in genotypes of groundnut under moisture deficit condition at harvest, which ensured plants a continued supply of photosynthesis to the sink until maturity.

Wien *et al.* (1979) reported substantially fewer leaves in cowpea under moderate drought stress in field.

2.2.3 Leaf area

Kumar *et al.* (2014) found that water stress effect on some growth related morphological, physiological and biochemical characters was studied in ten mungbean genotypes (*Vigna radiata* L. wilczek) subject to phasic drought at vegetative, flowering and pod development stages. The first recorded physiological parameters in vegetative stage for both the non-stress and stress conditions increased further in the successive flowering and pod development stages. Water stress induced significant reduction in some characters and increase in others. Significant reduction in the measurements was observed in leaf area, dry matter production, relative water content, leaf water potential, transpiration rate, chlorophyll content, soluble protein and nitrate reductase activity.

Babu *et al.* (1994) showed the reduction in leaf area due to moisture stress has been reported by many workers in many different crops.

Islam *et al.* (1994) conducted an experiment on mungbean in Japan. They reported that plant produced lower leaf area under drought conditions.

Hutami *et al.* (1991) conducted an experiment on the water stress of mungbean. They observed that a seven — day's water stress imposed at first flowering reduced leaf area.

Hughes *et al.* (1981) observed a reduction in leaf area to water stress. Hoogenboom *et al.* (1987) stated that leaf area expansion rates decreased significantly during period of water stress, and leaves in stressed plants became smaller than those of irrigated plants.

Kramer (1963) reported that the reduction of leaf area with increased thickness when plants were exposed to moisture stress. Furthermore, rapid leaf senescence was associated with stressed plant causing reductional in total functional leaf area.

2.2.4 Dry matter

Fooladivanda *et al.* (2014) reported that water stress had a significant effect on total dry weight of mungbean .The lowest total dry weight observed at severe stress treatment (4506.5 kg / ha), compared to control, decreased by 22%.

Yagoob and Yagoob (2014) showed that leaf dry weight decreased with increasing drought stress in all genotypes. The most(51.33 plant^{-1}) and the least (19.00 g plant^{-1}) stem dry weight was achieved fromVC4386 genotype in irrigated after 50 mm evaporation from pan and NM92 genotype in irrigated after 200 mm evaporation, respectively.

Uddin *et al.* (2013) reported that stem dry weight plant^{-1} (g) also varied among different treatment .At the 30DAS the highest stem dry weight (1.75g) was found from irrigation treatment T_5 which was statistically similar from irrigation treatment T_3, T_4, T_6 and T_7, respectively and the lowest stem dry weight (0.5g) from no irrigation condition (T_1).

Moradi *et al.* (2008) examined mungbean in conditions of extreme and mild water stress and state that the effect of water stress on total dry matter in vegetative stage was more than reproductive growth.

De Costa and Shanmugathasan (2002) reported that maximum total biomass increased significantly with the number of stages irrigated, with irrigation during the vegetative stages having the highest positive effect and found that drought stress significantly decreased the total dry matter production.

Hamid *et al.* (1990) found that photosynthetic components, dry matter production and yield in water stressed plants were compared with those of non-stressed or well watered plants grown in a semi-controlled environment. Plants were subjected to variable water stress at three growth stages viz. from pre-flowering, flowering and pod development to harvest.

Sangakara *et al.* (2001) conducted an experiment to study influence of soil moisture and fertilizer potassium on the vegetative growth of mungbean and cowpea and found that potassium increased shoot growth of mungbean to a greater extent than in cowpea under suboptimal moisture conditions. The roots of cowpea showed a greater response to potassium fertilizer than in mungbean under suboptimal soil moisture.

Miah *et al.* (1996) suggested that in adequate soil moisture condition plant had higher photosynthesis and growth and produced higher dry matter in mungbean.

In an experiment with mungbean, Islam *et al.* (1994) observed that drought conditions reduced total dry matter of plants.

Morizet *et al.* (1984) concluded from their experiment, dry matter production in drought resistant varieties appeared higher while it was lower in susceptible varieties. This further means high and sustainable dry matter production in stress condition could he used as selection criteria for future variety development programs.

2.2.5 Number of pods per plant

Adnan (2005) found that the number of pods per plant, number of seeds per pod, 1000-seed weight, seed yield per plant, total dry matter per plant and harvest index (HI) were the highest in 80% FC and gradually decreased with gradual decrease in field capacity levels. The highest seed yield obtained in the 80% FC followed by 60% FC and 40% FC.

Siddique (2004) found that number of pods per plant, number of seeds per pod. 100-seed weight, seed yield per plant were observed from the 80% FC followed by 60% and 40% FC.

Alam (2002) conducted a research where it comprised of three irrigation levels i.e., (1) no irrigation (control), (ii) one irrigation at 25 days after sowing (DAS) and (iii) 2 irrigations at 25 and 35 DAS. Results revealed that significantly higher seed yield was obtained from the irrigated plants over the non-irrigated ones. Higher number of pods plant^{-1} and greater amount of assimilate towards the seed contributed to higher seed yield in the plants irrigated twice at 25 and 35 DAS. The lowest seed yield was obtained from each genotype under control.

Gupta *et al.* (1996) conducted an experiment in French bean under 4 moisture regimes (1W: CPE ratio 0.25, 0.50. 0.75 and 1.00) and found that irrigation regimes significantly increased number of seeds/plant (21.9%) and 100-seed weight (22.9gm).

In mungbean, Hutami and Achlan (1992) observed that there was interaction between water stress condition and mungbean genotypes on number of pods/plant and number of seeds/plant.

Prasad *et al.* (1990) found that yield attributes like number of pods/plant, pod length, number of seeds/pod and 1000-grain weight was significantly greater with 2-3 irrigations than in the rain fed or one irrigation. Soil moisture depletion was more in the upper layer with 2-3 irrigation than in the rain fed condition or one irrigation. The grain yield was significantly higher with 2-3 irrigations at 30 DAS while 1000-seed weight was the lowest under rain fed condition or 1 supplement irrigation at 30 DAS.

Hamid *et al.* (1990) observed that over watering and slight and severe water stress (soil moisture contents of 0.2306, 0.1056 and 0.0614cm; respectively) imposed at pre-flowering, flowering or pod development reduced water use efficiency and number of pods/plant in mungbean.

Hasan and Rahman (1987) conducted a pot experiment with lentil grown in a sandy loam soil and subjected to water stress (temporary wilting point

9.5% by weight) and observed that the number of seeds was highest while the plant was receiving adequate water.

2.2.6 Seed Yield

Fooladivanda *et al.* (2014) reported that water stress and potassium fertilizer significantly affect all traits. The highest grain yield (2093 kg /ha) was obtained from no stress treatment in the case of 180 kg /ha potassium.

Naresh *et al.* (2013) showed Improved moisture supply through various irrigation treatments increased the yield attributes and grain yield significantly over I_5 “control” treatment. The maximum yield attributes and grain yield were recorded under I_2 and minimum under I_5 treatment.

Kulathunga *et al.* (2008) found that the impact of different irrigation schedules showed significant differences for 100 seeds weight and seed yield. The soil moisture is a critical factor for the crop growth and pod filling of mung bean.

Rahman (2004) found that mulches induced significant effect on the growth, yield and yield components of the mungbean varieties and also caused significant changes in soil and canopy temperatures as well as conservation of soil moisture.

Hamid *et al* (2005) reported that the highest seed weight (34.09 g) of 1000-seeds weight was obtained from 70% FC followed by 50% FC. The lowest seed weight.

Mahmood *et al.* (1996) reported that yield per plant was positively correlated with plant height and days to flowering, but the correlation between yield and days to maturity was non-significant 28.21 g) was recorded from 30% FC.

Villegas (1981) tested the effect of different soil moisture regimes on yield of four seed legumes (mungbean, cowpea, soybean and peanut) and found that moisture stress greatly reduced the yield and the magnitude being 83% in mungbean, 65% in cowpea and soybean and 46% in peanut.

Wu *et al.* (1995) noted yield in mungbean is positively correlated with number of pods per plant, plant height and number of branches per plant.

Hutami *et al.* (1991) conducted a pot experiment to study the effect of water stress on growth and yield of mungbean found that water stress throughout the growing period significantly decreased yield and yield components of mungbean.

2.2.7 Harvest Index (%)

Akhtar (2005) reported that harvest index (HI), were decreased but total sugar, reducing sugar increased with increasing soil moisture stress. The highest seed yield/plant was obtained from 70% FC than that of 50% FC and 30% FC.

Siddique (2004) found that harvest index was found at the 80% FC. The most satisfactory growth and yield attributes were observed from the 80% FC followed by 60% and 40% FC.

Joseph *et al*. (1999) reported that water stress during pod-filling stage significantly reduced pod initiation and pod growth rates and thereby reduced HI.

Islam *et al.* (1996) conducted an experiment to assess the effect of moisture stress on the growth and yield of groundnut and observed that harvest index (HI) was less sensitive compared to TDM and pod yield.

Collinson *et al.* (1996) observed that decreasing amount of *water* applied, resulted in a decline in total dry matter production, and Harvest index (HI).

Salam and Islam (1994) conducted a pot experiment in the glasshouse with some advanced mutant lentil lines *(Lens culinaris)* under different soil moisture regimes. Under stress, they found that the mutant lines had greater harvest indices (HI) than local cultivars.

Ludlow and Muchow (1990) had the opinion that in drying soil environments lower shoot dry weight or harvest index could result from the higher partitioning of dry matter to roots at the expenses of shoot.

2.3Effect of sowing method on Growth and yield of mungbean

2.3.1 Morphological characteristics of Mungbean

Amin *et al.* (2014) reported that mean values for plant height due to different sowing methods ranged between 75.8 to78.5 cm. Maximum plant height of (78.5 cm) was noted when the SD(seed drill) method of sowing was used; while minimum plant height of (75**.**8 cm) was obtained when BC(broadcast) method of sowing was used.

Zaher *et al.* (2014) showed that the highest plant height (60.26 cm) was achieved by 15 cm row spacing with three times of weeding. The highest number of leaves plant^{-1} (11.08) and dry weight plant^{-1} (15.63 g) were gained by 30 cm row spacing with three times of weeding.

Rana *et al.* (2011) showed that plant height did not differ significantly due to plant population up to 50 DAS but differed significantly thereafter. Tallest plants at all the sampling dates were found in the 30 plants/m^2. At harvest, significantly tallest plant was found with 30 plants/m^2 (36.84 cm), followed by 45 plants/m^2 (35.19 cm) and the shortest plant was noted with 60 plants/m^2 (33.59 cm). The plants under higher population became smaller might be due to shortage of nutrient, water and other related component elements.

Kabir *et al.* (2008) reported that the tallest plant was observed at a planting density of 40 cm × 30 cm mainly due to more space for growing up the individual plant. The shortest plant was observed at a planting density of 20 cm × 20 cm.

Sathyamoorthi *et al.* (2008) found that root volume was more with lesser population and it decreased with higher population. Functional root nodules were higher with recommended plant population of 3.33 lakh plants ha^{-1}.

Mansoor *et al*. (2010) noted varying seed rates had significantly affected the number of branches $plant^{-1}$. Maximum branches (5.78) were noted in plots with 20 kg ha^{-1} seed rate. This might be due to the fact that lesser plants per unit area had utilized nutrients like water, light, CO_2 and N in abundance, which ultimately resulted in the formation of more photo-synthates and number of branches.

Jain and Chauhan (1988) stated that the plant density was the most important nonmonetary input which could be manipulated to attain the maximum productivity of green gram. But it is also varied with seasons, locations and soil types. For example 20 x 10 cm spacing was significantly superior for green gram raised during *Kharif* in Tamil Nadu and medium density of planting (3.33 x 105 plants ha^{-1}) proved to be superior for summer green gram raised in Uttar Pradesh.

Venkateswarlu *et al*. (1983) reported that Spacing of 22.5 cm x 10 cm under irrigated condition and 30 cm x 10 cm under rain fed condition during *Rabi* season in Andhra Pradesh, 25 or 30 x 10 cm spacing at Shalimar during July – October.

2.3.2 Dry matter of Mungbean

Rana *et al.* (2011) showed dry matter production significantly differed with plant population and it is seen that treatment having maximum plant population (60 plants /m^2) produced significantly highest dry matter at all sampling dates followed by 45 plants /m^2. The lowest value was recorded under minimum plant population (30 plants /m^2). However, at harvest, the highest dry matter weight (334.06 g /m^2) was achieved at 60 plants/m^2 followed by 273.82 g /m^2 at 45 plants/m^2 and the lowest 216.37 g /m^2 from 30 plants /m^2.

Kabir and Sarkar (2008) reported that the highest dry matter plant^{-1} was produced at spacing of 30 cm × 10 cm, which was identical to that of 40 cm × 30 cm. The lowest dry matter plant^{-1} was produced in 20 cm × 20 cm spacing. The highest number of branches plant^{-1} was observed at 30 cm × 10 cm spacing followed in order by 40 cm × 30 cm and 20 cm × 20 cm.

George and Barnes (1997) showed that dry matter yields tended to follow the same trend as for light interception .For the first four harvests, dry matter yields were highest for the 25 cm spacing. Maximum dry matter yields were produced for March 24 when physiological maturity was reached and senescence had commenced. However, senescence in the 100 cm spacing was delayed. This may result from decreased early water usage compared with narrower spacings. Emerald produced higher dry matter yields than Berken for March 24 (5.80 v 5.33 t/ha) and March 31 (5.82 v 4.89 t/ha). Light interception was higher for Emerald than Berken and this extended flowering duration would be reflected in increased dry matter.

Panwar and Singh (1975) reported that highest dry matter accumulation only recorded at wider row spacing of 40 cm over closer row spacings of 20-30 cm.

Shukla and Dixit (1996) observed that highest dry matter accumulation at harvest was maintained by 30cm row spacing during both the seasons in green gram.

2.3.3 Seed Yield

Amin *et al.* (2014) reported that average values for biological yield with different sowing methods ranged between 3998-4537 kg ha^{-1}. A maximum biological yield of 4537 kg ha^{-1} was recorded when the SD seed drill was used followed by CD with (4518 kg ha^{-1}), while minimum (3998 kg ha^{-1}) was obtained when broadcast method of sowing was used. This may be due to the proper placement and covering of seeds by drill sowing methods, which provide better environment for plant growth and increased biological yield as compared to broadcast sowing.

Singh *et al.* (2011) reported that optimum plant population is a prerequisite for obtaining high yields of any crop. At PAU, 40 plants m^{-2} at 25x10 cm spacing gave significantly higher grain yield than 33 plants m^{-2} at 30x10 cm spacing. Genotypes Pusa Vishal (selection from AVRDC material NM 92), SML 668 (selection from NM 94) and Pusa 9531 were on par in the grain yield and were better than UPM 98-1 and MH 96-1. Pusa Vishal and SML 668 had significantly larger seed size compared to Pusa 9531 and MH 96-1. At AVRDC, 20 plants m^{-2} sown at 50x10 cm spacing was the optimum for achieving higher grain yield and at higher plant densities, the yield tended to decrease. Lodging score was higher under higher plant densities. Genotypes NM 92 and VC 3890-A were superior to NM 94 and SML 134 in grain yield. Interaction between genotypes and plant density was non-significant for grain yield and other characters at both the locations.

