INFLUENCE OF PLANTING GEOMETRY ON GROWTH AND YIELD OF MUNGBEAN

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INFLUENCE OF PLANTING GEOMETRY ON GROWTH AND YIELD OF MUNGBEAN

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CERTIFICATE

This is to certify that the thesis entitled "INFLUENCE OF PLANTING GEOMETRY 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 (MS) in AGRONOMY, embodies the results of a piece of bona fide research work carried out by KHAIRUN NAHAR, Registration No. 09-03294 under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

Dated:

Dhaka, Bangladesh

(Prof. Dr. Md. Fazlul Karim)

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INFLUENCE OF PLANTING GEOMETRY ON GROWTH AND YIELD OF MUNGBEAN

ABSTRACT

An experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka during March to June 2015 to study the effect of spacing on the growth, yield and yield attributes of three varieties of mungbean. The experiment comprised with two factors viz. (i) variety and (ii) spacing. Five spacing treatment (30 cm × 10 cm, 20 cm × 20 cm, 30 cm × 30 cm, 40cm × 40 cm, 50 cm × 50 cm) and three varieties (BARI mung 4, BARI mung 5, BARI mung 6) were used. There were fifteen treatment combinations under the study. Results showed that cultivar and spacing significantly influenced all the parameters studied. The mungbean variety BARI mung 6 stand superior than BARI mung 4 and BARI mung 5 in respect of plant height (8.11 cm, 17.86cm, 26.31cm, 48.737cm) , branches plant^{-1}(2.14, 2.85, 3.68) , dry matter plant^{-1}(1.06 g, 7.68 g, 13.57g, 17.87g) , pods plant^{-1} (37.8), pod length (7.63 cm), length of pods, seed pod^{-1}(9.64), 1000 seed weight(44.208 g) , seed yield (0.515 tha^{-1}) and stover yield (1.69 tha^{-1}). The 20cm × 20 cm spacing was superior in terms of plant height(8.59cm, 20.09cm, 30.57cm, 49.290cm), branches plant^{-1} (2.84, 4.15, 5.07), dry matter plant^{-1}(2.23g,13.15g, 17.02g, 22.77g), pods plant^{-1} (35.71), length of pod (9.03 cm), seed pod^{-1} (10.77), 1000 seed weight (45.72 g), seed yield (0.8989 tha^{-1}) and stover yield (2.19 tha^{-1}). In interaction, the variety BARI mung 6 in combination with 20 cm × 20 cm spacing produced maximum yield (1.16 tha^{-1}) as well as yield attributes. This treatment showed 77.8% higher seed yield than control.

LIST OF CONTENTS

LIST OF CONTENTS (contd.)

LST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACCRONYMS AND ABBREVIATIONS

Agric. = Agriculture

Agril. = Agricultural

AVRDC = Asian Vegetables Research and Development center

BARI = Bangladesh Agricultural Research Institute

BBS = Bangladesh Bureau of Statistics

BINA = Bangladesh Institute of Nuclear Agriculture

cm = Centimeter

C^0 = Degree Centigrade

DAE = Days after emergence

DAS = Days after sowing

Dev.= Development

Environ.= Environmental

et al.= and others (at elli)

g = gram (s)

i.e. = idest (L), that is

Kg ha^{-1}= Kilogram per hectare

LSD = Least Significant Difference

MoA= Ministry of Agriculture

m = meter

No. = Number

Sci. = Science

SAU = Sher-e-Bangla Agricultural University

t ha^{-1} = ton hectare

UNDP = United Nations Development Programme

Viz. = Namely

Wt. = Weight

% = Percent

CHAPTER I

INTRODUCTION

Food security has become a major and fast growing concern worldwide. It is proposed that there is a need to double the world food production in order to feed the ever increasing population which is set to reach nine billion mark by 2050 (UN, 2013). Population growth in Bangladesh is just as alarming. In order to secure food supply for the rapidly increasing population of Bangladesh, immediate measures should be taken in the field of agriculture. Boro rice has been occupying the title of major crop in terms of production (BBS 2012).

However, affordable sources of protein are also required for the people of Bangladesh, the majority of which don’t have the financial ability to include animal protein in their diet. In this context, grain legume crops i.e. pulses can play an excellent role as sources of plant protein. Mungbean (*Vigna radiata* L. Wilczek) is one such pulse crop quite popular in Bangladesh.

Mungbean is an affordable and easily available source of dietary protein. It is fairly digestible and doesn’t cause flatulence effects (Ahmed *et al.*, 2005). Mungbean grain contains 24.7% protein, 0.6% fat, 0.9% fiber and 3.7% ash (Potter and Hotchkins, 1997). It acts as a suitable compliment with the staple cereal of Bangladesh, rice.

Despite being an important component of agriculture in Bangladesh, acreage production of pulse has been in a declining trend over the recent years (BBS, 2012). The total production of mungbean in Bangladesh in 2013-14 was 1.81 lac metric tons from an area of 1.73 lac hectares. It produced an average yield of 1.04 t ha^{-1} (MoA, 2014). In order to ensure increased production of mungbean, application of improved technology is necessary.

The variety of the crop is undoubtedly important in producing a significant yield. Experiments have been conducted to observe the yield performance of different mungbean cultivars. Aside from that, quite a number of experiments and research work has been carried out in Bangladesh concerning spacing of mungbean. The goal of this has been to find out the most suitable plant population to get maximum yield (Mondal, 2007). Improper spacing can cause reduction in yield by as much as 40% (AVRDC, 1976) caused by competition for light, space, water and nutrition. On the other hand, optimum spacing allows the plants to flourish in both their above-ground and underground portions through efficient use of natural resources, hence increasing the production. Reduction of plant spacing by increasing seed rate would ensure a more even distribution of plant over the land occupied by the crop. As a result the plant has the chance to utilize maximum solar radiation through the canopy and also provide shade which suppress weed. Wider spacing generally provides less competition for each individual plant; however it also means fewer plants per unit area, so the number of pods is lesser.

In order to ensure efficient use of space and maximized yield, the principle of wider spacing and square geometry which is implemented in System of Rice Intensification (SRI) was put to use. SRI is a package of technologies that cuts the seed cost by 80-90% and water savings up to 25-50%. The system is environment friendly. Recommended SRI management practices include widely spaced plants in order to encourage greater root and canopy growth. The plants are laid out in a square grid pattern, such as 25 cm × 25 cm or wider in good quality soil. The plant geometry and spatial configuration exploit the initial vigor of the genotypes. Effect of the square planting geometry as is used in SRI have proven to be useful in other crops as well (Abraham *et al.*, 2014). SRI entails rather unconventional cultivation practices, especially in plant and water management. SRI is more of a system than a technology. Following that principle, SCI has been employed in various other crops as well, such as wheat, pulses, sugarcane, oilseed and some vegetables. Adapted from SRI, the System of Crop Intensification (SCI) is based on improved planting and growing techniques, rather than improved seed varieties and other inputs. It aims to produce more from less, using fewer seeds and less water, but carefully managing the relationship between the plant and soil.

The present investigation has been undertaken to study the effect on spacing and variety on the following aspects of mungbean-

1) To compare the performance of different varieties of mungbean

2) To evaluate the effect of plant density on the yield and yield attributes of mungbean, and

3) To determine the influence of combine effect of variety and spacing on the yield performance of mungbean.

CHAPTER II

REVIEW OF LITERATURE

Variety and management practices both have considerable effects on the growth and development of any crop. Among these, plant geometry is an undoubtedly important. A number of studies have been performed evaluating the influence of variety and planting geometry on mungbean. Among the above factors some of the recent past information on variety and planting geometry on mungbean have been reviewed under the following headings:

2.1 Influence of varieties on plant characters of mungbean

2.1.1 Plant height

Imam (2014) carried out an experiment to investigate the effect of cultivars and flower removal on the performance of mungbean. The varieties used were BARI mung 3, BARI mung 4, BARI mung 5 and BARI mung 6. The tallest plant (54.05 cm), was observed in BARI mung 6.

Field studies were conducted by Kumar *et al.,* (2009) in Haryana, India to determine the growth behavior of mungbean genotypes sown on different dates under irrigated conditions. The treatment consisted of 2 genotypes (SMP 668 and MH 318) and 6 sowing dates starting from 1 March to 19 April, at 10 days interval. Results showed that SML 668 had higher plant height than MH 318 and the less height of both the genotypes during summer was due to low average temperature during the initial growth stage.