Mansoor *et al.* (2010) noted the highest harvest index % was recorded in 30 cm row spacing with the value of 49.9%. The lowest value of harvest index (46.02%) was recorded in 20 cm row spacing.

Sathyamoorthi *et al.* (2008) found that Yield attributes *viz.*, pods plant^{-1}, pod length, seeds pod^{-1} and seed yield plant^{-1} were higher with recommended plant population (3.33 lakh plants ha^{-1}) and tended to decrease with increasing population.

Kabir and Sarkar (2008) reported that the highest harvest index was obtained in the variety BARIMung-2 planted at a spacing of 30 cm × 10 cm mainly due to the highest seed yield Similar harvest index was obtained from the variety BARI Mung-2 planted at a spacing of 40 cm × 30 cm. The lowest harvest indices were obtained from the varieties BARI Mung-4 and Binamoog-2 planted at a spacing of 40 cm × 30 cm and the variety Binamoog -2 planted at a spacing of 30 cm × 10 cm and the highest number of pods plant^{-1} was found at

30 cm × 10 cm spacing and the lowest one was found at 40 cm × 30 cm. However, 20 cm × 20 cm spacing produced similar pods plant^{-1} as that of 40 cm × 30 cm spacing. The highest pod length was observed at 30 cm × 10 cm spacing. The lowest pod length was observed at 20 cm × 20 cm spacing, which was statistically identical to 40 cm × 30 cm spacing. The highest 1000-seed weight was observed at 40 cm × 30 cm spacing followed in order by 30 cm × 10 cm and 20 cm × 20 cm spacing.

Singh *et al.* (2007) who reported that drill sowing methods produced higher grain and straw yield kg ha^{-1} followed by conventional sowing methods.

Mondal (2007) reported that grain yield is positively correlated with harvest index in mungbean in a population pressure study (250,000, 333,333, 400,000 or 500,000 plants ha^{-1}).

Fraz *et al.* (2006) conducted planting patterns (30 cm apart flat sowing, 30 cm apart ridge sowing & 20 cm apart bed sowing 40 cm wide beds) on growth and yield of mungbean. The results revealed that higher number of pods per plant, number of grains per pod, 1000-grain weight and harvest index were produced by 3rd week of July and 20 cm apart 40 cm wide beds.

Jahan and Hamid (2005) showed that the optimum plant density is a pre-requisite for obtaining higher productivity. Plant density affects the plant growth as well as grain yield in mungbean.

Jahan and Hamid (2004) observed that among the six levels of population densities (10, 20, 30, 40, 50 and 60 plants m^{-2}) the seed yield per plant decreased progressively with the increase in planting density.

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 x10 cm plant density always showed highest yield performance. Field investigations were undertaken at Punjab Agricultural University (PAU), Ludhiana, India on a loamy sand soil and at Asian Vegetable Research and Development Center

(AVRDC), Taiwan on a sandy loam soil. PAU higher grain yields were obtained at 40 plants m^{-2} (planted at 25x10 cm) on light-textured and low fertility soil and under harsh temperatures while at AVRDC, 20 plants m^{-2} (planted at 50x10 cm) were optimum on high fertility soil and under mild climatic conditions with high relative humidity.

Khan *et al*. (2001) revealed that a spacing of 50 cm between rows and 10 cm within rows produced maximum number of pods/plant, grains/ pod, higher thousand grain weight, lower per cent hard grain and higher biological yield, harvest index and grain yield (kg ha^{-1}).

Chowdhury (1999) found that seed rate had effect on grain size and reported that 1000 grain weight decreased with increasing seed rate in mungbean.

George and Barnes (1997) reported that grain yield for the 25 cm spacing was highest, followed by the 50 cm spacing, then the 75 cm and finally the 100 cm spacing which was not different to the 75 cm spacing. Increased yield appeared to be the result of increased pod number as seed weight and seeds/pod were not different for spacings. It appears the higher dry matter yields of the narrower spacings have translated into higher grain yields. Emerald produced higher grain yield than Berken (2.90 v 2.66 t/ha; P=0.07). This was due to more seeds/pod (10.6 vs. 8.9) which counteracted the effect of lower 200 seed weight of Emerald (14.0 v 14.8 g). There was no effect of cultivar on pod number. Increased grain yield for Emerald may result from its extended flowering period which enabled it to intercept more light and thus produce more dry matter which was translated into higher grain yield.

Dolli and Swamy (1997) noted 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.

Miranda *et al.* (1997) carried out a field trial using 5 plant population of 100,000, 200,000, 300,000, 400,000 and 500,000 plants ha^{-1} and found that 300,000 plants ha^{-1} had the greater seed yield and harvest index than the others plant densities.

Hague (1995) found that 333,333 plants ha^{-1} showed the highest harvest index as well as seed yield.

Talukder *et al.* (1993) conducted a field trial to investigate the effect of crop density (33 and 50 plants m^{-2}) on seed yield and found that the density of 33 plants m^{-2} produced higher seed yield than 50 plants m^{-2}.

Tomar *et al.* (1993).reported that Among four levels of plant population, a density of 4 lakh plants ha^{-1} was optimum for sowing at the onset of monsoon, while the density of 10 lakh plants ha^{-1} gave higher grain yield and returns compared to other plant densities in green gram during summer season in Madhya Pradesh.

Pookpakdi and Pataradilok (1993) recorded higher yields of both green gram and black gram grown in garden land soils of Thailand with increasing plant density from 2 to 8 lakhs ha^{-1} while pod number per plant decreased with increasing plant density.

Prasad and Yadav (1990) stated that among the three inter-row spacings *viz*., 15, 22.5 and 30 cm with intra-row spacing kept as 7 cm higher grain yield was recorded with 22.5 x 7 cm than with 30 x 7 cm spacing in green gram raised during March at Faizabad.

Thakuria and Saharia (1990) reported from summer green gram raised at Shillongani regions of Assam that between two plant densities (220 x 103 and 330 x 103), grain yield was significantly higher with the plant density of 330 x 103 plants ha^{-1}.

Rahman and Miah (1988) found that the results of the experiments on green gram at different locations in Bangladesh with different plant population density revealed that higher grain yield (900-950 kg ha^{-1}) of green gram could be obtained with a spacing of 20 x 10 cm accommodating 0.5 million plants ha^{-1} compared to 25 x 10 cm and 30 x 10 cm spacing.

In Australia, Lawn *et al*. (1988) found that plant population of 250,000 to 350,000 plants ha^{-1} was found optimum.

Yilu *et al*. (1988) stated that in Jiangsu Province of China, green gram yields of 2043 and 1473 kg ha^{-1} were produced from plant populations of 1.5 x 105, 3.0 x 105 and 4.5 x 105 plants ha^{-1}.

Chapter 3

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

The experiment was done to find out the growth and yield of mungbean as affected by soil moisture and planting methods. The materials and methods that were used for conducting the experiment have been presented in this chapter. It provides description of the location of experimental site, soil and climate condition of the experimental area, materials used for the experiment, design of the experiment, data collection and analysis procedure.

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from March 20, 2014 to June 20, 2014.

3.1.2 Description of the experimental site

The experiment was conducted at the experimental field (plot no: 39) of Sher-e-Bangla Agricultural University, (SAU), Dhaka-1207. It was located in 24.09^0N latitude and 90.26^0E longitude. The altitude of the location was 8 m from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207.

3.1.3 Climatic condition

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix I. During the experimental period the maximum temperature (35.4^0C), minimum temperature

(22.5^0C), the highest relative humidity (80%) and the highest rainfall (227 mm) was recorded in the month of June 2014, whereas the lowest relative humidity (67%) and the lowest rainfall (78 mm) was recorded in the month of April, 2014. No rainfall was occurred from 27th March to 9th April, 2014.

3.1.4 Characteristics of Soil

The soil of the experimental field belongs to the Tejgaon series under the Agro ecological Zone, Madhupur Tract (AEZ- 28) and the general soil type is Shallow Red Brown Terrace soil. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of silty clay with pH and organic matter 6.1 and 1.13, respectively. The results showed that the soil composed of 27% sand, 43% silt and 30% clay, which have been presented in Appendix II.

3.2 Experimental details

3.2.1 Treatments of the experiment

The design of the experiment was split-plot design where soil moisture given in the main plot and planting method in the sub plot.

Factor A: Soil moisture (3 levels)

i) Sm_1-No watering

ii) Sm_2-½ of field capacity

iii) Sm_3-Field capacity

A watering can was filled with water. The amount of water in the watering can was measured. In the day before evening of seed sowing date, 1 m^2 area was measured which was just outside of the experimental area and then continued adding water slowly by the watering can until water deposits on the soil surface. The remaining water in the watering can was measured and subtracted from the original amount. This amount of water was needed to wet the soil at field capacity. It was found that 2 cans water (12 liter) was appropriate for field capacity. Just at the beginning of sowing, the different moisture levels for the experimental plot were maintained.

- ½ of Field capacity took 1 can water (6 liter)/m^2 area
- Field capacity took 2 cans water/m^2 area

Factor B: Planting Methods (4 levels)

i) Pm_1 – Sowing in furrow without watering

ii) Pm_2 – Dibbling (30cm×7cm)

iii) Pm_3 -Broadcasting

iv) Pm_4- Sowing in furrow with watering at the bottom of furrow

There were in total 12 (3×4) treatment combinations such as Sm_1Pm_1, Sm_1Pm_2, Sm_1Pm_3, Sm_1Pm_4, Sm_2Pm_1, Sm_2Pm_2, Sm_2Pm_3, Sm_2Pm_4, Sm_3Pm_1, Sm_3Pm_2, Sm_3Pm_3 and Sm_3Pm_4.

3.2.2 Planting material

The variety of mungbean (BARI Mung-6) was used as the test crop for this study. The seeds of BARI Mung-6 were voluntarily given from the Pulse Seed Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. It was the released variety of mungbean, which was released in the year of 2003 with the recommended by the National Seed Board of Bangladesh. This variety can be cultivated in all the cropping seasons.

3.2.3 Land preparation

The land was first opened at 20th March, 2014 with the tractor drawn disc plough. Ploughed soil was brought into desirable fine tilth by ploughing and cross-ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 23th and 25th March, 2014, respectively. Experimental land was divided into unit plots following the experimental design.

3.2.4 Fertilizer application

Urea, Triple super phosphate (TSP), Muriate of potash (MoP) and gypsum were used as a source of nitrogen, phosphorous, potassium and sulphur respectively. Urea, TSP, MP and gypsum were applied at the rate of 17, 34, 13 and 5 kg per hectare, respectively following the Bangladesh Agricultural Research Institute (BARI) recommendation during final land preparation (25th March, 2014).

3.2.5 Experimental design and layout

The two factors experiment was laid out in split plot design with three replications. An area of 17.10 m × 15.50 m was divided into blocks. Soil moisture was assigned in the main plot and planting methods in sub-plot. The size of the each unit plot was 2.1 m × 2.0 m. The space between two blocks and two plots were 0.75 m and 0.5 m, respectively. The layout of the experimental plot is shown in Figure 1.

3.3 Growing of crops

3.3.1 Sowing of seeds in the field

The seeds of mungbean were sown on March 27, 2014 in the furrows with no watering, dibbling, furrows with watering and broadcasted having a depth of 2-3 cm with maintaining plant densities as per treatments of the experiment.

3.3.2 Intercultural operations

3.3.2.1 Irrigation, drainage and weeding

Irrigation was not provided in any plot after emergence of seedlings during Research. Proper drain also made for drained out excess water from rainfall

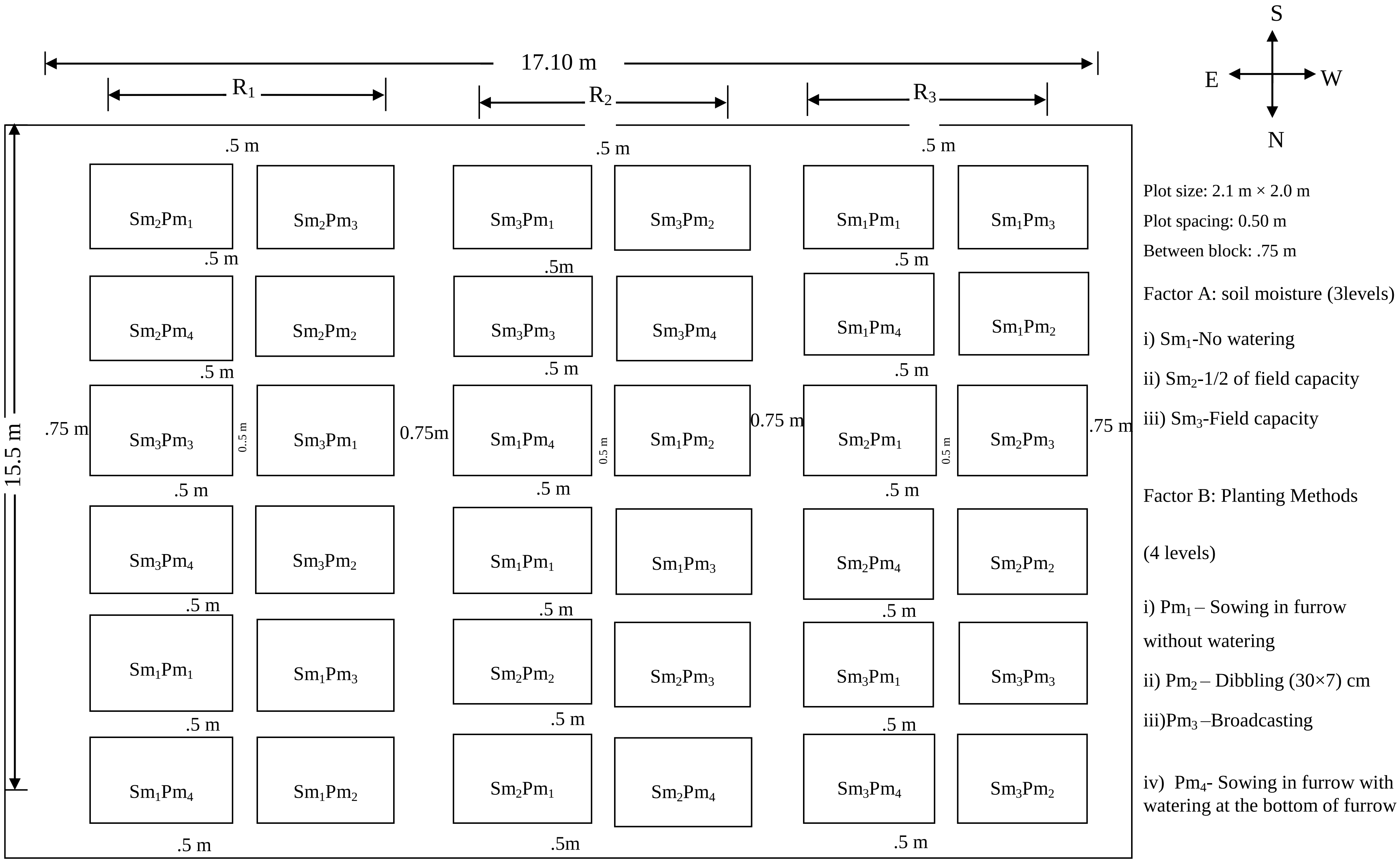

Figure 1. Experimental (split plot) design

from the experimental plot. The crop field was weeded and herbicides were applied properly.

3.3.2.2 Plant protection measures

At early stage of growth few worms (*Agrotis ipsilon*) infested the young plants and at later stage of growth pod borer (*Maruca testulalis*) attacked the plant. Ripcord 10 EC was sprayed at the rate of 1 ml with 1 litre water of 5 decimal lands for two times at 15 days interval after seedlings germination to control the insects. Plants were also attacked by yellow mosaic disease caused by yellow mosaic virus that was controlled in proper way. Before sowing seeds were treated with Bavistin 50 WP to protect seed borne diseases.

3.4 Crop sampling and data collection

Five plants from each treatment were randomly selected and marked with sample card. Plant height, number of leaves, number of branches and dry matter content in plant were recorded from selected plants at an interval of 15 days started from 15 DAS (days after sowing) to 60 DAS.

3.5 Harvest and post-harvest operations

Harvesting was done for 3 times when 90% of the pods became brown to black in color**.** The matured pods were collected by hand picking from each plot.

3.6 Data collection

The following data were recorded

i. Germination percentage
ii. Plant height at 15, 30, 45, 60 DAS.
iii. Number of branches plant^{-1} at 15, 30, 45, 60 DAS.
iv. Number of leaves plant^{-1} at 15, 30, 45, 60 DAS.
v. Leaf area plant^{-1} at 15, 30, 45, 60 DAS.

vi. Shoot dry weight plant^{-1} at 15, 30, 45, 60 DAS.

vii. Root dry weight plant^{-1} at 15, 30, 45, 60 DAS.

viii. Number of nodules plant^{-1} at 15, 30, 45, 60 DAS.

ix. Number of pods plant^{-1}

x. Number of seeds pod^{-1}

xi. Weight of 1000 seeds

xii. Seed yield hectare^{-1}

xiii. Stover yield hectare^{-1}

xiv. Biological yield hectare^{-1}

xv. Harvest index (%)

3.7 Procedure of data collection

3.7.1 Germination (%)

From the 50 cm of 3 lines of every plot, germination was recorded up to 10 DAS. Then Germination percentage was estimated.

$$\text{Germination (\%)} = \frac{\text{Number of seedlings}}{\text{Number of seeds sown}} \times 100$$

3.7.2. Crop growth characters

3.7.2.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at 15, 30, 45, 60 DAS. Data were recorded from 5 plants from each plot and average plant height plant^{-1} was recorded as per treatment. The height was measured from the ground level to the tip of the plant by a meter scale.

3.7.2.2 Number of branches plant^{-1}

The number of branches plant^{-1} was counted at 15, 30, 45, 60 DAS. Data were recorded from 5 plants from each plot and average number of branches plant^{-1} was recorded as per treatment.

3.7.2.3 Number of leaves plant^{-1}

The number of leaves plant^{-1} was counted at 15, 30, 45, 60 DAS. Data were recorded from 5 plants from each plot and average number of leaves plant^{-1} was recorded as per treatment.

3.7.2.4 Number of Nodules plant^{-1}

The Number of Nodules plant^{-1}was counted at 15, 30, 45, 60 DAS. Data were recorded from 5 plants from each plot and average Number of Nodules plant^{-1}was was recorded as per treatment.

3.7.2.5 Leaf Area plant^{-1}

The Leaf Area plant^{-1} counted at 15, 30, 45, 60 DAS. Data were recorded from 5 plants from each plot and average Leaf Area plant^{-1} was recorded as per treatment.

3.7.2.6 Dry Shoot and root weight plant^{-1}

5 plants were collected randomly from each plot at 15, 30, 45, 60 DAS and Shoot was separated from root. Fresh shoot and root samples from each plot were put into envelops and placed in oven maintained at 70^{0}C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final dry weight of the sample was taken and recorded in gram.

The dry weight was computed by simple calculation by the following formula:

$$\text{Dry weight per plant} = \frac{\text{Dry weight (g)}}{\text{No. of plants}}$$

3.7.3 Yield contributing characters

3.7.3.1 Number of pods plant^{-1}

Numbers of total pods of 5 plants from each plot were counted and the mean numbers were expressed as plant^{-1} basis.

3.7.3.2 Number of seeds pod^{-1}

The number of seeds pods^{-1} was recorded randomly from selected pods at the time of harvest. Data were recorded as the average of 5 pods from each plot.

3.7.3.3 Weight of 1000 seeds

One thousand cleaned, dried seeds were counted randomly from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g).

3.7.4 Yield characters

3.7.4.1 Seed yield

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

3.7.4.2 Stover yield

The stover collected from 2 square meter of each plot was sun dried properly. The weight of stover was taken and converted the yield in t ha^{-1}.

3.7.4.3 Biological yield

Grain yield and stover yield together were regarded as biological yield of mungbean. The biological yield was calculated with the following formula:

Biological yield (t ha^{-1}) = Grain yield + Stover yield

3.7.4.4 Harvest index

Harvest index was calculated from the seed and stover yield of mungbean expressed in percentage.

$$\text{HI (\%)} = \frac{\text{Economic yield (seed weight)}}{\text{Biological yield (Total dry weight)}} \times 100$$

3.8 Statistical analysis

The data obtained for different parameters were statistically analyzed find out the effect of soil moisture and planting methods. The mean values of all the characters were calculated and the analysis of variance (ANOVA) was performed by the ‘F’ (variance ratio) test. The significance of the difference among the treatment means was estimated by the Least Significance Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

CHAPTER 04

RESULTS AND DISCUSSION

This chapter comprised presentation and discussion of the results obtained from the study of the growth and yield of mungbean as affected by soil moisture and planting methods. The analyses of variance (ANOVA) of the data on seed germination, growth characters, yield contributing characters and yield of mungbean are presented in Appendix III-IX. The results which are influenced by different treatment have been presented and discussed under the following headings:

4.1 Germination (%) of mungbean

Different level of soil moistures affected significantly in terms of seed germination (%) of mungbean (Appendix VIII). The highest germination (71.25%) was found from Sm_3 which was followed (55.24 %) by Sm_2, while the lowest germination (39.31%) was recorded from Sm_1 treatment (Figure 2). This result was supported by Hosseini *et al.* **(**2009) who reported that significant differences (P <0.001) as regards plant emergence and early growth were observed among different soil moisture contents (from 100 to 50, then to 25% field capacity).

Statistically significant variations in seed germination (%) of mungbean were observed for different planting methods (Appendix VIII). The highest germination (63.44%) was recorded from Pm_4 followed by (57.88 % and 51.69 %) Pm_2 and Pm_1 whereas the lowest germination (48.06 %) from Pm_3 (Figure 3). It was similar result of Woodhead (1994) who reported that emergence for mungbean was 65± 5% and 26± 5% for the mechanical relay seeder and broadcast seeding, respectively.

Seed germination (%) of mungbean varied significantly due to interactions of soil moistures and planting methods (Appendix VIII). The highest germination (%) (84.42) were observed from Sm_3Pm_4 while the lowest germination (%) (32.92) were found from Sm_1Pm_3 treatment combination (Table 1).

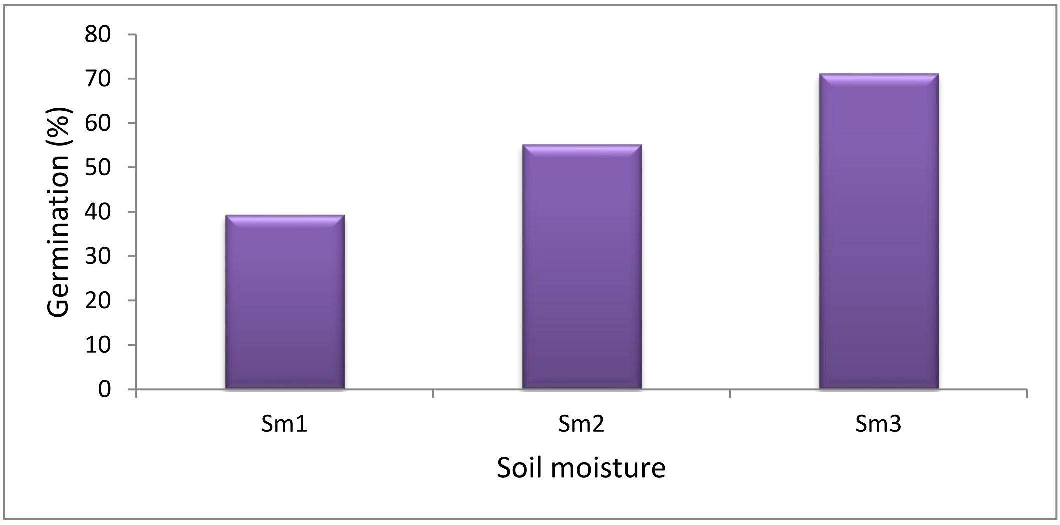

Figure 2. Effect of soil moisture on germination (%) of mungbean (LSD0.05=1.35)

Sm_1-No watering, Sm_2-1/2 of field capacity, Sm_3-Field capacity

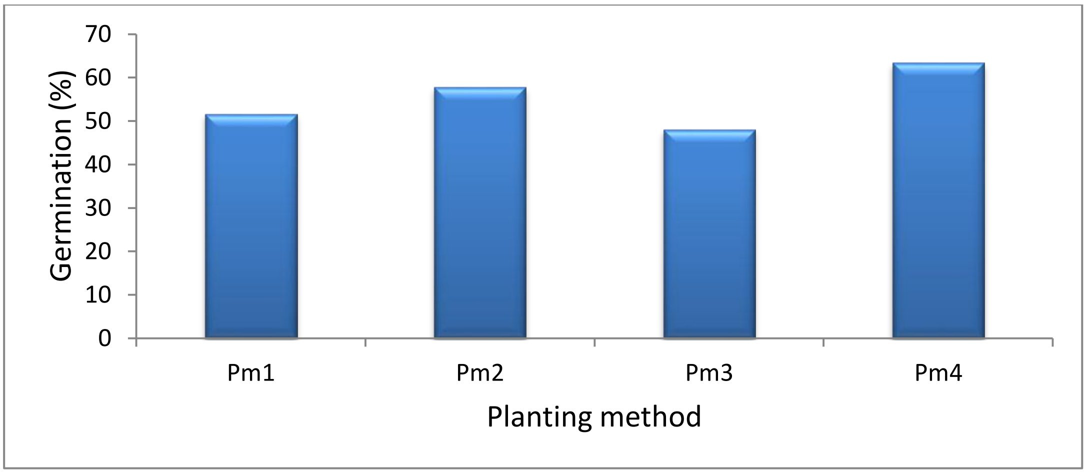

Figure 3. Effect of planting method on germination (%) of mungbean (LSD0.05=1.91)

Pm_1 – Sowing in furrow without watering

Pm_2 – Dibbling (30cm×7cm)

Pm_3 -Broadcasting

Pm_4- Sowing in furrow with watering at the bottom of furrow

Table 1. Interaction effect of soil moisture and planting methods on germination (%) of mungbean

Interaction	Germination (%)
Sm_1Pm_1	37.23 j
Sm_1pm_2	40.58 i
Sm_1Pm_3	32.92 k
Sm_1Pm_4	46.50 h
Sm_2Pm_1	54.19 f
Sm_2pm_2	57.41 ef
Sm_2Pm_3	49.98 g
Sm_2Pm_4	59.40 de
Sm_3Pm_1	63.66 c
Sm_3pm_2	75.65 b
Sm_3Pm_3	61.27 cd
Sm_3Pm_4	84.42 a
LSD(0.05)	3.30
CV (%)	6.49

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering
Sm_2-1/2 of field capacity
Sm_3-Field capacity

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 –Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

4.2 Crop growth Characters

4.2.1 Plant height

Plant height of mungbean at 15, 30, 45 and 60 DAS varied significantly due to different level of soil moistures (Appendix III). At 15, 30, 45 and 60 DAS, the tallest plant (23.63, 34.04, 59.23, 61.76 cm, respectively) were observed from Sm_3 and followed (21.54, 30.48, 55.93, 58.32 cm, respectively) by Sm_2 whereas shortest plant (15.36, 26.20, 50.16, 53.11 cm, respectively) from Sm_1 (Figure 4). It was revealed that with increase of soil moisture plant height was also increased due to proper cell division in plants. It was agreed with result of Adnan (2005) who found that plant height was the highest in 80% FC (field capacity) and gradually decreased with gradual decrease in field capacity levels.

Planting methods showed significant variation in plants height of mungbean at 15, 30, 45 and 60 DAS (Appendix III). At 15, 30, 45 and 60 DAS, the tallest plant (23.67, 34.22, 58.89, 61.20 cm, respectively) were recorded from Pm_4 which were followed (21.34, 30.62, 56.07, 58.68 cm respectively) by Pm_2 and then followed (18.89, 28.63, 54.18, 56.79 cm, respectively) by Pm_1whereas shortest plant (18.58, 27.49, 51.29, 54.24 cm, respectively) from Pm_3 (Figure 5). Similar result was found by Amin *et al.* (2014) who reported that maximum plant height of (78.5 cm) was noted when the SD (seed drill) method of sowing was used; while minimum plant height of (75**.**8 cm) was obtained when BC (broadcast) method of sowing was used.

Interaction effect of different soil moistures and planting methods showed significant variation in terms of plant height at 30, 45 and 60 DAS but non-significant at 15 DAS (Appendix III). At 15, 30, 45 and 60 DAS, the tallest plant (26.56, 38.23, 62.89, 64.72 cm, respectively) were observed from Sm_3Pm_4 while the shortest plants (13.21, 24.33, 46.39, 49.44 cm, respectively) were found from Sm_1Pm_3 treatment combination (Table 2).