2.1.2 Branches plant $^{-1}$

The performance of 20 mungbean cultivars were evaluated by Madriz-Isturiz and Luciani-Marcano (2004) in a field experiment conducted in Venezuela. Significant difference in plant height was observed due to cultivars was recorded.

2.1.3 Dry matter plant $^{-1}$

Rahman *et al*., (2005) carried out an experiment with mungbean in Jamalpur, Bangladesh, involving 2 planting methods, i.e. line sowing and broadcasting; 5 mungbean cultivars, namely Local, BARI mung 2, BARI mung 3, BINA mung 2 and BINA mung 5. Significantly the highest dry matter production ability was found in the 4 modern mungbean cultivars, and dry matter partitioning was found highest in seeds of BINA mung 2 and the lowest in Local. However the local cultivar produced the highest portion of dry matter in leaf and stem .

Field studies were conducted by Kumar *et al*., (2009) in Haryana, India to determine the growth behavior of mungbean genotypes sown on different dates under irrigated conditions. The treatment consisted of 2 genotypes (SMP 668 and MH 318) and 6 sowing dates starting from 1 March to 19 April, at 10 days interval. SML 668 accumulated more dry mater than MH 318. The contribution of leaves and stem was more in SML 668, whereas the contribution of pods towards total aboveground biomass at harvest was higher in MH 318.

2. 1.4. Nodules plant^{-1}

Sattar and Ahmed (1995) conducted a field experiment on mungbean to study the response of inoculation with *Bradyrhizobium* inoculants incorporating BINA 403, BINA 407, RC 3824 and RC 3825 strains as single and mixed culture. They observed that *Bradyrhizobium* inoculation increased the number of nodules and nodule weight significantly.

2.1.5 Pods plant $^{-1}$

Imam (2014) carried out an experiment to investigate the effect of cultivars and flower removal on the performance of mungbean. The varieties used were BARI mung 3, BARI mung 4, BARI mung 5 and BARI mung 6. the maximum number of pods plant^{-1} (18.16) was observed in BARI mung 6.

Mansoor *et al.* (2010) carried out an experiment with row spacing and seed rates and reported that number of pod clusters plant^{-1} were significantly affected by various seed rates.

2.1.6 Length of pods

Two summer mungbean cultivars, i.e. BINA mung 2 and BINA mung 5 were grown during the kharif-1 season (February –May), in Mymensingh, Bangladesh, under no irrigation or with irrigation once at 30 DAS, twice at 30 and 50 DAS, and thrice at 20, 30 and 50 DAS by Shamsuzzaman *et al.,* (2004). Data were recorded for days to first flowering, days to first leaf senescence, days to pod maturity, flower + pod abscission, root, stem + leaf, pod husk and seed dry matter content, pods per plant, seeds per pod, 1000 seed weight, seed yield, biological yield and harvest index. The two cultivars tested were synchronous in flowering, pod maturity and leaf senescence, which were significantly delayed under different irrigated frequencies. BINA mung 2 performed slightly better than BINA mung 5 for most of the growth and yield parameter studied.

2.1.7 Seeds pod $^{-1}$

Taj *et al*. (2003) carried out an experiment to find out the effects of sowing rates (10, 20, 30, and 40 kg seed ha^{-1}) on the performance of 5 mungbean cultivars (NM-92, Nm 19-19, NM 121-125, N/41 and a local cultivar) were studied in Ahmadwala, Pakistan, during the summer session of 1998. Among the cultivars, NM 121-125 recorded the highest average seeds pod^{-1} (9.79).

2.1.8 1000 seed weight

Taj *et al*. (2003) carried out an experiment to find out the effects of sowing rates (10, 20, 30, and 40 kg seed ha^{-1}) on the performance of 5 mungbean cultivars (NM-92, Nm 19-19, NM 121-125, N/41 and a local cultivar) were studied in Ahmadwala, Pakistan, during the summer session of 1998. Among the cultivars, NM 121-125 recorded the highest 1000-grain weight (28.09g).

2.1.9 Seed and stover yield

Four mungbean accessions from the Asian Vegetable Research and Development Centre (AVRDC) were grown by Agugo *et al*. (2010). Results showed a significant difference in the yield of the varieties with VC 6372 (45-8-1) producing the highest seed yield of 0.53 t/ha. This was followed by NM 92, 0.48 t/has; NM 94, 0.40 t/ha; and VC 1163 with 0.37 t/ha. The variety, VC 6372 (45-8-1), also formed good yield contributing characters.

Quaderi *et al*. (2006) carried out an experiment in the Field Laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh to evaluate the influence of seed treatment with Indole Acetic Acid (IAA) at a concentration of 50 ppm, 100 ppm and 200 ppm of the growth, yield and yield contributing characters of two modern mungbean (*Vigna radiata* L.) varieties viz. BARI mung 4 and BARI mung 5. The two-factor experiment was laid out in Randomized Complete Block Design (RCBD) (factorial) with 3 replications, Among the mungbean varieties, BARI mung 5 performed better than that of BARI mung 4.

To study the nature of association between *Rhizobium phaseoli* and mungbean, an experiment was conducted by Muhammad *et al.*(2006). Inocula of two Rhizobium strains, Tal-169 and Tal-420 were applied to four mungbean genotypes viz., NM-92, NMC-209, NM-98 and Chakwal Mung-97. A control treatment was also included for comparison. The experiment was carried out at the University of Arid Agriculture, Rawalpindi, Pakistan, during kharif. Both the strains in association with NM-92 has higher nodule dry weight, which was 13% greater than other strains × mungbean genotypes combinations. Strain Tal-169 was specifically more effective on genotype NCM-209 and NM-98 compared to NM- 92 and Chakwal Mung-97. Strain Tal-420 increased branches per plant of all the genotypes. Strain Tal-169 in association with NCM-209 produced the highest yield of 670 kg ha^{-1} which was similar (590 kg ha^{-1}) in case of NCM-209 either inoculated with strain Tal-420 or uninoculated. Variety NM-92 produced the lowest grain yield (330 kg ha^{-1}) either inoculated with strain Tal-420 or uninoculated.

Islam *et al.*(2006) carried out an experiment at the field laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh to evaluate the effect of biofertilizer (*Bradyrhizobium*) and plant growth regulators (GA_3 and IAA) on growth of 3 cultivars of summer mungbean (*Vigna radiata* L.). Among the mungbean varieties, BINA mung 5 performed better than that of BINA mung 2 and BINA mung 4.

Mungbean cultivars Pusa 105 and Pusa Vishal were sown at 22.5 and 30 cm spacing and supplied with 36-46 and 58-46 kg NP ha^{-1} in a field experiment conducted in Delhi, India during the kharif season by Tickoo *et al.* (2006). Cultivar Pusa Vishal recorded higher biological and grain yield (3.66 and 1.63 t ha^{-1}, respectively) compared to cv. Pusa 105.

To evaluate the effects of crop densities (10, 13 , 20 and 40 plants m^{-2}) on yield and yield components of two cultivars (Partow and Gohar) and a line of mungbean (VC-1973A) against other cultivars, a field experiment was conducted by Aghaalikhani *et al.* (2006) at the seed and Plant Improvement Institute of Karaj, Iran, in the summer of 1998. The results indicated that VC-1973A had the highest grain yield. This line was superior to the other cultivars due to its early and uniform seed maturity and easy mechanized harvest.

Studies were conducted by Bhati *et al.* (2005) to evaluate the effects of cultivars and nutrient management strategies on the productivity of different kharif legumes (mungbean, mothbean and clusterbean) in the arid region of Rajasthan, India. The experiment with mungbean showed that K-851 gave better yield than Ash and the local cultivar. In another experiment, mungbean cv. PDM-54 showed 56.9% higher grain yield and 13.7% higher fodder yield than the local cultivar. The experiment with mothbean showed that RMO-40 gave 34.8-35.2% higher grain yield and 30.2-33.4% higher fodder yield over the local cultivar as well as 11.8% higher grain yield and 9.2% higher fodder yield over RMO-257. The experiment with clusterbean showed that improved cultivars of RGC-936 gave 135.0 and 73.5% higher yield and 124.9 and 67.3% higher fodder yield over the local cultivar and Maru Guar, respectively .

Imam (2014) carried out an experiment to investigate the effect of cultivars and flower removal on the performance of mungbean. The varieties used were BARI mung-3, BARI mung 4, BARI mung 5 and BARI mung 6. The highest seed yield (1.99 t ha^{-1}), the highest stover yield (2.47 t ha^{-1}) was observed in BARI mung 6.