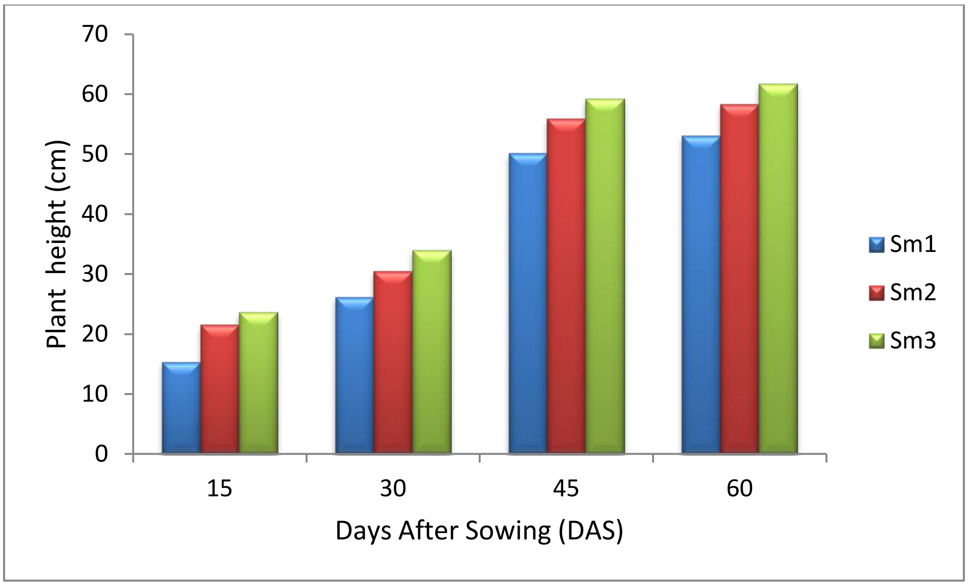

Figure 4. Effect of soil moisture on plant height (cm) of mungbean (LSD0.05=1.88, 1.82, 1.55, 2.19 at 15, 30, 45 and 60 DAS)

Sm_1-No watering, Sm_2-1/2 of field capacity, Sm_3-Field capacity

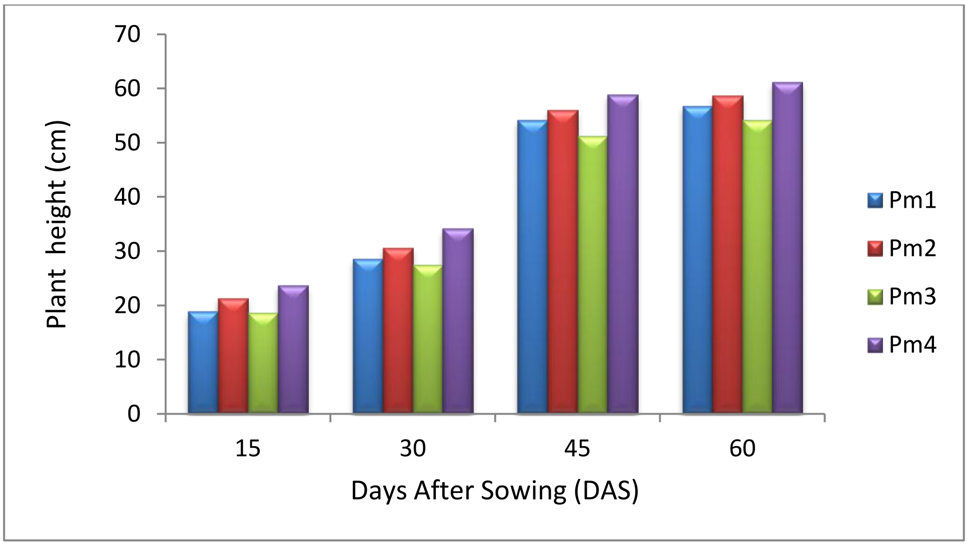

Figure 5. Effect of planting method on plant height (cm) of mungbean (LSD0.05=2.14, 2.29, 1.17, 1.80 at 15, 30, 45 and 60 DAS)

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 –Broadcasting
Pm_4- Sowing in furrow with watering at bottom of furrow

Table 2. Interaction effect of soil moisture and planting methods on plant height of mungbean

Interaction	Plant height (cm) at			
	15 DAS	30 DAS	45 DAS	60 DAS
Sm_1Pm_1	13.38	24.25 f	48.83 g	51.27 f
Sm_1pm_2	15.52	25.98 ef	51.66 f	54.66 e
Sm_1Pm_3	13.21	24.33 f	46.39 h	49.44 g
Sm_1Pm_4	21.36	30.24 cd	53.78 de	57.05 cd
Sm_2Pm_1	18.22	29.52 d	54.77 d	57.33 c
Sm_2pm_2	21.62	30.83 cd	56.66 c	58.77 c
Sm_2Pm_3	17.27	27.39 e	52.27 ef	55.33 de
Sm_2Pm_4	23.34	34.20 b	60.00 b	61.83 b
Sm_3Pm_1	21.23	32.12 c	58.94 b	61.77 b
Sm_3pm_2	25.28	35.05 b	59.89 b	62.61 b
Sm_3Pm_3	21.62	30.76 cd	55.22 cd	57.94 c
Sm_3Pm_4	26.56	38.23 a	62.89 a	64.72 a
LSD(0.05)	NS	1.992	1.524	1.816
CV (%)	8.77	7.65	8.15	8.16

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering
Sm_2-1/2 of field capacity
Sm_3-Field capacity

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 –Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

4.2.2 Number of branches plant^{-1}

Soil moistures showed significant variation in number of branches plant^{-1} of mungbean at 30, 45 and 60 DAS but non-significant at 15DAS (Appendix IV). At 15, 30, 45 and 60 DAS, the highest number of branches plant^{-1} (0.05, 0.76, 1.82, 2.33, respectively) were observed from Sm_3 and followed (0.01, 0.51, 1.61, 2.13, respectively) by Sm_2 whereas the lowest number of branches plant^{-1} (0.01, 0.31, 1.27, 1.85, respectively) from Sm_1 (table 3). It was resembled with the result of Uddin *et al.* (2013) who reported that the highest number of branches plant^{-1} was found in T_4 where one irrigation was at pod setting to maturity (P-M) and the lowest was observed in T_1 with no irrigation condition.

Number of branches plant^{-1}of mungbean was significantly affected by planting methods at 15, 30, 45 and 60 DAS (Appendix IV). At 15, 30, 45 and 60 DAS, the highest number of branches plant^{-1} (0.11, 0.91, 1.96, 2.47, respectively) were observed from Pm_4 and followed (0.00, 0.60, 1.65, 2.16, respectively) by Pm_2 whereas the lowest number of branches plant^{-1} (0.00, 0.20, 1.23, 1.83, respectively) from Pm_3 (Table 4). This result was in line of Mansoor *et al.* (2010) who noted varying seed rates had significantly affected the number of branches plant^{-1}. Maximum branches (5.78) were noted in plots with 20 kg ha^{-1} seed rate. This might be due to the fact that lesser plants per unit area had utilized nutrients like water, light, CO_2 and N in abundance, which ultimately resulted in the formation of more photo-synthates and number of branches.

Number of branches plant^{-1}of mungbean at 45 and 60 DAS varied significantly except 15 and 30 DAS due to interactions of soil moistures and planting methods (Appendix IV). At 15, 30, 45 and 60 DAS, the highest number of branches plant^{-1} (0.2, 1.26, 2.34, 2.83 cm, respectively) were observed from

Sm_3Pm_4 while the lowest number of branches plant^{-1} (0, 0.06, 1.12, 1.56, respectively) were found from Sm_1Pm_3 treatment combination (Table 5).

Table 3. Effect of soil moisture on number of branches plant^{-1} of mungbean

Treatments	Number of branches plant^{-1} at			
Soil moisture	15 DAS	30 DAS	45 DAS	60 DAS
Sm_1	0.01	0.31 c	1.27 c	1.85 c
Sm_2	0.01	0.51 b	1.61 b	2.13 b
Sm_3	0.05	0.76 a	1.82 a	2.33 a
LSD(0.05)	NS	0.16	0.19	0.05
CV (%)	8.21	10.53	7.84	7.56

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering, Sm_2-1/2 of field capacity, Sm_3-Field capacity

Table 4. Effect of planting methods on number of branches plant^{-1} of mungbean

Treatments	Number of branches plant^{-1} at			
Planting method	15 DAS	30 DAS	45 DAS	60 DAS
Pm_1	0.00 b	0.40 c	1.34 c	1.94 c
Pm_2	0.00 b	0.60 b	1.65 b	2.16 b
Pm_3	0.00 b	0.20 d	1.23 d	1.83 c
Pm_4	0.11 a	0.91 a	1.96 a	2.47 a
LSD(0.05)	0.06	0.12	0.11	0.14
CV (%)	8.21	10.53	7.84	7.56

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 -Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

Table 5. Interaction effect of soil moisture and planting methods on number of branches plant^{-1} of mungbean

Interaction	Number of branches plant^{-1} at			
	15 DAS	30 DAS	45 DAS	60 DAS
Sm_1Pm_1	0	0.20	1.29 e	1.70 g
Sm_1pm_2	0	0.40	1.47 d	1.96 ef
Sm_1Pm_3	0	0.06	1.12 f	1.56 h
Sm_1Pm_4	0.06	0.60	1.67 c	2.16 c
Sm_2Pm_1	0	0.40	1.45 d	2.03 de
Sm_2pm_2	0	0.60	1.67 c	2.16 c
Sm_2Pm_3	0	0.20	1.28 e	1.90 f
Sm_2Pm_4	0.06	0.86	1.86 b	2.43 b
Sm_3Pm_1	0	0.60	1.67 c	2.10 cd
Sm_3pm_2	0	0.80	1.86 b	2.36 b
Sm_3Pm_3	0	0.40	1.46 d	2.03 de
Sm_3Pm_4	0.2	1.26	2.34 a	2.83 a
LSD(0.05)	NS	NS	0.12	0.13
CV (%)	8.21	10.53	7.84	7.56

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering
Sm_2-1/2 of field capacity
Sm_3-Field capacity

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 –Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

4.2.3 Number of leaves plant^{-1}

Number of leaves plant^{-1}of mungbean at 15, 30, 45 and 60 DAS varied significantly due to different level of soil moistures (Appendix IV). At 15, 30, 45 and 60 DAS, the highest number of leaves plant^{-1} (4.48, 5.31, 7.53, 5.78, respectively) were recorded from Sm_3 which were followed (3.81, 4.92, 6.88, 5.00, respectively) by Sm_2 whereas the lowest number of leaves plant^{-1} (3.41, 4.52, 6.16, 4.41, respectively) from Sm_1 (Figure 6). It was fact that leaves number of plant increased because of proper growth of plants which are favorably affected by field capacity. Same trend was found by Adnan (2005) who reported that Plant height and number of leaves plant^{-1} was the highest in 80% FC and gradually decreased with gradual decrease in field capacity levels.

Planting methods showed significant variation in number of leaves plant^{-1}of mungbean at 15, 30, 45 and 60 DAS (Appendix IV). At 15, 30, 45 and 60 DAS, the highest number of leaves plant^{-1} (4.42, 5.53, 7.44, 5.68, respectively) were observed from Pm_4 and followed (3.95, 4.88, 7.06, 5.15, respectively) by Pm_2 and then followed (3.75, 4.73, 6.66, 4.93) by pm_1whereas the lowest number of leaves plant^{-1} (3.48, 4.51, 6.26, 4.48, respectively) from Pm_3 (Figure 7).This result indicates that furrow with watering gives highest number of leaves plant^{-1} than that of the broadcasting method. Zaher *et al.* (2014) showed that the highest number of leaves plant^{-1} (11.08) was gained by 30 cm line spacing.

Interaction effect of different soil moistures and planting methods showed significant variation in terms of number of leaves plant^{-1}at 15, 30, 45 and 60 DAS (Appendix IV). At 15, 30, 45 and 60 DAS, the highest number of leaves plant^{-1} (5.31, 6.20, 8.13, 6.46, respectively) were observed from Sm_3Pm_4 while the lowest number of leaves plant^{-1} (3.12, 4.00, 5.33, 3.86, respectively) were found from Sm_1Pm_3 treatment combination (Table 6).

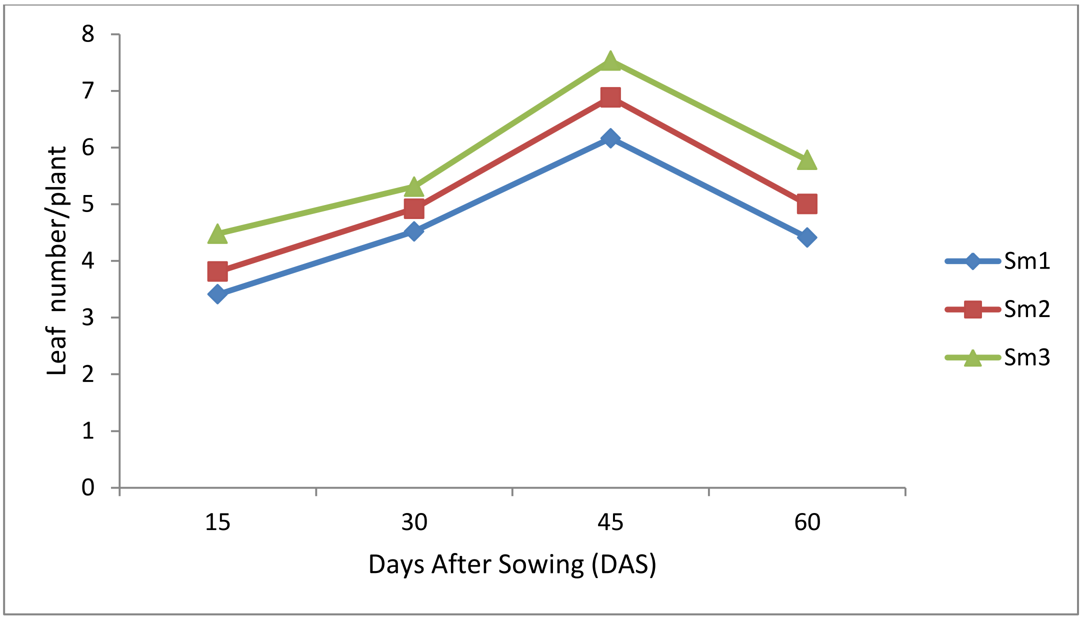

Figure 6. Effect of soil moisture on number of leaf plant^{-1} of mungbean (LSD0.050=0.22, 0.38, 0.18, 0.30 at 15, 30, 45 and 60 DAS)

Sm_1-No watering, Sm_2-1/2 of field capacity, Sm_3-Field capacity

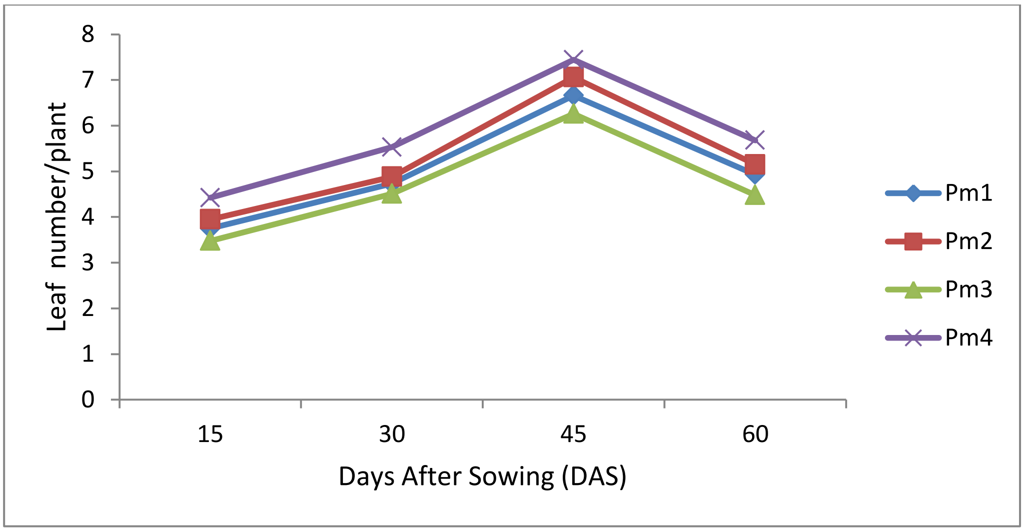

Figure 7. Effect of planting method on number of leaf plant^{-1} of mungbean (LSD0.05=0.17, 0.16, 0.23, 0.26 at 15, 30, 45 and 60 DAS)

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 -Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

Table 6. Interaction effect of soil moisture and planting methods on number of leaves plant^{-1} of mungbean

Interaction	Number of leaves plant^{-1} at			
	15 DAS	30 DAS	45 DAS	60 DAS
Sm_1Pm_1	3.29	4.33 f	6.13 g	4.26 g
Sm_1pm_2	3.82	4.53 ef	6.46 fg	4.60 f
Sm_1Pm_3	3.12	4.00 g	5.33 h	3.86 h
Sm_1Pm_4	3.72	4.80 cd	6.73 ef	4.93 e
Sm_2Pm_1	3.58	4.66 de	6.73 ef	4.93 e
Sm_2pm_2	3.73	4.86 cd	7.06 de	5.00 e
Sm_2Pm_3	3.34	4.46 ef	6.26 g	4.40 g
Sm_2Pm_4	4.19	5.26 b	7.46 bc	5.66 c
Sm_3Pm_1	4.32	5.26 b	7.13 cd	5.60 c
Sm_3pm_2	4.61	5.46 b	7.66 b	5.86 b
Sm_3Pm_3	4.19	5.00 c	7.20 cd	5.20 d
Sm_3Pm_4	5.31	6.20 a	8.13 a	6.46 a
LSD(0.05)	NS	0.24	0.35	0.17
CV (%)	6.41	5.21	7.39	8.26

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering
Sm_2-1/2 of field capacity
Sm_3-Field capacity

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 –Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

4.2.4 Leaf area plant^{-1}

Statistically significant variations in leaf area plant^{-1} were recorded at 15, 30, 45 and 60 DAS for different soil moistures level (Appendix V). At 15, 30, 45 and 60 DAS, the highest leaf area plant^{-1} (401.7, 558.3, 765.5, 593.9 cm^{2,} respectively) were recorded from Sm_3 which were followed (257.4, 372.4, 529.7, 387.4 cm^2, respectively) by Sm_2 whereas the lowest leaf area plant^{-1} (185.4, 273.8, 379.7, 279.9 cm^2, respectively) from Sm_1 (Table 7). It was supported by Babu *et al.* (1994) showed the reduction in leaf area due to moisture stress has been reported by many workers in many different crops.

Leaf area plant^{-1} of mungbean at 15, 30, 45 and 60 DAS varied significantly due to different planting methods (Appendix V). At 15, 30, 45 and 60 DAS, the highest leaf area plant^{-1} (416.5, 595.4, 815.1, 635.6 cm^2, respectively) were recorded from Pm_4 which were followed (291.9, 415.2, 588.2, 437.6 cm^2, respectively) by Pm_2 and then followed (219.7, 335.8, 469.2, 352.1 cm^2, respectively) by Pm_1 whereas the lowest leaf area plant^{-1} (197.9, 259.6, 360.6, 256.4 cm^2, respectively) from Pm_3 (Table 8). It was revealed that higher population reduces the all growth parameters due to insufficient nutrients. Rana *et al.* (2011) showed that the plants under higher population became smaller might be due to shortage of nutrient, water and other related component elements. So the leaf area must be lower.

Leaf area plant^{-1} of mungbean at 15, 30, 45 and 60 DAS varied significantly due to interactions of soil moistures and planting methods (Appendix V). At 15, 30, 45 and 60 DAS, the highest leaf area plant^{-1} (554.5, 827.9, 1093.0, 876.5 cm^2, respectively) were observed from Sm_3Pm_4 while the lowest leaf area plant^{-1} (124.6, 179.7, 233.5, 162.5 cm^2, respectively) were found from Sm_1Pm_3 treatment combination (Table 9).

Table 7. Effect of soil moisture on leaf area plant^{-1} of mungbean

Treatments	Leaf Area (cm^2) at			
Soil moisture	15 DAS	30 DAS	45 DAS	60 DAS
Sm_1	185.4 c	273.8 c	379.7 c	279.9 c
Sm_2	257.4 b	372.4 b	529.7 b	387.4 b
Sm_3	401.7 a	558.3 a	765.5 a	593.9 a
LSD(0.05)	39.75	58.02	62.63	63.39
CV (%)	10.33	9.39	8.81	9.07

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering, Sm_2-1/2 of field capacity, Sm_3-Field capacity

Table 8. Effect of planting methods on leaf area plant^{-1} of mungbean

Treatments	Leaf Area (cm^2) at			
Planting Method	15 DAS	30 DAS	45 DAS	60 DAS
Pm_1	219.7 c	335.8 c	469.2 c	352.1 c
Pm_2	291.9 b	415.2 b	588.2 b	437.6 b
Pm_3	197.9 c	259.6 d	360.6 d	256.4 d
Pm_4	416.5 a	595.4 a	815.1 a	635.6 a
LSD(0.05)	28.80	37.35	48.69	37.77
CV (%)	10.33	9.39	8.81	9.07

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 -Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

Table 9. Interaction effect of soil moisture and planting methods on leaf area plant^{-1} of mungbean

Interaction	Leaf Area (cm^2) at			
	15 DAS	30 DAS	45 DAS	60 DAS
Sm_1Pm_1	139.7 ef	224.6 h	314.5 f	230.7 f
Sm_1pm_2	183.1 e	289.8 fg	403.5 e	296.3 e
Sm_1Pm_3	124.6 f	179.7 h	233.5 f	162.5 g
Sm_1Pm_4	294.3 cd	401.0 d	567.3 cd	430.3 d
Sm_2Pm_1	183.9 e	307.3 ef	446.0 e	319.8 e
Sm_2pm_2	274.2 d	397.5 d	574.0 cd	411.5 d
Sm_2Pm_3	170.8 ef	227.5 gh	313.4 f	218.4 fg
Sm_2Pm_4	400.7 b	557.3 b	785.5 b	599.9 b
Sm_3Pm_1	335.4 c	475.4 c	647.2 c	505.7 c
Sm_3pm_2	418.4 b	558.4 b	787.2 b	605.1 b
Sm_3Pm_3	298.3 cd	371.7 de	534.9 d	388.4 d
Sm_3Pm_4	554.5 a	827.9 a	1093.0 a	876.5 a
LSD(0.05)	49.89	64.69	84.34	65.42
CV (%)	10.33	9.39	8.81	9.07

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering
Sm_2-1/2 of field capacity
Sm_3-Field capacity

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 –Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

4.2.5 Number of nodules plant^{-1}

Soil moistures showed significant variation in number of nodules plant^{-1}of mungbean at 15, 30, 45 and 60 DAS (Appendix VI). At 15, 30, 45 and 60 DAS, the highest number of nodules plant^{-1} (6.19, 8.77, 18.52, 10.18, respectively) were observed from Sm_3 and followed (3.38, 5.45, 12.56, 5.91, respectively) by Sm_2 whereas the lowest number of nodules plant^{-1} (1.29, 3.38, 7.57, 2.98, respectively) from Sm_1 (Figure 8). It was the same line of Ranawake *et al.* (2011) who revealed that number of lateral roots, length of tap root and number of root nodules was measured after one week recovery period in stressed plants at three different growth stages and in relevant control plants where water stress significantly affects them.

Number of nodules plant^{-1}of mungbean was significantly affected by planting methods at 15, 30, 45 and 60 DAS (Appendix VI). At 15, 30, 45 and 60 DAS, the highest number of nodules plant^{-1} (5.31, 8.07, 15.11, 7.85, respectively) were observed from Pm_4 which was followed (4.18, 6.30, 13.66, 6.68, respectively) by Pm_1 and then followed (3.12, 5.00, 11.87, 5.86) by Pm_2 whereas the lowest number of nodules plant^{-1} (2.02, 4.09, 10.91, 5.03, respectively) from Pm_3 (Figure 9). It was revealed that optimum population increases the functional root nodules due to proper microclimate of a plant. Sathyamoorthi *et al.* (2008) found that root volume was more with lesser population and it decreased with higher population. Functional root nodules were higher with recommended plant population of 3.33 lakh plants ha^{-1}.

Interaction effect of different soil moistures and planting methods showed significant variation in terms of number of nodules plant^{-1}at 15, 30, 45 and 60 DAS (Appendix VI). At 15, 30, 45 and 60 DAS, the highest number of nodules plant^{-1} (8.91, 13.22, 22.54, 12.67, respectively) were observed from Sm_3Pm_4 while the lowest number of nodules plant^{-1} (0.74, 2.62, 6.73, 2.07, respectively) were found from Sm_1Pm_3 treatment combination (Table 10).

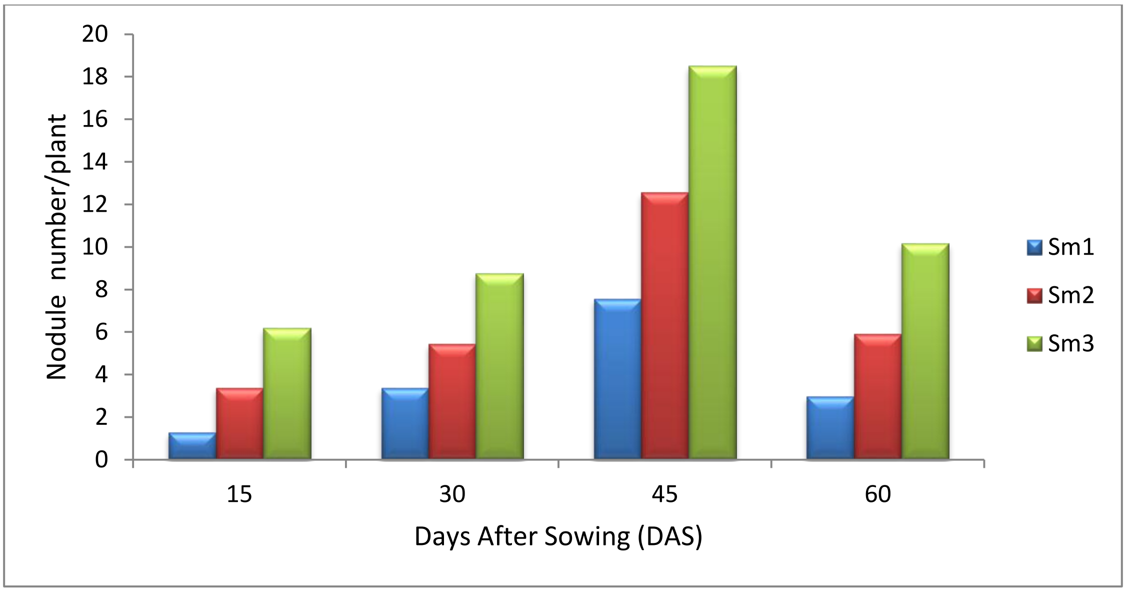

Figure 8. Effect of soil moisture on number of nodules plant^{-1} of mungbean (LSD0.05=1.98, 1.34, 3.63, 2.731 at 15, 30, 45 and 60 DAS)

Sm_1-No watering, Sm_2-1/2 of field capacity, Sm_3-Field capacity

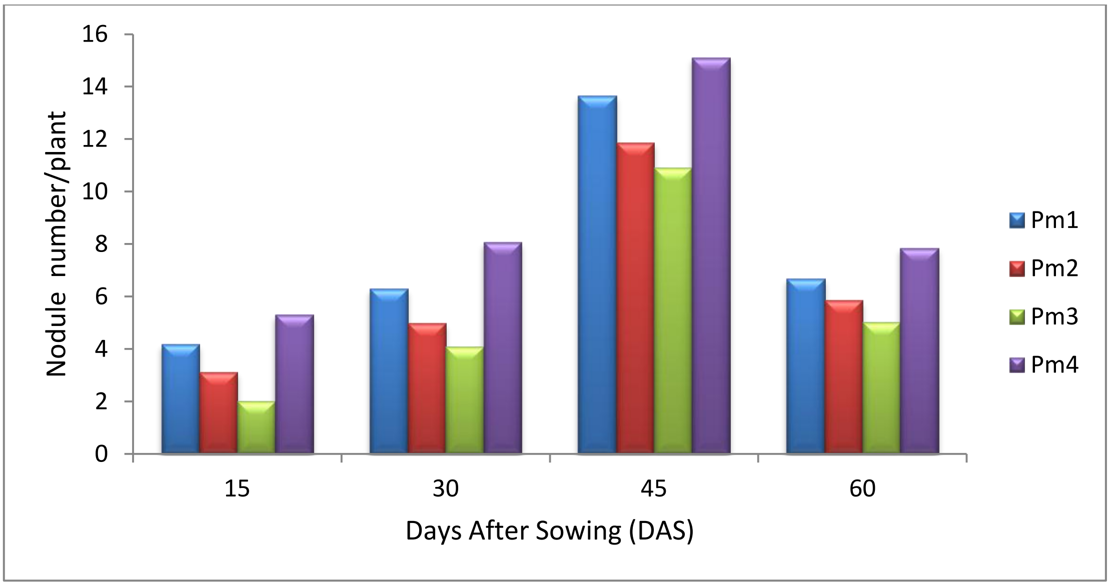

Figure 9. Effect of planting method on number of nodules plant^{-1} of mungbean (LSD0.05=0.21, 0.43, 0.94, 0.40 at 15, 30, 45 and 60 DAS)

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 -Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

Table 10. Interaction effect of soil moisture and planting methods on number of nodules plant^{-1} of mungbean

Interaction	Number of nodules plant^{-1} at			
	15 DAS	30 DAS	45 DAS	60 DAS
Sm_1Pm_1	1.54 g	3.60 g	7.86 gh	3.51 h
Sm_1pm_2	0.78 h	2.81 h	7.16 gh	2.44 i
Sm_1Pm_3	0.74 h	2.62 h	6.73 h	2.07 i
Sm_1Pm_4	2.47 e	4.52 f	8.55 g	3.88 gh
Sm_2Pm_1	3.62 d	5.75 de	13.67 e	6.21 f
Sm_2pm_2	3.54 d	5.44 e	11.78 f	5.92 f
Sm_2Pm_3	2.05 f	4.12 fg	10.56 f	4.53 g
Sm_2Pm_4	4.38 c	6.49 cd	14.22 de	7.00 e
Sm_3Pm_1	7.42 b	9.54 b	19.44 b	10.33 b
Sm_3pm_2	4.52 c	6.77 c	16.67 c	9.22 c
Sm_3Pm_3	3.51 d	5.55 e	15.44 cd	8.48 d
Sm_3Pm_4	8.91 a	13.22 a	22.54 a	12.67 a
LSD(0.05)	0.37	0.75	1.63	0.70
CV (%)	5.87	7.48	7.40	6.49

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering
Sm_2-1/2 of field capacity
Sm_3-Field capacity

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 –Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

4.2.4 Dry matter plant^{-1}

4.2.4.1 Shoot dry weight plant^{-1}

Statistically significant variations in shoot dry weight plant^{-1} were recorded at 15, 30, 45 and 60 DAS for different soil moistures level (Appendix VII). At 15, 30, 45 and 60 DAS, the highest shoot dry weight plant^{-1} (1.782, 2.279, 6.718, 13.230 g, respectively) were recorded from Sm_3 which were followed (1.212, 1.711, 5.024, 11.560 g, respectively) by Sm_2 whereas the lowest shoot dry weight plant^{-1} (0.936, 1.437, 4.459, 8.515 g, respectively) from Sm_1 (Table 11).This result was agreed with the result of Fooladivanda *et al*. (2014) who reported that water stress had a significant effect on total dry weight of mungbean.The lowest total dry weight observed at severe stress treatment (4506.5 kg / ha), compared to control, decreased by 22%.