2.1.10 Harvest index

To find out the effects of *Rhizobium* inoculation on the nodulation, plant growth, yield attributes, seed and stover yields, and seed protein content of six mungbean cultivars were investigated by Hossain and Solaiman (2004). The mungbean cultivars were BARI mung 2, BARI mung 3, and BARI mung 4. BARI mung4 performed the best in all aspects showing the highest seed yield of 1135 kg ha^{-1}. *Rhizobium* strain TAL-169 did better than TAL-441 in most of the studied parameters. It was concluded that BARI mung 4 in combination with TAL- 169 performed the best in terms of nodulation, plant growth, seed and stover yields, and seed protein content.

2.2 Influence of planting geometry on plant characters of mungbean

2.2.1 Plant height

Mansoor *et al.* (2010) carried out an experiment with row spacing and seed rates and reported that plant height was significantly affected by various seed rates and the tallest plants were observed in 20 cm row spacing and 40 kg seed ha^{-1} while the smallest plant in the treatment with 40 cm row spacing and 20 kg ha^{-1}.

Kabir and Sarkar (2008) conducted an experiment to study the effect of variety and planting density on the yield of mungbean in Kharif-1 season with five varieties and three spacing of planting viz. 30cm × 10 cm, 20 cm × 20 cm and 40 cm × 30. They reported that plant spacing of 30 cm × 10 cm produced the longest plant while 40 cm × 30 cm spacing produced the shortest plant.

Rana *et al.* (2011) reported that plant height did not differ significantly due to plant population up to 50 DAS but differed significantly thereafter and the tallest plants at all the sampling dates were found in the 30 plants m^{-2}.

2.2.2 Dry matter plant $^{-1}$

Rana *et al.* (2011) reported that dry matter production significantly differed with plant population and treatment having maximum plant population (60 plants m^{-2}) produced significantly higher dry matter at all sampling dates followed by 45 plants m^{-2}. The lowest value was recorded with minimum plant population (30 plants m^{-2})

2.2.3 Pods plant $^{-1}$

Islam *et al.* (2011) conducted a field experiment at the Horticultural farm of the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, and found that number of fruits plant $^{-1}$, fruit length were significantly increased with the increasing of plant density.

Pook pakdi and Patardilok (1993) reported that in Mungbean and Black Gram, pod length, pods plant $^{-1}$ increased with decreasing density.

2.2.4 Length of pods

Mansoor *et al.,* (2010) carried out an experiment with row spacing and seed rates and reported that pods with maximum length were recorded in plots having 20 cm row spacing.

Ahmed *et al.* (2005) conducted a field experiment in 2000 to investigate the effect of P fertilizer and plant density on the yield and yield components of mungbean cm. NM-92 in Punjab, Pakistan. They found pod length was the highest with 45 cm row spacing.

2.2.5 Seeds pod $^{-1}$

Ahmed *et al.* (2005) conducted a field experiment in 2000 to investigate the effect of P fertilizer and plant density on the yield and yield components of mungbean cm. NM-92 in Punjab, Pakistan. They found number of Seeds pod $^{-1}$ was highest with 45 cm row spacing.

2.2.6 1000 seed weight

Hasan (2004) observed that 1000 grain weight was not influenced by seed rate.

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

2.2.7 Seed and stover yield

Pookpakdi and Patardilok (1993) reported about decreased yield of mungbean and black gram with decreasing plant density.

Baloch (2004) found that crop sown in closer row spacing resulted in significantly higher seed yield, but the yield components depicted better performance under wider row plant density.

Mozumder *et al.* (2012) conducted an experiment at the Horticulture Field Laboratory of Bangabandhu Sheikh Mujibur Rahman Agricultural University during December 2007 to July 2008 of *Eryngium foetidum* at different spacing. They found that thousand seed weight was higher in wider spacing but marketable fresh yield and seed yield per unit area was better in medium (10 cm × 10 cm) spacing.

One approach of elevating the seed yield of mungbean by Asian Vegetables Research and Development Center (AVRDC) is to increase yield by increasing plant density. However, the yield of mungbean does not increase linearly with increase in density as it does in soybean. The number of pods per plant of mungbean decreases as density increases unlike soybean (MacKenzie *et al.*, 1975).

Kabir and Sarkar (2008) conducted an experiment to study the effect of variety and planting density on the yield of mungbean in Kharif-1 season with five varieties and three spacing of planting viz. 30cm × 10 cm, 20 cm × 20 cm and 40 cm × 30. Plant spacing of 30 cm × 10 cm produced the highest seed yield of mungbean while 40 cm × 30 cm spacing produced the lowest seed yield.

2.2.8 Harvest index

Joarder (2014) conducted an experiment to find out the growth and yield of mungbean as affected by plant density and methods of weed control. The experiment comprised of 4 plant spacings viz. D_1= 30 cm × continuous, D_2 = 30 cm × 5 cm, D_3 = 30 cm × 10 cm and D_4 = 30 cm × 15 cm. The other factor was methods of weed control viz. W_0= No weeding (control), W_1= Two hand weeding at 15 and 30 DAS, W_2 = Pre emergence herbicide application (application of Topstar 80 WP @ 75 g ha^{-1} at 3 DAS) and W_3 = Post emergence herbicide application (application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 and 30 DAS). Using BARI mung 6 as the test crop, the investigation concluded that the highest number of pods $plant^{-1}$ (18.92), highest number of seeds pod^{-1} (12.23), the longest pod (9.02 cm), the highest weight of 1000-seeds (45.36g), the highest seed yield (1.36 t ha^{-1}), the highest biological yield (3.1 t ha^{-1}) and the highest harvest index (43.86%) was attained from D3 (30 cm×10 cm).

Zaher *et al*. (2014) conducted an experiment with four row spacings (S_1 = 15 com, S_2 = 20 cm, S_3 = 25 cm and S_4 = 30 cm) and four weeding treatments (W_0 = 0 weeding, W_1 = weeding at 15 days after sowing (DAS), W_2= weeding at 15 and 30 days after sowing (DAS) and W_3= Weeding at 15, 30 and 45 days after sowing (DAS) were used and results showed that the highest number of pods $plant^{-1}$ was gained by 30 cm row spacing with three times of weeding. The highest pod length (6.69) cm and highest number of seeds pod^{-1} (9.43) as well as highest 1000 seed weight (30.49 gm) was observed from 30 cm row spacing. The highest grain yield (1591 kg ha^{-1}) and biological yield (3964 kg ha^{-1}) were gained by 30 cm row spacing with three times of weeding. The highest harvest index (44.26%) was achieved by 25 cm row spacing with two times of weeding.

2.3 Influence of SCI on plant characters

System of Wheat Intensification (SWI) was first tested in northern India in 2006 by farmers working with the People's Science Institute (PSI). First-year trials near Dehradun, using several varieties, showed average increases of 18% to 67% in grain yield and 9% to 27% higher straw yields (important for subsistence farmers as fodder) compared with the yields that farmers usually attained with conventional broadcast methods for crop establishment. Impressed with these results, PSI began promoting SWI in the states of Uttarakhand and Himachal Pradesh (Prasad, 2008).

In Mali, simply imitating SRI was not very successful; the mortality of transplanted seedlings was 9% to 22%, and 25 × 25 cm spacing was too wide for plants to utilize all the arable area. Transplanted SWI produced 29% less grain than the control plots (1.4 t ha^{-1} vs. 1.97 t ha^{-1}). Direct-seeded SWI, on the other hand, with widely spaced individual plants showed a 13% yield increase, producing 2.22 t ha^{-1}. Farmers were pleased with their 94% reduction in seed requirements with this method of SWI (10 kg ha^{-1} vs. 170 kg ha^{-1}); also they found their labor investment reduced by 40%, and their need for irrigation water was 30% less (Styger *et al.*, 2008) . Thus, farmer interest in this innovation was aroused.

In eastern India, the bihar rural livelihood support program has reported a tripling of yields from mungbean when using SCI methods. Usual yields are about 625 kg ha^{-1}, whereas with SCI management, the average is 1.875 t ha^{-1} on farmer’s fields. In northern India, Proteomics Society of India (PSI) reported that with adaptations of SRI practices to the cultivation of various legumes, small farmers in Uttarakhand and Himachal Pradesh states obtained higher yields (Abraham *et al.* 2014). They found:

- 65% increase for lentils or black gram (*Vigna mungo*) – yields are being raised from 850 kg ha^{-1} to 1.4 t ha^{-1};
- 50% increase for soya bean (*Glysine max*)- yields go up from 2.2 t ha^{-1} to 3.0 t ha^{-1};
- 67% increase for kidney beans (*Phaseolus vulgaris*)- yields rise from 1.8 t ha^{-1} to 3/0 t ha^{-1}; and
- 42% increase for peas (*Pisum sativum*)- yields go up from 2.13 t ha^{-1} to 3.02 t ha^{-1}.