Planting methods showed significant variation in shoot dry weight plant^{-1} of mungbean at 15, 30, 45 and 60 DAS (Appendix VII). At 15, 30, 45 and 60 DAS, the highest shoot dry weight plant^{-1} (1.724, 2.235, 6.477, 12.430 g, respectively) were observed from Pm_4 and followed (1.450, 1.961, 5.347, 11.570 g, respectively) by Pm_2 and then followed (1.011, 1.658, 5.149, 10.630 g, respectively) by Pm_1whereas the lowest shoot dry weight plant^{-1} (0.871, 1.381, 4.629, 9.764 g, respectively) from Pm_3 (Table 12). Optimum population increases total dry matter due to their proper cell division. It was similar trend with Kabir and Sarkar (2008).

Shoot dry weight plant^{-1} of mungbean at 15, 30, 45 and 60 DAS varied significantly due to interactions of soil moistures and planting methods (Appendix VII). At 15, 30, 45 and 60 DAS, the highest shoot dry weight plant^{-1} (2.533, 3.044, 8.471, 14.403 g, respectively) were observed from Sm_3Pm_4 while the lowest shoot dry weight plant^{-1} (0.675, 1.186, 3.671, 6.660 g, respectively) were found from Sm_1Pm_3 treatment combination (Table 13).

Table 11. Effect of soil moisture on shoot dry weight $plant^{-1}$ of mungbean

Treatments	Shoot dry weight (g) $plant^{-1}$ at			
Soil moisture	15 DAS	30 DAS	45 DAS	60 DAS
Sm_1	0.936 b	1.437 b	4.459 b	8.515 c
Sm_2	1.212 b	1.711 b	5.024 b	11.560 b
Sm_3	1.782 a	2.279 a	6.718 a	13.230 a
LSD(0.05)	0.287	0.294	0.847	0.473
CV (%)	12.16	11.69	10.98	9.39

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering Sm_2-1/2 of field capacity, Sm_3-Field capacity

Table 12. Effect of planting methods on shoot dry weight $plant^{-1}$ of mungbean

Treatments	Shoot dry weight (g) $plant^{-1}$ at			
Planting Method	15 DAS	30 DAS	45 DAS	60 DAS
Pm_1	1.011 c	1.658 c	5.149 b	10.630 c
Pm_2	1.450 b	1.961 b	5.347 b	11.570 b
Pm_3	0.871 d	1.381 d	4.629 c	9.764 d
Pm_4	1.724 a	2.235 a	6.477 a	12.430 a
LSD(0.05)	0.210	0.206	0.427	0.482
CV (%)	12.16	11.69	10.98	9.39

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 -Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

Table 13. Interaction effect of soil moisture and planting methods on shoot dry weight plant^{-1} of mungbean

Interaction	Shoot dry weight (g) plant^{-1} at			
	15 DAS	30 DAS	45 DAS	60 DAS
Sm_1Pm_1	0.873 ef	1.384 ef	4.398 ef	7.833 f
Sm_1pm_2	1.126 de	1.637 de	4.651 e	9.005 e
Sm_1Pm_3	0.675 f	1.186 f	3.671 f	6.660 g
Sm_1Pm_4	1.029 def	1.540 def	5.117 cde	10.56 d
Sm_2Pm_1	1.016 def	1.527 def	4.763 e	11.230 d
Sm_2pm_2	1.296 cd	1.807 cd	4.978 de	12.221 c
Sm_2Pm_3	0.880 ef	1.391 ef	4.511 e	10.442 d
Sm_2Pm_4	1.609 bc	2.120 bc	5.844 bc	12.331c
Sm_3Pm_1	1.552 c	2.063 c	6.288 b	12.840 bc
Sm_3pm_2	1.930 b	2.441 b	6.411 b	13.495 b
Sm_3Pm_3	1.056 de	1.567 de	5.703 bcd	12.201 c
Sm_3Pm_4	2.533 a	3.044 a	8.471 a	14.403 a
LSD(0.05)	0.352	0.363	0.739	0.835
CV (%)	12.16	11.69	10.98	9.39

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering
Sm_2-1/2 of field capacity
Sm_3-Field capacity

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 –Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

4.2.4.2 Root dry weight plant^{-1}

Soil moistures showed significant variation in root dry weight plant^{-1}of mungbean at 15, 30, 45 and 60 DAS (Appendix VII). At 15, 30, 45 and 60 DAS, the highest root dry weight plant^{-1} (0.255, 0.316, 0.816, 1.444 g, respectively) were observed from Sm_3 and followed (0.234, 0.296, 0.495, 1.104 g, respectively) by Sm_2 whereas the lowest root dry weight plant^{-1} (0.172, 0.231, 0.456, 0.755 g, respectively) from Sm_1 (Table 14). This result supported by Moradi *et al.* (2008) who examined mungbean in conditions of extreme and mild water stress and state that the effect of water stress on total dry matter in vegetative stage was more than reproductive growth.

Statistically significant variations in root dry weight plant^{-1} were recorded at 15, 30, 45 and 60 DAS for different planting methods (Appendix VII). At 15, 30, 45 and 60 DAS, the highest root dry weight plant^{-1} (0.252, 0.311, 0.783, 1.277 g, respectively) were recorded from Pm_4 which were followed (0.232, 0.293, 0.567, 1.124 g, respectively) by Pm_2 whereas the lowest root dry weight plant^{-1} (0.189, 0.250, 0.502, 0.960 g, respectively) from Pm_3 (Table 15). Similar trend was found by Panwar and Singh (1997) reported that highest dry matter accumulation only recorded at wider row spacing of 40 cm over closer row spacing's of 20-30 cm.

Interaction effect of different soil moistures and planting methods showed significant variation in terms of root dry weight plant^{-1}at 15, 30, 45 and 60 DAS (Appendix VII). At 15, 30, 45 and 60 DAS, the highest root dry weight plant^{-1} (0.285, 0.346, 1.197, 1.692 g, respectively) were observed from Sm_3Pm_4 while the lowest root dry weight plant^{-1} (0.144, 0.205, 0.401, 0.679 g, respectively) were found from Sm_1Pm_3 treatment combination (Table 16).

Table 14. Effect of soil moisture on root dry weight plant^{-1} of mungbean

Treatments	Root dry weight (g) plant^{-1} at			
Soil moisture	15 DAS	30 DAS	45 DAS	60 DAS
Sm_1	0.172 b	0.231 b	0.456 b	0.755 c
Sm_2	0.234 a	0.296 a	0.495 b	1.104 b
Sm_3	0.255 a	0.316 a	0.816 a	1.444 a
LSD(0.05)	0.058	0.061	0.097	0.038
CV (%)	9.11	8.38	10.73	7.88

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering, Sm_2-1/2 of field capacity, Sm_3-Field capacity

Table 15. Effect of planting methods on root dry weight plant^{-1} of mungbean

Treatments	Root dry weight (g) plant^{-1} at			
Planting method	15 DAS	30 DAS	45 DAS	60 DAS
Pm_1	0.211 bc	0.272 bc	0.504 b	1.044 c
Pm_2	0.232 ab	0.293 ab	0.567 b	1.124 b
Pm_3	0.189 c	0.250 c	0.502 b	0.960 d
Pm_4	0.252 a	0.311 a	0.783 a	1.277 a
LSD(0.05)	0.029	0.031	0.070	0.044
CV (%)	9.11	8.38	10.73	7.88

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 -Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

Table 16. Interaction effect of soil moisture and planting methods on root dry weight plant^{-1} of mungbean

Interaction	Root dry weight (g) plant^{-1} at			
	15 DAS	30 DAS	45 DAS	60 DAS
Sm_1Pm_1	0.164 ef	0.225 ef	0.421 f	0.724 hi
Sm_1pm_2	0.179 def	0.240 def	0.459 ef	0.769 h
Sm_1Pm_3	0.144 f	0.205 f	0.401 f	0.679 i
Sm_1Pm_4	0.195 def	0.256 def	0.546 de	0.849 g
Sm_2Pm_1	0.224 cd	0.285 bcd	0.419 f	1.051 e
Sm_2pm_2	0.245 abc	0.306 abc	0.452 ef	1.123 e
Sm_2Pm_3	0.202 cde	0.263 cde	0.504 def	0.952 f
Sm_2Pm_4	0.269 ab	0.330 ab	0.605 cd	1.289 cd
Sm_3Pm_1	0.244 abc	0.305 abc	0.673 bc	1.357 c
Sm_3pm_2	0.271 ab	0.332 ab	0.792 b	1.479 b
Sm_3Pm_3	0.221 bcd	0.283 bcd	0.603cd	1.250 d
Sm_3Pm_4	0.285 a	0.346 a	1.197 a	1.692 a
LSD(0.05)	0.054	0.049	0.121	0.076
CV (%)	9.11	8.38	10.73	7.88

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering
Sm_2-1/2 of field capacity
Sm_3-Field capacity

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 –Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

4.3 Yield contributing characters

4.3.1 Number of pods plant^{-1}

Different level of soil moistures varied significantly in terms of number of pods plant^{-1} of mungbean (Appendix VIII).The highest number of pods plant^{-1} (17.50) was found from Sm_3 which was followed (12.92) by Sm_2, while the lowest number of pods (10.72) was recorded from Sm_1 treatment (Table 17). Very similar result was found by Adnan (2005) noted that the number of pods per plant was the highest in 80% FC and gradually decreased with gradual decrease in field capacity levels.

Number of pods plant^{-1}of mungbean was significantly affected by planting methods (Appendix VIII). The highest number of pods plant^{-1} (17.80) was observed from Pm_4 and followed (14.76 and 12.47) by Pm_3 and Pm_2 whereas the lowest number of pods plant^{-1} (9.82) from Pm_1 (Table 18). It was agreed with Sathyamoorthi *et al.* (2008) who found that Yield attributes *viz.*, pods plant^{-1} and pod length was higher with recommended plant population (3.33 lakh plants ha^{-1}) and tended to decrease with increasing population.

Statistically significant variations in number of pods plant^{-1} were for interaction of different soil moistures level and planting methods (Appendix VIII). The highest number of pods plant^{-1} (22.27) was recorded from Sm_3Pm_4 whereas the lowest number of pods plant^{-1} (7.067) from Sm_1Pm_1 treatment combination (Table 19).

Table 17. Effect of soil moisture on number of pods plant^{-1}, number of seeds pod^{-1} and weight of 1000 seeds of mungbean

Soil moisture	Number of pods plant^{-1}	Number of seeds pod^{-1}	Weight of 1000 seeds (g)
Sm_1	10.72 c	8.81 c	49.50 c
Sm_2	12.92 b	10.12 b	52.37 b
Sm_3	17.50 a	11.47 a	55.88 a
LSD(0.05)	1.20	0.36	1.35
CV (%)	7.59	10.18	6.13

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering , Sm_2-1/2 of field capacity, Sm_3-Field capacity

Table 18. Effect of planting methods on number of pods plant^{-1}, number of seeds pod^{-1} and weight of 1000 seeds of mungbean

Planting Method	Number of pods plant^{-1}	Number of seeds pod^{-1}	Weight of 1000 seeds (g)
Pm_1	9.822 d	9.95 b	51.83 c
Pm_2	12.47 c	10.42 a	52.29 bc
Pm_3	14.76 b	9.48 c	52.43 b
Pm_4	17.80 a	10.67 a	53.77 a
LSD(0.05)	1.75	0.32	0.58
CV (%)	7.59	10.18	6.13

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 -Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

Table 19. Interaction effect of soil moisture and planting methods on number of pods plant^{-1}, number of seeds pod^{-1} and weight of 1000 seeds of mungbean

Interaction	Number of pods plant^{-1}	Number of seeds pod^{-1}	Weight of 1000 seeds (g)
Sm_1Pm_1	7.067 g	8.80 h	49.13 hi
Sm_1pm_2	9.533 f	9.20 gh	49.70 h
Sm_1Pm_3	11.87 e	7.93 i	48.70 i
Sm_1Pm_4	14.40 d	9.33 fgh	50.47 g
Sm_2Pm_1	8.800 f	9.86 ef	51.40 f
Sm_2pm_2	11.87 e	10.33 de	51.93 ef
Sm_2Pm_3	14.27 d	9.73 fg	52.50 e
Sm_2Pm_4	16.73 c	10.53 d	53.63 d
Sm_3Pm_1	13.60 d	11.20 bc	54.97 c
Sm_3pm_2	16.00 c	11.73 ab	55.23 c
Sm_3Pm_3	18.13 b	10.80 cd	56.10 b
Sm_3Pm_4	22.27 a	12.13 a	57.20 a
LSD(0.05)	1.85	0.55	0.69
CV (%)	7.59	10.18	6.13

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering
Sm_2-1/2 of field capacity
Sm_3-Field capacity

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 –Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

4.3.2 Number of seeds pod^{-1}

Number of seeds pod^{-1} showed significant variation for different level of moistures (Appendix VIII). The highest number of seeds pods $^{-1}$ (11.47) was found from Sm_3 which was followed (10.12) by Sm_2, while the lowest number of seeds pods $^{-1}$ (8.81) was recorded from Sm_1 treatment (Table 17). Similar result showed by Siddique (2004) found that number of seeds per pod plant was observed from the 80% FC followed by 60% and 40% FC.

Planting methods showed significant variation in number of seeds pods $^{-1}$ mungbean (Appendix VIII). The highest number of seeds pods $^{-1}$ (10.67) was observed from Pm_4 which was statistically similar to (10.42) Pm_2 and followed (9.95) by Pm_1 whereas the lowest number of seeds pods $^{-1}$ (9.48) from Pm_3 (Table 18). This result was in line of Singh *et al.* (2007) who reported that drill sowing methods produced higher grain and straw yield kg ha^{-1} followed by conventional sowing methods.

Interaction effect of different soil moistures and planting methods showed significant variation in terms of number of seeds pods $^{-1}$(Appendix VIII). The highest number of seeds pods $^{-1}$ (12.13) was observed from Sm_3Pm_4 which was statistically similar to (11.73) Sm_3Pm_2 while the lowest number of seeds pods $^{-1}$ (7.93) was found from Sm_1Pm_3 treatment combination (Table 19).

4.3.3 Weight of 1000 seeds (g)

Weight of 1000 seeds (g) showed significant variation for different level of moistures (Appendix VIII). The highest weight of 1000 seeds (55.88 g) was found from Sm_3 which was followed (52.37 g) by Sm_2, while the lowest Weight of 1000 seeds (49.50 g) was recorded from Sm_1 treatment (Table 17). Very similar trend was found by Hamid *et al* (2005) who reported that the highest seed weight (34.09 g) of 1000-seeds weight was obtained from 70% FC followed by 50% FC. The lowest seed weight (28.21 g) was recorded from 30% FC.

Statistically significant variations in weight of 1000 seeds (g) were for different planting methods (Appendix VIII). The highest weight of 1000 seeds (g) (53.77) was recorded from Pm_4 followed by (52.43 g and 52.29 g) Pm_3 and Pm_2 which are statistically similar whereas the lowest weight of 1000 seeds (51.83 g) from Pm_1 which is statistically similar to Pm_2 (52.29 g) (Table 18).Proper population at optimum spacing with soil moisture provided better Seeds weight revealed by Fraz *et al.* (2006).

Weight of 1000 seeds (g) of mungbean varied significantly due to interactions of soil moistures and planting methods (Appendix VIII). The highest weight of 1000 seeds (57.20 g) was observed from Sm_3Pm_4 while the lowest weight of 1000 seeds (48.70 g) was found from Sm_1Pm_3 treatment combination which was statistically similar to (49.13) Sm_1Pm_1 (Table 19).

4.4 Yield characters

4.4.1 Seed yield ha^{-1}

Different level of soil moistures varied significantly in terms of Seed yield ha^{-1} of mungbean (Appendix IX).The highest seed yield ha^{-1} (1.438 ton) was found from Sm_3 which was followed (1.138 ton) by Sm_2, while the lowest seed yield ha^{-1} (0.910 ton) was recorded from Sm_1 treatment (Table 20). A very similar result was found by Fooladivanda *et al.* (2014) who reported that water stress and potassium fertilizer significantly affect all traits. The highest grain yield (2093 kg /ha) was obtained from no stress treatment in the case of 180 kg /ha potassium.

Seed yield ha^{-1} of mungbean was significantly affected by planting methods (Appendix IX). The highest seed yield ha^{-1} (1.289 ton) was observed from Pm_4 and followed (1.199 ton and 1.117 ton) by Pm_2 and Pm_1 whereas the lowest seed yield ha^{-1} (1.043 ton) from Pm_3 (Table 21). This result was supported by Sathyamoorthi *et al.* (2008) who found that yield attributes *viz.*, pods plant^{-1}, pod length, seeds pod^{-1} and seed yield plant^{-1} were higher with recommended plant

Table 20. Effect of soil moisture on seed yield, stover yield, biological yield and harvest index of mungbean

Soil moisture	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Sm_1	0.910 c	1.376 c	2.286 c	39.70 b
Sm_2	1.138 b	1.682 b	2.820 b	40.24 ab
Sm_3	1.438 a	2.057 a	3.495 a	41.07 a
LSD(0.05)	0.097	0.089	0.151	1.17
CV (%)	11.72	12.58	10.83	8.71

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering, Sm_2-1/2 of field capacity, Sm_3-Field capacity

Table 21. Effect of planting methods on seed yield, stover yield, biological yield and harvest index of mungbean

Planting Method	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Pm_1	1.117 c	1.670 c	2.787 c	39.96 bc
Pm_2	1.199 b	1.749 b	2.948 b	40.56 ab
Pm_3	1.043 d	1.586 d	2.629 d	39.51 c
Pm_4	1.289 a	1.815 a	3.104 a	41.32 a
LSD(0.05)	0.062	0.031	0.082	1.04
CV (%)	11.72	12.58	10.83	8.71

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 -Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

Table 22. Interaction effect of soil moisture and planting methods on seed yield, stover yield, biological yield and harvest index of mungbean

Interaction	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Sm_1Pm_1	0.845 i	1.296 i	2.141 h	39.47 ef
Sm_1pm_2	0.966 h	1.430 h	2.397 g	40.26 de
Sm_1Pm_3	0.805 i	1.272 i	2.078 h	38.76 f
Sm_1Pm_4	1.024 gh	1.505 g	2.529 fg	40.32 d
Sm_2Pm_1	1.133 ef	1.701 e	2.834 e	39.86 de
Sm_2pm_2	1.133 ef	1.713 e	2.845 e	39.79 de
Sm_2Pm_3	1.070 fg	1.593 f	2.663 f	39.97 de
Sm_2Pm_4	1.216 de	1.722 e	2.938 e	41.33 bc
Sm_3Pm_1	1.373 c	2.012 c	3.385 c	40.55 cd
Sm_3pm_2	1.498 b	2.104 b	3.602 b	41.62 ab
Sm_3Pm_3	1.253 d	1.894 d	3.147 d	39.79 de
Sm_3Pm_4	1.626 a	2.219 a	3.845 a	42.30 a
LSD(0.05)	0.093	0.054	0.143	0.84
CV (%)	11.72	12.58	10.83	8.71

In a column having similar letters are statistically similar and those having dissimilar letters differ significantly at 0.05 level of probability

Sm_1-No watering
Sm_2-1/2 of field capacity
Sm_3-Field capacity

Pm_1 – Sowing in furrow without watering
Pm_2 – Dibbling (30cm×7cm)
Pm_3 –Broadcasting
Pm_4- Sowing in furrow with watering at the bottom of furrow

population (3.33 lakh plants ha^{-1}) and tended to decrease with increasing population.

Interaction effect of different soil moistures and planting methods showed significant variation in terms of seed yield ha^{-1} (Appendix IX). The highest seed yield ha^{-1} (1.626 ton) was observed from Sm_3Pm_4 while the lowest seed yield ha^{-1} (0.805 ton) was found from Sm_1Pm_3 which was statistically similar to (0.845 ton) Sm_1Pm_1 treatment combination (Table 22).

4.4.2 Stover yield ha^{-1}

Stover yield ha^{-1} showed significant variation for different level of moistures (Appendix IX). The highest stover yield ha^{-1} (2.057 ton) was found from Sm_3 which was followed (1.682 ton) by Sm_2, while the lowest stover yield ha^{-1} (1.376 ton) was recorded from Sm_1 treatment (Table 20). It observed that decreasing amount of water applied, resulted in a decline in total dry matter production (Collinson *et al.* 1996).

Statistically significant variations in stover yield ha^{-1} were observed for different planting methods (Appendix IX). The highest stover yield ha^{-1} (1.815 ton) was recorded from Pm_4 followed by (1.749 ton and 1.670 ton) Pm_2 and Pm_1 which are statistically similar whereas the lowest stover yield ha^{-1} from Pm_3 (1.586 ton) (Table 21). This result was in the line of Singh *et al.* (2007) who reported that drill sowing methods produced higher grain and straw yield kg ha^{-1} followed by conventional sowing methods.

Stover yield ha^{-1} of mungbean varied significantly due to interactions of soil moistures and planting methods (Appendix IX). The highest stover yield ha^{-1} (2.219 ton) was observed from Sm_3Pm_4 while the lowest stover yield ha^{-1} (1.272 ton) was found from Sm_1Pm_3 which was similar to (1.296 ton) Sm_1Pm_1 treatment combination (Table 22).

4.4.3 Biological yield ha^{-1}

Different level of soil moistures varied significantly in terms of biological yield ha^{-1} of mungbean (Appendix IX).The highest biological yield ha^{-1} (3.495 ton) was found from Sm_3 which was followed (2.820 ton) by Sm_2, while the lowest biological yield ha^{-1} (2.286 ton) was recorded from Sm_1 treatment (Table 20). Miah *et al.* (1996) suggested that in adequate soil moisture condition plant had higher photosynthesis and growth and produced higher dry matter (biological yield) in mungbean.

Biological yield ha^{-1} of mungbean was significantly affected by planting methods (Appendix IX). The highest biological yield ha^{-1} (3.104 ton) was observed from Pm_4 and followed (2.948 ton and 2.787 ton) by Pm_2 and Pm_1 whereas the lowest biological yield ha^{-1} (2.629 ton) from Pm_3 (Table 21). Amin *et al.* (2014) reported that average values for biological yield with different sowing methods ranged between 3998-4537 kg ha^{-1}. A maximum biological yield of 4537 kg ha^{-1} was recorded when the SD (seed drill) was used followed by CD with (4518 kg ha^{-1}), while minimum (3998 kg ha^{-1}) was obtained when broadcast method of sowing was used.

Interaction effect of different soil moistures and planting methods showed significant variation in terms of biological yield ha^{-1} (Appendix IX). The highest biological yield ha^{-1} (3.845 ton) was observed from Sm_3Pm_4 while the lowest biological yield ha^{-1} (2.078 ton) was found from Sm_1Pm_3 which was statistically similar to (2.141 ton) Sm_1Pm_1 treatment combination (Table 22).

4.4.4 Harvest index (%)

Harvest index (%) showed significant variation for different level of moistures (Appendix IX). The highest harvest index (%) (41.07) was found from Sm_3 which was statistically similar to (40.24) Sm_2, while the lowest harvest index (%) (39.70) was recorded from Sm_1 which is also similar to (40.24 %) Sm_2 (Table 20). Very similar result was reported by Siddique (2004) who found that harvest index was found at the 80% FC. The most satisfactory growth and yield attributes were observed from the 80% FC followed by 60% and 40% FC.

Statistically significant variations in harvest index (%) were for different planting methods (Appendix IX). The highest harvest index (%) (41.32) was recorded from Pm_4 which was statistically similar to (40.56 %) Pm_2 whereas the lowest harvest index (%) (39.51) from Pm_3 which is statistically similar to Pm_1 (39.96 %) (Table 21). Similar result was observed by Mansoor *et al.* (2010) who noted the highest harvest index % was recorded in 30 cm row spacing with the value of 49.9%. The lowest value of harvest index % (46.02) was recorded in 20 cm row spacing.

Harvest index (%) of mungbean varied significantly due to interactions of soil moistures and planting methods (Appendix IX). The highest harvest index (%) (42.30) was observed from Sm_3Pm_4 while the lowest harvest index (%) (38.76) was found from Sm_1Pm_3 which was similar to (39.47) Sm_1Pm_1 treatment combination (Table 22).

Chapter 5

Summary and conclusion

CHAPTER 05
SUMMARY AND CONCLUSION

The experiment was conducted during the period from March 20, 2014 to June 20, 2014. The experiment was done to find out the growth and yield of mungbean as affected by soil moisture and planting methods. The design of my experiment was split-plot design where Soil moisture given in the main plot and planting method in the sub plot. Factor A: soil moisture (3levels) i) Sm_1-No watering ii) Sm_2-1/2 of field capacity iii) Sm_3-Field capacity. Factor B: Planting Methods (4 levels) i) Pm_1 – Sowing in furrow without watering ii) Pm_2 – Dibbling (30cm×7cm) iii) Pm_3 -Broadcasting iv) Pm_4- Sowing in furrow with watering at the bottom of furrow. The variety of mungbean (BARI Mung-6) was used as the test crop for this study. The two factors experiment was laid out in split-plot design with three replications. Recorded data on germination (%), growth parameters, yield contributing characters and yield of mungbean showed statistically significant differences for soil moistures and planting methods.

For soil moisture, the highest seed germination (71.25 %) was observed from Sm_3 (field capacity) and while the lowest germination (39.31 %) was recorded from Sm_1 treatment. At 15, 30, 45 and 60 DAS, the tallest plant (23.63, 34.04, 59.23, 61.76 cm, respectively) were observed from Sm_3whereas shortest plant (15.36, 26.20, 50.16, 53.11 cm, respectively) from Sm_1. At 15, 30, 45 and 60 DAS, the highest number of branches plant^{-1} (0.05, 0.76, 1.82, and 2.33, respectively) were observed from Sm_3 whereas the lowest number of branches plant^{-1} (0.01, 0.31, 1.27, and 1.85, respectively) from Sm_1. At 15, 30, 45 and 60 DAS, the highest number of leaves plant^{-1} (4.48, 5.31, 7.53, and 5.78, respectively) were recorded from Sm_3 whereas the lowest number of leaves plant^{-1} (3.41, 4.52, 6.16, and 4.41, respectively) from Sm_1. At 15, 30, 45 and 60 DAS, the highest leaf area plant^{-1} (401.7, 558.3, 765.5, 593.9 cm^{2,} respectively) were recorded from Sm_3 whereas the lowest leaf area plant^{-1} (185.4, 273.8, 379.7, 279.9 cm^2, respectively) from Sm_1. At 15, 30, 45 and 60 DAS, the highest number of nodules $plant^{-1}$ (6.19, 8.77, 18.52, and 10.18, respectively) were observed from Sm_3 whereas the lowest number of nodules $plant^{-1}$ (1.29, 3.38, 7.57, and 2.98, respectively) from Sm_1. At 15, 30, 45 and 60 DAS, the highest shoot dry weight $plant^{-1}$ (1.782, 2.279, 6.718, 13.230 g, respectively) were recorded from Sm_3 whereas the lowest shoot dry weight $plant^{-1}$ (0.936, 1.437, 4.459, 8.515 g, respectively) from Sm_1. At 15, 30, 45 and 60 DAS, the highest root dry weight $plant^{-1}$ (0.255, 0.316, 0.816, 1.444 g, respectively) were observed from Sm_3 whereas the lowest root dry weight $plant^{-1}$ (0.172, 0.231, 0.456, 0.755 g, respectively) from Sm_1. The highest number of pods $plant^{-1}$ (17.50) was found from Sm_3 which was followed (12.92) by Sm_2, while the lowest number of pods (10.72) was recorded from Sm_1 treatment. The highest number of seeds pods $^{-1}$ (11.47) was found from Sm_3 which was followed (10.12) by Sm_2, while the lowest number of seeds pods $^{-1}$ (8.81) was recorded from Sm_1 treatment. The highest seed yield ha^{-1}(1.438 ton) was found from Sm_3 which was followed (1.138 ton) by Sm_2, while the lowest seed yield ha^{-1} (0.910 ton) was recorded from Sm_1 treatment. The highest stover yield ha^{-1} (2.057 ton) was found from Sm_3 which was followed (1.682 ton) by Sm_2, while the lowest stover yield ha^{-1} (1.376 ton) was recorded from Sm_1 treatment. The highest biological yield ha^{-1} (3.495 ton) was found from Sm_3 which was followed (2.820 ton) by Sm_2, while the lowest biological yield ha^{-1} (2.286 ton) was recorded from Sm_1 treatment. The highest Harvest index (%) (41.07) was found from Sm_3 while the lowest Harvest index (%) (39.70) was recorded from Sm_1.