No transplanting is involved with these legume crops, just sowing only 1-2 seeds per hill as much wider spacing than in conventional practice. The resulting SCI crops were found to be more robust, more resistant to pest and disease damage, and less affected by adverse climatic conditions.

A World Bank evaluation of SCI in Bihar reported that average yield increases for pulses by 56%, and profitability increases by 67% (Behera *et al.* 2013)

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka Bangladsh. The experimental site is situated between 23° 74´ N latitude and 90º 35´ E longitude (Anon., 1989). The soil of the experimental site belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28) and the General Soil Type is Deep Red Brown Terrace soil (UNDP, 1988).

3.1 Climate Condition

The climate of the experimental site is subtropical, characterized by high temperature and heavy rainfall during Kharif season (April-September) and scarce rainfall during Rabi season (October-March), associated with moderately low temperature. The prevailing weather conditions during the study period have been presented in Appendix- II.

3.2 Planting Material

Three varieties of mungbean were used as test crops. The seeds were collected from the Pulse Research Centre of Bangladesh Agricultural Research Institute, Joydevpur, Gazipur. They grow both in Kharif and Rabi season. Life cycle ranges from 55-60 days. Maximum seed yield is 1.1-1.6 t ha^{-1}.

3.3 Land preparation

The land was irrigated before ploughing. After having ‘zoe’ condition the land was first opened with the tractor. Ploughed soil was brought into desirable fine tilth by 3 ploughing and cross-ploughing, harrowing and laddering. The first ploughing and the final land preparation were done on 05 March and 12 March

2015, respectively. Experimental land was divided into unit plots following the experimental design.

3.4 Fertilizer application

Urea, Triple super phosphate (TSP), Muriate of potash (MOP) and gypsum were used as a source of nitrogen, phosphorus, potassium and sulphur respectively. Urea, TSP, MOP and gypsum were applied at the rate of 50, 85, 35 and 5 kg per hectare, respectively following the Bangladesh Agricultural Research Institute (BARI) recommendation during final land preparation.

3.5 Experimental design and layout

The two factors experiment was laid out in split plot design with three replications. An area of 19.5 m × 14.5 m was divided into blocks. Three mungbean varieties were assigned in the main plot and five spacing treatments were in sub-plot. In total there were 45 unit plots. The treatments were assigned to the main plots and sub plots randomly. The size of each unit plot was 2.5m × 1.5 m. The space between two adjacent blocks was 1.5 m. The space between two adjacent plots was 0.5 m. The layout of the experimental plot is shown in Appendix III.

3.6 Treatments of the experiment

The experiment comprised of two factors

Factor A: Variety (3)

V_1= BARI mung 4

V_2= BARI mung 5

V_3= BARI mung 6

Factor B: Spacing (5)

S_1 = 30 cm × 10 cm

S_2 = 20 cm × 20 cm

S_3 = 30 cm × 30 cm

S_4 = 40cm × 40 cm

S_5 = 50 cm × 50 cm

There were in total 15 (5x3) treatment combinations, such as- V_1S_1, V_1S_2, V_1S_3, V_1S_4, V_1S_5, V_2S_1, V_2S_2,V_2S_3, V_2S_4, V_2S_5, V_3S_1, V_3S_2, V_3S_3 ,V_3S_4, V_3S_5.

3.7 Sowing of seeds in the field

The seeds of mungbean were sow on March 12, 2015 in solid rows in the furrows having a depth of 2-3 cm with maintaining plant densities as per treatments of the experiment.

3.8 Intercultural Operations

Irrigation, Drainage and weeding

Irrigation was provided on 15 and 28 Days after emergence (DAE) to optimize the vegetative growth and flowering of mungbean for all experimental plots equally. Proper drainage was provided on 14 DAS to drain out of excess water from irrigation and also rainfall. The crop field was weeded as per treatment of weed control methods.

Thinning

Seed germination started after five Days after Sowing (DAS). Thinning was done two times, first at 7 DAS and second at 14 DAS to maintain proper spacing as per treatment.

Plant protection measures

The insecticide Ripcord was sprayed at the rate of 1 litre ha^{-1} to protect the crop against insect pests.

3.9 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 days after emergence (DAE) to 75 day DAE.

3.10 Harvest and post harvest operations

The crop harvest was completed at 65 DAE. The crop was harvested plot wise after about 80% of the pods became mature. The harvested pods were sorted into individual bags for each plot. They were taken to the threshing floor and sun dried for three days. Afterwards the seeds and stover were separately weighed.

3.11 Recording of data

The data were recorded on the following parameters

- Plant height
- Branches per plant
- Dry matter per plant
- Nodules per plant
- Pods per plant
- Length of pods
- Seeds per pod

- 1000 seed weight
- Grain yield
- Stover yield
- Harvest index

3.12 Procedure of recording data

Plant height (cm)

The height of the selected plant was measured from the ground level to the tip of the plant at 15, 30, 45, 60 days after emergence (DAE).

Branches per plant (no.)

Number of branches were counted from each selected plant sample at 15, 30, 45, 60 days after emergence and then averaged.

Dry weight per plant (g)

Five plants were collected from each plot at 15, 30, 45, 60 days after emergence. The sample plants were oven dried for 24 hours at 70 degrees Celsius. The plant was measured for dry weight.

Nodules per plant (no.)

Five plants were collected from each plot at 15, 30, 45, 60 days after emergence. The roots of sample plants were gently washed under running water and then the number of nodules of each plant was counted.

Pods per plant (no.)

Pods were counted from 10 selected plants and then the average pod number was determined.

Length of pods (cm)

The length of pods per plant was measured from 20 selected pods and then the average length of pod was determined.

Seeds per pod (no.)

Number of seeds per pod was counted from 20 selected pods and then the average seed number was determined.

1000 seed weight (g)

1000 seeds were counted out from the seed sample of each plot separately. Then they were weighed on an electric balance and the data were recorded at 65, 75 and 85 DAS.

Seed yield (kg ha^{-1})

Seed yield was recorded from marked area and was expressed in terms of yield (kg ha^{-1}).

Stover yield (kg ha^{-1})

After separation of seeds from plant, the straw and shell harvested was sun dried and the weight was recorded and then it was converted into kg ha^{-1}.

Harvest Index (%)

Harvest Index was calculated with the help of following formula-

Harvest index (HI%) = (Seed yield/Biological yield) ×100.

Here, Biological yield = (Seed yield + Stover yield)

3.13 Statistical Analysis

The data obtained for different parameters were statistically analyzed using Statistix 10.0 software to find out difference among different treatments on yield and yield contributing characters of mungbean. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The treatment means were estimated by the LSD method at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

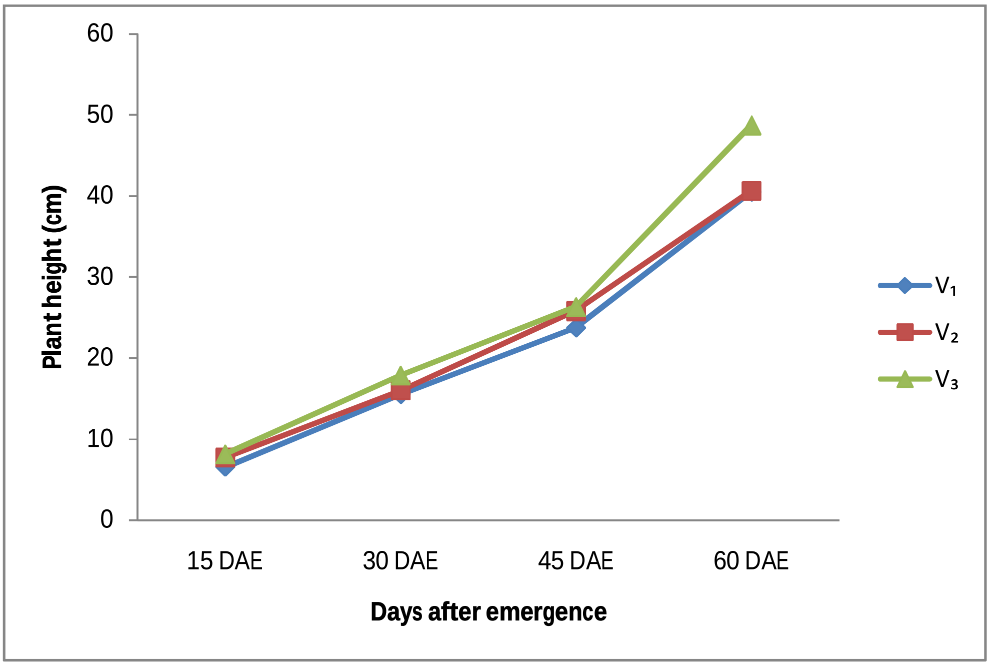
This chapter comprised presentation and discussion of the results obtained from the study of the growth and yields of mungbean as affected by variety and spacing, under agro climatic condition of Sher-e-Bangla Agricultural University (SAU), Dhaka. The analysis of variance (ANOVA) of the data on different yield contributing characters and yield of mungbean are presented in Appendix. The results which are influenced by different treatment have been presented and discussed in different tables and graphs and possible interpretations given under the following headings:

4.1 Plant height (cm)

Significant variation was recorded in plant height of mungbean for different factors at 15, 30, 45 and 60 DAE (Figure 1). The tallest plant was recorded from V_3 (7.74 cm) at 15 DAE, 18.11 cm at 30 DAE, 25.76 cm at 45 DAE and 46.91 cm at 60 DAE) and the shortest plat was found in V_1 (6.8 cm at 15 DAE, 15.38 cm at 30 DAE, 22.35 cm at 45 DAE and 38.7 cm at 60 DAE). The plant height of V_3 at 15 DAE (7.74 cm) was statistically similar to that of V_2 (7.45 cm). But, in case of plant height at 60 DAE, the shortest plant found in V_1 (38.78 cm) was similar to that of V_2 (39.39 cm). The variation in plant height was observed due to the varietal characteristics which was supported by Hanlan *et al.* (2006) and they reported 03 m to 0.44 m plant height in different cultivars of mungbean.

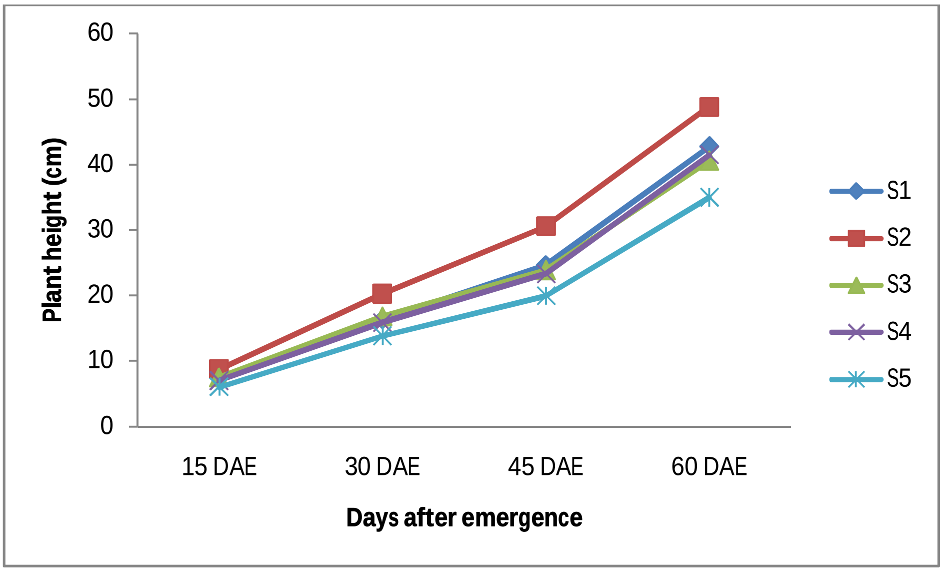
On the other hand, at all stages of growth, the tallest plant was found in S_2 spacing (8.77 cm at 15 DAE, 20.26 cm at 30 DAE, 30.57 cm at 45 DAE and 48.80 cm at 60 DAE), whereas the shortest plant was found from S_5 spacing at all growth stages (5.99 cm at 15 DAE, 13.88 cm at 30 DAE, 19.87 cm at 45 DAE and 34.95 cm at 60 DAE). Variation in plant height found in different spacing was attributed to different plant population. This result was in agreement with the results of Mansoor *et al*. (2010) who reported that the tallest plants were obtained from 20 cm row spacing. But Rana *et al*. (2011) reported that plant height did not differ significantly due to plant population up to 50 DAS but differed significantly thereafter.

Statistically significant differences were recorded due to the interaction effect of cultivar and spacing for plant height at 15, 30, 45 and 60 DAE (Table 1). The tallest plant (9.5cm at 15 DAE, 22.48cm at 30 DAE, 33.59cm at 45 DAE, 55.02cm 60 DAE) was recorded from V_3S_2 treatment combination and the shortest plant (5.27 cm at 15 DAE, 12.56cm at 30 DAE, 17.95cm at 45 DAE, 32.84cm at 60 DAE) was recorded from V_1S_5 treatment combination.



V_1: BARI mung-4, V_2: BARI mung-5, V_3: BARI mung-6

Figure 1. Effect of cultivar on plant height of mungbean ($LSD_{(0.05)}$ = 0.14, 0.27, 0.13, 1.05 for 15, 30, 45 and 60 DAE, respectively)



S_1: 30 cm × 10 cm, S_2: 20 cm × 20 cm, S_3: 30 cm × 30 cm, S_4: 40 cm × 40 cm, S_5: 50 cm × 50 cm

Figure 2. Effect of spacing on plant height of mungbean ($LSD_{(0.05)}$ = 0.13, 0.32, 0.19, 0.86 for 15, 30, 45 and 60 DAE, respectively)

Table 1. Interaction effect of variety and spacing on plant height of mungbean

Treatment	Plant height (cm) at			
	15 DAE	30 DAE	45 DAE	60 DAE
V_1S_1	6.81de	15.09f	22.54f	40.63c
V_1S_2	8.05c	18.82b	27.60c	44.97b
V_1S_3	7.10de	15.35ef	21.97fg	36.63de
V_1S_4	6.93de	15.06f	21.71gh	38.82cde
V_1S_5	5.27g	12.56g	17.95j	32.84f
V_2S_1	7.26d	16.38de	25.61d	39.85cd
V_2S_2	8.78b	19.49b	30.51b	46.41b
V_2S_3	8.05c	16.66d	25.25d	37.26cde
V_2S_4	7.06de	15.50ef	24.02e	38.41cde
V_2S_5	6.12f	13.73g	20.55i	35.02ef
V_3S_1	8.34bc	17.49cd	25.59d	47.72b
V_3S_2	9.50a	22.48a	33.59a	55.02a
V_3S_3	7.26d	18.35bc	24.32e	47.73b
V_3S_4	7.02de	17.05d	24.17e	47.09b
V_3S_5	6.59ef	15.19ef	21.15hi	36.99cde
$LSD_{(0.05)}$	0.47	1.15	0.71	3.09
CV (%)	3.82	4.14	1.72	4.40

In a column, means having similar letter(s) are statistically similar but those having dissimilar letter(s) differ significantly at 0.05 level of significance

V_1: BARI mung 4, V_2: BARI mung 5, V_3: BARI mung 6

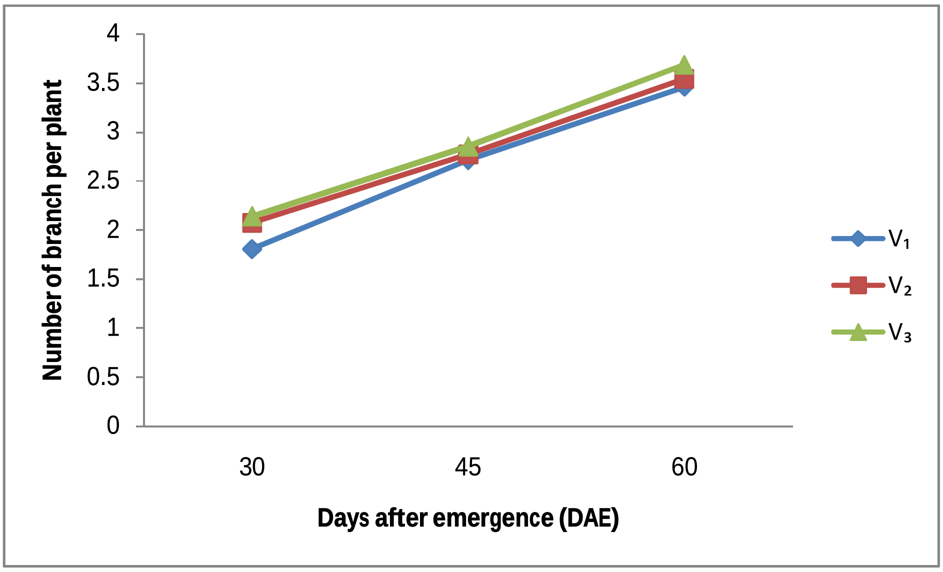
S_1: 30 cm × 10 cm, S_2: 20 cm × 20 cm, S_3: 30 cm × 30 cm, S_4: 40 cm × 40 cm, S_5: 50 cm × 50 cm

4.2 Branches per plant

Number of branches per plant varied significantly due to cultivar at 30, 45 and 60 DAE (Figure 3). The highest number of branches per plant was obtained from V_3 (2.14 at 30 DAE, 2.85 at 45 DAE and 3.68 at 60 DAE), while the lowest number of branches per plant was found in V_2 (1.80 at 30 DAE, 2.71 at 45 DAE and 3.46 at 60 DAE).

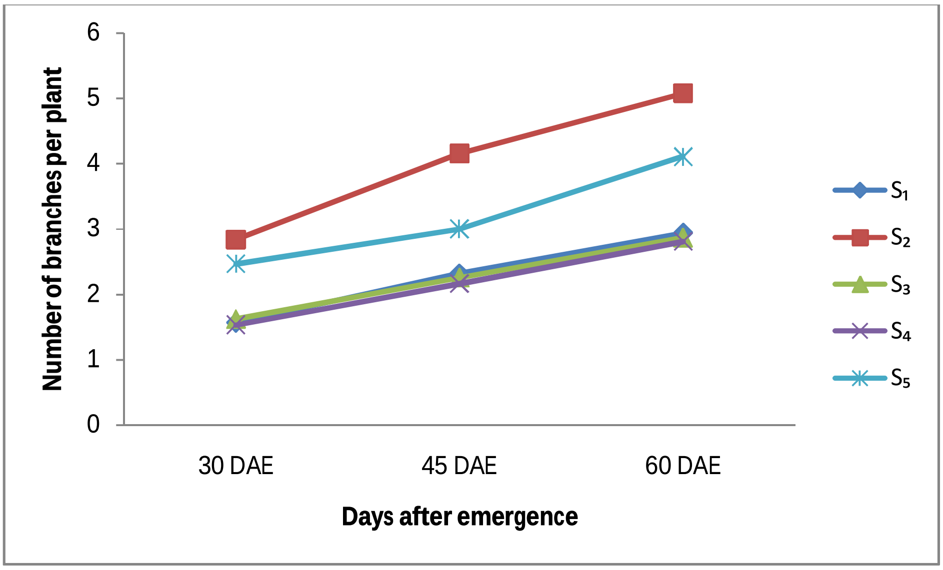
Statistically significant variation was recorded for number of branches per plant of mungbean at 30, 45 and 60 DAE due to different spacings (Figure 4). At 30, 45 and 60 DAE the highest number of branches per plant was found in S_2 (2.84, 4.15 and 5.07, respectively)and the lowest number of branches per plant was obtained from S_4 (1.53, 2.16 and 2.81, respectively) . In general, number of branches per plant increased in optimum plant density and it was probably due to availability of suitable space, nutrition and environment viz. air, moisture, humidity, water, light intensity etc. The present result is in agreement with the results of El-Habbasha *et al.* (1996).

Statistically significant differences were found due to the interaction effect of cultivar and spacing for number of branches at 30, 45 and 60 DAE (Table 2). The highest number of branches was observed in the treatment combination V_3S_2 (3.16, 4.33 and 5.46, respectively) whereas the lowest number of branches was observed in the combination V_2S_3 (1.23, 1.96 and 2.8, respectively).



V_1: BARI mung 4, V_2: BARI mung 5, V_3: BARI mung 6

Figure 3. Effect of cultivar on number of branches plant^{-1} of mungbean (LSD $_{(0.05)}$ = 0.0968, 0.1206, 0.1940 for 30, 45 and 60 DAE, respectively)



S_1: 30 cm × 10 cm, S_2: 20 cm × 20 cm, S_3: 30 cm × 30 cm, S_4: 40 cm × 40 cm, S_5: 50 cm × 50 cm

Figure 4. Effect of spacing on number of branches plant^{-1} of mungbean (LSD $_{(0.05)}$ = 0.1981, 0.1664, 0.2226 for 30, 45 and 60 DAE, respectively)

Table 2. Interaction effect of variety and spacing on number of branches per plant of mungbean

Treatment	Dry matter (g) at			
	15 DAE	30 DAE	45 DAE	60 DAE
V_1S_1	0.63def	8.04d	8.31fg	17.16cd
V_1S_2	1.61c	10.73c	14.04c	21.47ab
V_1S_3	0.36f	6.56e	10.23e	16.29cd
V_1S_4	0.45ef	2.68f	7.66g	12.79e
V_1S_5	0.61def	5.90e	10.15e	16.27cd
V_2S_1	0.80d	8.37d	11.55d	16.50cd
V_2S_2	2.30b	12.79b	15.39b	22.40a
V_2S_3	0.77d	6.37e	13.29c	17.67c
V_2S_4	0.65de	2.77f	8.87f	14.20de
V_2S_5	0.60def	5.94e	10.67de	15.77cde
V_3S_1	0.48ef	8.71d	13.77c	18.32bc
V_3S_2	3.00a	16.43a	19.19a	24.37a
V_3S_3	0.79d	6.65e	14.27bc	16.67cd
V_3S_4	0.54def	2.41f	8.99f	13.70de
V_3S_5	0.55def	6.41e	11.6d	16.88cd
LSD $_{(0.05)}$	0.28	1.34	1.13	2.44
CV (%)	17.86	10.82	5.69	8.37

In a column, means having similar letter(s) are statistically similar but those having dissimilar letter(s) differ significantly at 0.05 level of significance

V_1: BARI mung 4, V_2: BARI mung 5, V_3: BARI mung 6

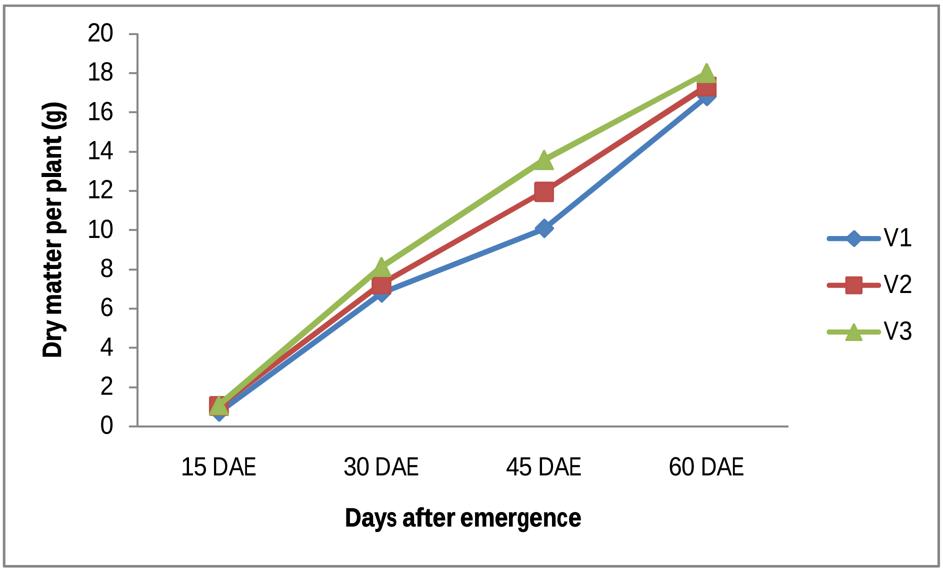
S_1: 30 cm × 10 cm, S_2: 20 cm × 20 cm, S_3: 30 cm × 30 cm, S_4: 40 cm × 40 cm, S_5: 50 cm × 50 cm

4.3 Dry matter per plant

Dry matter per plant varied significantly due to cultivar at 15, 30, 45 and 60 DAE (Figure 5). The highest dry matter per plant was obtained from V_3 (1.06 g, 7.68 g, 13.57g and 17.87g at 15, 30, 45 and 60 DAE, respectively) while the lowest dry matter per plant was found in V_1 (0.70g, 7.25g, 10.91g and 15.98g at 15, 30, 45 and 60 DAE, respectively).

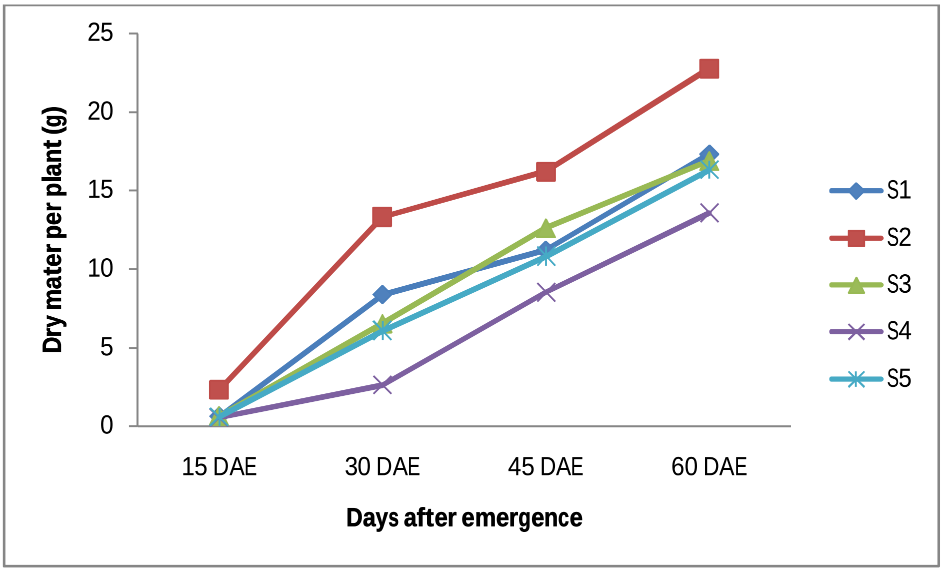
Statistically significant variation was recorded for dry matter per plant of mungbean at 15, 30, 45 and 60 DAE due to different spacings (figure 6). At 15, 30, 45 and 60 DAE the highest dry matter per plant was found in S_2 (2.23g,13.15g, 17.02g and 22.77g at 15, 30, 45 and 60 DAE, respectively) and the lowest dry matter per plant was obtained from S_4 (0.56 g, 3.29g, 8.488g and 13.566g at 15, 30, 45 and 60 DAE, respectively). Mansoor *et al.* (2010) reported that dry matter content in plants was significantly affected by various seed rates as well as plant population.

Statistically significant differences were observed due to the interaction effect of cultivar and spacing for dry matter at 15, 30, 45 and 60 DAE (Table 3). The highest dry matter was observed in the treatment combination V_3S_2 (3.00g, 16.43g, 19.19g and 24.37 g at 15, 30, 45 and 60 DAE, respectively), whereas the lowest dry matter was observed in the combination VS_4 (0.36g, 2.41g, 7.66g and 12.79g at 15, 30, 45 and 60 DAE, respectively).



V_1: BARI mung 4, V_2: BARI mung 5, V_3: BARI mung 6

Figure 5. Effect of cultivar on dry matter per plant (g) of mungbean (LSD $_{(0.05)}$ = 0.0476, 0.2341, 0.1787, 1.0912 for 15, 30, 45 and 60 DAE, respectively)



S_1: 30 cm × 10 cm, S_2: 20 cm × 20 cm, S_3: 30 cm × 30 cm, S_4: 40 cm × 40 cm, S_5: 50 cm × 50 cm

Figure 6. Effect of spacing on dry matter per plant (g) of mungbean, (LSD $_{(0.05)}$ = 0.0797, 0.3769, 0.3186, 0.6850 for 15, 30, 45 and 60 DAE, respectively)

Table 3. Interaction effect of variety and spacing on dry matter content of mungbean

Treatment	Dry matter (g) at			
	15 DAE	30 DAE	45 DAE	60 DAE
V_1S_1	0.63def	8.04d	8.31fg	17.16cd
V_1S_2	1.61c	10.73c	14.04c	21.47ab
V_1S_3	0.36f	6.56e	10.23e	16.29cd
V_1S_4	0.45ef	2.68f	7.66g	12.79e
V_1S_5	0.61def	5.90e	10.15e	16.27cd
V_2S_1	0.80d	8.37d	11.55d	16.50cd
V_2S_2	2.30b	12.79b	15.39b	22.40a
V_2S_3	0.77d	6.37e	13.29c	17.67c
V_2S_4	0.65de	2.77f	8.87f	14.20de
V_2S_5	0.60def	5.94e	10.67de	15.77cde
V_3S_1	0.48ef	8.71d	13.77c	18.32bc
V_3S_2	3.00a	16.43a	19.19a	24.37a
V_3S_3	0.79d	6.65e	14.27bc	16.67cd
V_3S_4	0.54def	2.41f	8.99f	13.70de
V_3S_5	0.55def	6.41e	11.6d	16.88cd
LSD $_{(0.05)}$	0.28	1.34	1.13	2.44
CV (%)	17.86	10.82	5.69	8.37

In a column, means having similar letter(s) are statistically similar but those having dissimilar letter(s) differ significantly at 0.05 level of significance

V_1: BARI mung 4, V_2: BARI mung 5, V_3: BARI mung 6

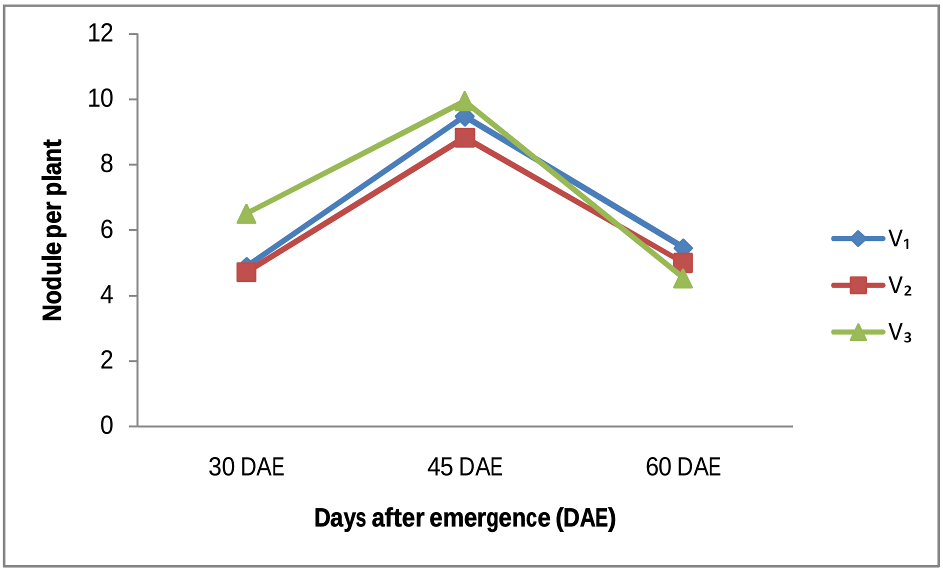
S_1: 30 cm × 10 cm, S_2: 20 cm × 20 cm, S_3: 30 cm × 30 cm, S_4: 40 cm × 40 cm, S_5: 50 cm × 50 cm

4.4 Nodules per plant

Number of nodules in mungbean plant root varied significantly due to cultivar at 30, 45 and 60 DAE (Figure 7). The highest number of nodules per plant was obtained from V_3 (6.5, 9.94 and 5.45 at 30, 45 and 60 DAE, respectively) while the lowest number of nodules per plant was found in V_2 (4.71, 8.82 and 5.00 at 30, 45 and 60 DAE, respectively), which was statistically similar to V_1 (4.88, 9.47 and 4.52 at 30, 45 and 60 DAE, respectively).

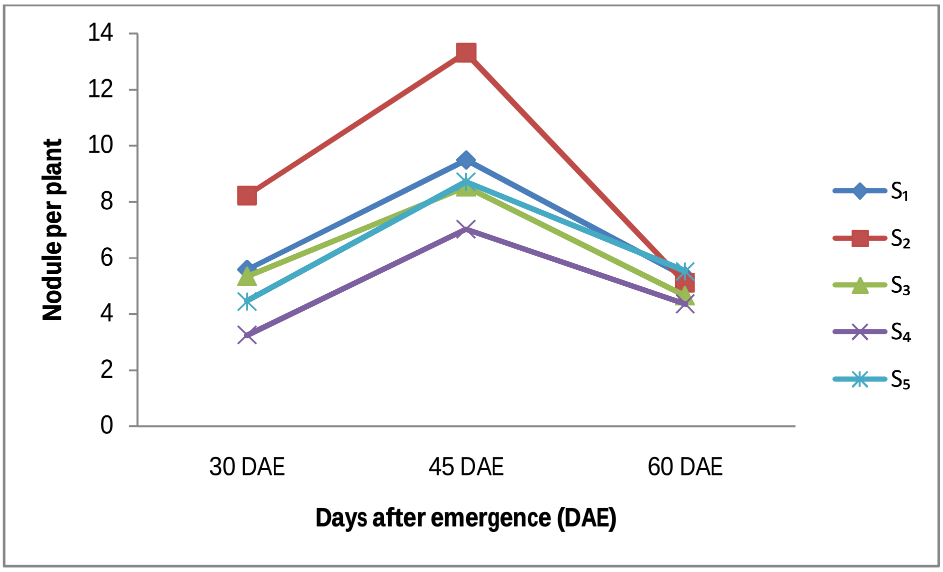
Statistically significant variation was recorded for number of nodules per plant of mungbean at 30, 45 and 60 DAE due to different spacings (Figure 8). At 30, 45 and 60 DAE the highest number of nodules per plant was found in S_2 (8.22, 13.11 and 5.522, respectively) and the lowest number of nodules per plant was obtained from S_4 (3.24, 7.02 and 4.35, respectively).

Statistically significant differences were found due to the interaction effect of cultivar and spacing for number of nodules per plant at 15, 30, 45 and 60 DAE. The highest number of nodules per plant was observed in the treatment combination V_3S_2 (10.4, 13.93 and 6.40 at 30, 45 and 60 DAE, respectively) whereas the lowest number of nodules per plant was observed in the combination V_1S_4 (3.06, 6.66 and 3.93 at 30, 45 and 60 DAE, respectively).



V_1: BARI mung 4, V_2: BARI mung 5, V_3: BARI mung 6

Figure 7. Effect of cultivar on nodule per plant of mungbean (LSD $_{(0.05)}$ = 0.2276, 0.3465, 0.2181 for 30, 45 and 60 DAE, respectively)



S_1: 30 cm × 10 cm, S_2: 20 cm × 20 cm, S_3: 30 cm × 30 cm, S_4: 40 cm × 40 cm, S_5: 50 cm × 50 cm

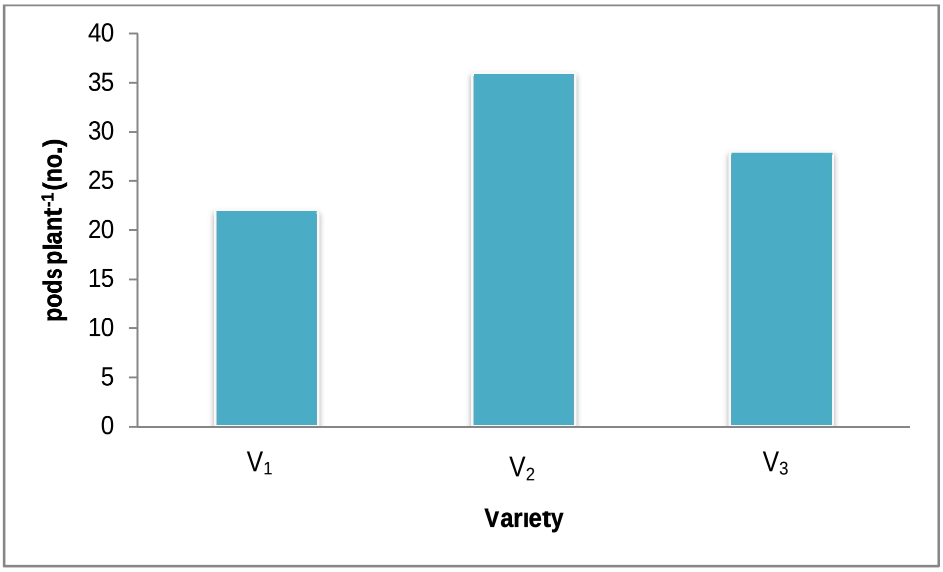
Figure 8. Effect of spacing on nodule per plant of mungbean (LSD $_{(0.05)}$ = 0.2980, 0.3060, 0.5189 for 30, 45 and 60 DAE, respectively)

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

A statistically significant variation was recorded for number of pods plant^{-1} due to different cultivar (Figure 9). The highest number of pods per plant was found in V_2 (36.04).The lowest number of pods per plant was found in V_1 (22.03), which were statistically similar to V_3 (27.97).

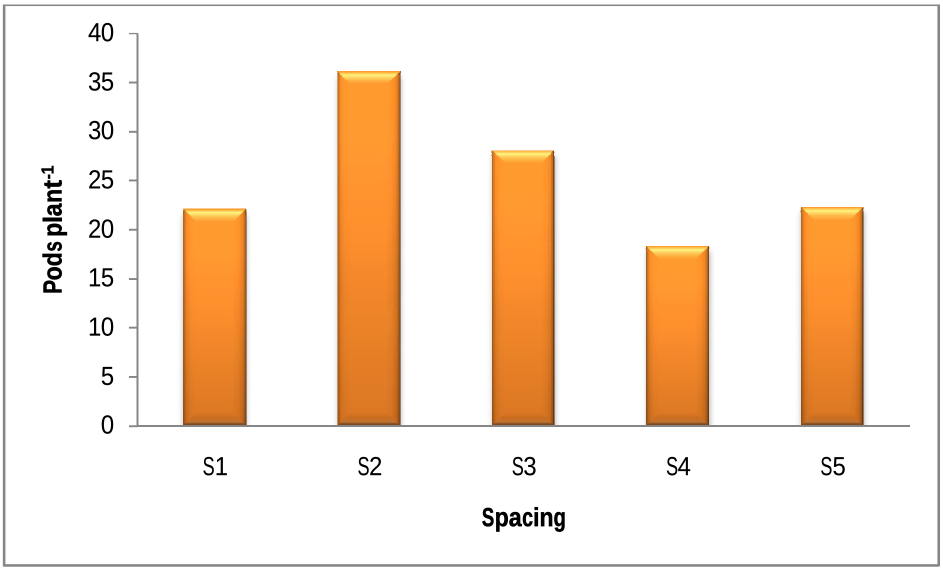
Number of pods per plant of mungbean varied significantly due to spacing (Figure 10). The highest number of pods per plant was found in S_2 (35.71). The lowest number of pods per plant was found in S_4 (19.1), which was statistically similar to S_5 (22.55). The optimum number of plants per unit area enabled the plants to utilize nutrient and light and might have caused the consequent result in number of pods per plant. Similar results were reported by many researchers (Singh and Singh, 1988; Chowdhury, 199; Hassan, 2000; Singh *et al.*, 2003).

Interaction effect of cultivar and spacing showed statistically significant differences in number of pods per plant (Table 4). The highest number of pods per plant was recorded from V_3S_2 (52.56) and the lowest was found in V_1S_4 (14.00).



V_1: BARI mung 4, V_2: BARI mung 5, V_3: BARI mung 6

Figure 9. Effect of cultivar on pods plant^{-1} of mungbean (LSD $_{(0.05)}$ = 2.4003)



S_1: 30 cm × 10 cm, S_2: 20 cm × 20 cm, S_3: 30 cm × 30 cm, S_4: 40 cm × 40 cm, S_5: 50 cm × 50 cm

Figure 10. Effect of spacing on pods plant^{-1} of mungbean (LSD $_{(0.05)}$ = 2.1051)

Table 4. Interaction effect of variety and spacing on yield and yield contributing characters of mungbean

Treatment	Pods plant^{-1}	Pod length (cm)	Seed pod^{-1}	Weight of 1000 seeds	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest Index (%)
V_1S_1	26.43cd	6.93efg	8.99cde	38.30fgh	0.50d	1.66e	23.33bc
V_1S_2	29.40c	7.52d	10.29b	39.65de	0.81b	2.08b	27.66a
V_1S_3	22.53c-f	6.78g	8.97cde	38.10fgh	0.33e	1.84cd	15.00g
V_1S_4	14.00g	6.24i	8.14f	37.30h	0.23fgh	1.05h	18.00efg
V_1S_5	19.63d-g	6.75gh	8.56ef	37.51gh	0.31e	1.59ef	19.00def
V_2S_1	15.66efg	8.08c	8.93cde	46.66bc	0.51d	1.55f	21.33cde
V_2S_2	26.16cd	8.86b	10.50b	48.40a	0.72c	1.92c	27.00ab
V_2S_3	19.86d-g	7