In case of planting methods, the highest germination (63.44%) was recorded from Pm_4 whereas the lowest germination (48.06 %) from Pm_3. At 15, 30, 45 and 60 DAS, the tallest plant (23.67, 34.22, 58.89, 61.20 cm, respectively) were recorded from Pm_4 whereas shortest plant (18.58, 27.49, 51.29, 54.24 cm, respectively) from Pm_3. At 15, 30, 45 and 60 DAS, the highest number of branches $plant^{-1}$ (0.11, 0.91, 1.96, and 2.47, respectively) were observed from

Pm_4 whereas the lowest number of branches plant^{-1} (0.00, 0.20, 1.23, and 1.83, respectively) from Pm_3. At 15, 30, 45 and 60 DAS, the highest number of leaves plant^{-1} (4.42, 5.53, 7.44, 5.68, respectively) were observed from Pm_4 whereas the lowest number of leaves plant^{-1}3.48, 4.51, 6.26, 4.48, respectively) from Pm_3. At 15, 30, 45 and 60 DAS, the highest leaf area plant^{-1} (416.5, 595.4, 815.1, 635.6 cm^2, respectively) were recorded from Pm_4 whereas the lowest leaf area plant^{-1} (197.9, 259.6, 360.6, 256.4 cm^2, respectively) from Pm_3. At 15, 30, 45 and 60 DAS, the highest number of nodules plant^{-1} (6.19, 8.77, 18.52, and 10.18, respectively) were observed from Sm_3 whereas the lowest number of nodules plant^{-1} (1.29, 3.38, 7.57, and 2.98, respectively) from Sm_1. At 15, 30, 45 and 60 DAS, the highest shoot dry weight plant^{-1} (1.724, 2.235, 6.477, 12.430 g, respectively) were observed from Pm_4 whereas the lowest shoot dry weight plant^{-1} (0.871, 1.381, 4.629, 9.764 g, respectively) from Pm_3. At 15, 30, 45 and 60 DAS, the highest root dry weight plant^{-1} (0.252, 0.311, 0.783, 1.277 g, respectively) were recorded from Pm_4 whereas the lowest root dry weight plant^{-1} (0.189, 0.250, 0.502, 0.960 g, respectively) from Pm_3. The highest number of pods plant^{-1} (17.80) was observed from Pm_4 whereas the lowest number of pods plant^{-1} (9.82) from Pm_1. The highest number of seeds pods $^{-1}$ (10.67) was observed from Pm_4 whereas the lowest number of seeds pods $^{-1}$ (9.48) from Pm_3. The highest Weight of 1000 seeds (53.77 g) was recorded from Pm_4 whereas the lowest Weight of 1000 seeds (51.83 g) from Pm_1 which is statistically similar to Pm_2(52.29 g). The highest seed yield ha^{-1} (1.289 ton) was observed from Pm_4 whereas the lowest seed yield ha^{-1} (1.043 ton) from Pm_3. The highest stover yield ha^{-1} (1.815 ton) was recorded from Pm_4 whereas the lowest stover yields ha^{-1} from Pm_3 (1.586 ton). The highest biological yield ha^{-1} (3.104 ton) was observed from Pm_4 whereas the lowest biological yield ha^{-1} (2.629 ton) from Pm_3. The highest harvest index (%) (41.32) was recorded from Pm_4 whereas the lowest harvest index (%) (39.51) from Pm_3 which is statistically similar to Pm_1 (39.96 %).

Due to interaction effect of different soil moistures and planting method of mungbean, the highest germination (%) (84.42) were observed from Sm_3Pm_4 while the lowest germination (32.92%) was found from Sm_1Pm_3 treatment combination. At 15, 30, 45 and 60 DAS, the tallest plant (26.56, 38.23, 62.89, 64.72 cm, respectively) were observed from Sm_3Pm_4 while the shortest plants (13.21, 24.33, 46.39, 49.44 cm, respectively) were found from Sm_1Pm_3 treatment combination. At 15, 30, 45 and 60 DAS, the highest number of branches plant^{-1} (0.2, 1.26, 2.34 , 2.83 cm, respectively) were observed from Sm_3Pm_4 while the lowest number of branches plant^{-1} (0, 0.06, 1.12, 1.56, respectively) were found from Sm_1Pm_3 treatment combination. At 15, 30, 45 and 60 DAS, the highest number of leaves plant^{-1} (5.31, 6.20, 8.13, 6.46, respectively) were observed from Sm_3Pm_4 while the lowest number of leaves plant^{-1} (3.12, 4.00, 5.33, 3.86, respectively) were found from Sm_1Pm_3 treatment combination. At 15, 30, 45 and 60 DAS, the highest leaf area plant^{-1} (554.5, 827.9, 1093.0, 876.5 cm^2, respectively) were observed from Sm_3Pm_4 while the lowest leaf area plant^{-1} (124.6, 179.7, 233.5, 162.5 cm^2, respectively) were found from Sm_1Pm_3 treatment combination. At 15, 30, 45 and 60 DAS, the highest number of nodules plant^{-1} (8.91, 13.22, 22.54, 12.67, respectively) were observed from Sm_3Pm_4 while the lowest number of nodules plant^{-1} (0.74, 2.62, 6.73, 2.07, respectively) were found from Sm_1Pm_3 treatment combination. At 15, 30, 45 and 60 DAS, the highest shoot dry weight plant^{-1} (2.533, 3.044, 8.471, 14.403 g, respectively) were observed from Sm_3Pm_4 while the lowest shoot dry weight plant^{-1} (0.675, 1.186, 3.671, 6.660 g, respectively) were found from Sm_1Pm_3 treatment combination. At 15, 30, 45 and 60 DAS, the highest root dry weight plant^{-1} (0.285, 0.346, 1.197, 1.692 g, respectively) were observed from Sm_3Pm_4 while the lowest root dry weight plant^{-1} (0.144 , 0.205, 0.401, 0.679 g, respectively) were found from Sm_1Pm_3 treatment combination. The highest number of pods plant^{-1} (22.27) was recorded from Sm_3Pm_4 whereas the lowest number of pods plant^{-1} (7.067) from Sm_1Pm_1 treatment combination. The highest number of seeds pods $^{-1}$ (12.13) was observed from Sm_3Pm_4 which was statistically similar to (11.73) Sm_3Pm_2 while the lowest number of seeds pods $^{-1}$ (7.93) was found from Sm_1Pm_3 treatment combination. The highest Weight of 1000 seeds (57.20 g) was observed from Sm_3Pm_4 while the lowest Weight of 1000 seeds (48.70 g) was found from Sm_1Pm_3 treatment combination. The highest seed yield ha^{-1} (1.626 ton) was observed from Sm_3Pm_4 while the lowest seed yield ha^{-1} (0.805 ton) was found from Sm_1Pm_3. The highest stover yield ha^{-1} (2.219 ton) was observed from Sm_3Pm_4 while the lowest stover yield ha^{-1} (1.272 ton) was found from Sm_1Pm_3 which was similar to (1.296 ton) Sm_1Pm_1 treatment combination. The highest biological yield ha^{-1}(3.845 ton) was observed from Sm_3Pm_4 while the lowest biological yield ha^{-1} (2.078 ton) was found from Sm_1Pm_3 which was statistically similar to (2.141 ton) Sm_1Pm_1 treatment combination. The highest harvest index (%) (42.30) was observed from Sm_3Pm_4 while the lowest harvest index (%) (38.76) was found from Sm_1Pm_3.

From above results it can be concluded that

- Significant germination, growth and yield were found at field capacity
- Furrow seed sowing with watering showed satisfactory result of mungbean
- Soil moisture at field capacity only just at the beginning of seed sowing and furrow seed sowing with watering can be more beneficial to get maximum yield from the cultivation of BARI Mung-6.

Before final recommendation the experiment may be repeated at different locations with varying soil and climatic conditions of the country.

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Appendices

APPENDICES

Appendix I. Monthly average of air temperature, relative humidity, total rainfall of the experimental site during the period from April to June, 2014

Months	*Air Temperature(^{0}c)		*Relative humidity (%)	*Rainfall (mm)(total)
	Maximum	Minimum		
April,2014	33.4	23.2	67	78
May,2014	34.7	25.9	70	185
June,2014	35.4	22.5	80	277

*Monthly average,

*Source: Bangladesh Metrological Department (Climate and Weather division) Agargoan, Dhaka-1212

Appendix II. Characteristics of the soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% sand	27
% silt	43
% clay	30
Textural class	Silty-clay
p^H	6.1
Organic matter	1.13
Total N (%)	0.03
Available P(ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S(ppm)	23

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

Appendix III. Analysis of variance of the data on plant height as influenced by different soil moistures and planting methods

Source of variation	Degrees of freedom (df)	Mean squares			
		Plant height (cm) at			
		15 DAS	30 DAS	45 DAS	60 DAS
Replication	2	2.067	1.125	2.239	1.064
Soil Moistture (A)	2	166.660**	184.963**	152.822**	127.756**
Error	4	2.966	4.525	3.294	6.672
Planting method (B)	3	65.859**	78.435**	91.844**	78.062**
Interaction(A×B)	6	1.692 ^{NS}	1.342*	1.626*	1.605*
Error	18	4.692	0.348	0.409	0.332

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability and ^{NS} Non-significant

Appendix IV. Analysis of variance of the data on number of branches and number of leaves plant^{-1} as influenced by different soil moistures and planting methods

Source of variation	Degrees of freedom (df)	Mean squares				Mean squares			
		Number of branches plant^{-1}				Number of leaves plant^{-1}			
		15 DAS	30 DAS	45 DAS	60 DAS	15DAS	30 DAS	45 DAS	60 DAS
Replication	2	0.014	0.018	0.024	0.012	0.701	0.423	0.062	0.570
Soil Moisture(A)	2	0.004^{NS}	0.610**	0.625**	0.708**	3.484**	3.546**	5.608**	5.643**
Error	4	0.011	0.013	0.015	0.004	0.269	0.354	0.043	0.123
Planting method (B)	3	0.028*	0.785**	0.765**	0.727**	1.397**	1.764**	2.321**	2.240**
Interaction(A×B)	6	0.004^{NS}	0.017^{NS}	0.042*	0.020*	0.044^{NS}	0.121*	0.106*	0.275*
Error	18	0.012	0.014	0.011	0.006	0.030	0.041	0.044	0.068

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability and ^{NS} Non-significant

Appendix V. Analysis of variance of the data on Leaf area (cm^2) plant^{-1} as influenced by different soil moistures and planting methods

Source of variation	Degrees of freedom (df)	Mean squares			
		Leaf area (cm^2) plant^{-1}			
		15 DAS	30 DAS	45 DAS	60 DAS
Replication	2	1416.820	1490.384	1587.690	1403.602
Soil Moisture (A)	2	145490.903**	250546.277**	453865.548**	305587.148**
Error	4	2148.351	4573.800	5331.280	5462.435
Planting Method (B)	3	87421.588**	186703.319**	341597.819**	234428.096**
Interaction(A×B)	6	1322.551*	7721.912*	7783.823*	6756.625*
Error	18	845.846	1422.082	1417.139	1454.389

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability and ^{NS} Non-significant

Appendix VI. Analysis of variance of the data on number of nodules plant^{-1} as influenced by different soil moistures and planting methods

Source of variation	Degrees of freedom (df)	Mean squares			
		Number of nodules plant^{-1}			
		15 DAS	30 DAS	45 DAS	60 DAS
Replication	2	0.066	0.141	1.873	1.930
Soil Moisture (A)	2	69.855**	88.616**	360.349**	157.123**
Error	4	0.068	0.159	0.542	0.728
Planting method (B)	3	17.975**	26.827**	31.349**	13.024**
Interaction(A×B)	6	2.712**	6.552**	4.541**	1.179**
Error	18	0.047	0.193	0.910	0.170

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability and ^{NS} Non-significant

Appendix VII . Analysis of variance of the data on shoot and root dry weight (g) plant^{-1} as influenced by different soil moistures and planting methods

Source of variation	Degrees of freedom (df)	Mean squares				Mean squares			
		Shoot dry weight(g) plant^{-1}				Root dry weight (g) plant^{-1}			
		15 DAS	30 DAS	45 DAS	60 DAS	15 DAS	30 DAS	45 DAS	60 DAS
Replication	2	0.060	0.078	1.485	0.446	0.008	0.010	0.015	0.012
Soil Moisture(A)	2	2.212**	3.564**	16.588**	68.631**	0.124**	0.231**	0.468**	1.425**
Error	4	0.118	0.175	0.977	0.305	0.011	0.015	0.013	0.017
Planting method (B)	3	1.236**	2.467**	5.465**	11.981**	0.046**	0.067**	0.158**	0.163**
Interaction(A×B)	6	0.182*	0.193*	0.509*	0.705*	0.021*	0.028*	0.045**	0.048**
Error	18	0.045	0.052	0.186	0.237	0.006	0.007	0.005	0.004

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability and ^{NS} Non-significant

Appendix VIII . Analysis of variance of the data on germination (%), number of Pod plant^{-1}, number of Seed pod^{-1} and 1000 seeds weight (g)as influenced by different soil moistures and planting methods

Source of variation	Degrees of freedom (df)	Mean squares			
		Germination (%)	Number of Pod plant^{-1}	Number of Seed pod^{-1}	1000 seeds weight(g)
Replication	2	2.175	1.151	0.251	0.295
Soil Moisture (A)	2	661.454**	143.721**	21.070**	122.334**
Error	4	2.496	1.973	0.183	2.483
Planting method (B)	3	415.035**	83.446**	2.444**	6.216**
A×B	6	42.062**	8.594*	1.106*	1.660*
Error	18	3.722	2.158	0.275	0.353

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant

Appendix IX. Analysis of variance of the data on Seed yield (t ha^{-1}), Stover yield (t ha^{-1}), Biological yield (t ha^{-1}), Harvest index (%) as influenced by different soil moistures and planting

Source of variation	Degrees of freedom (df)	Mean squares			
		Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.025	0.020	0.082	1.496
Soil Moisture (A)	2	0.840**	1.398**	4.404**	5.666*
Error	4	0.013	0.011	0.031	4.382
Planting method (B)	3	0.101**	0.088**	0.377**	5.524*
Interaction (A×B)	6	0.022*	0.038**	0.032**	1.723*
Error	18	0.005	0.008	0.007	0.574

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant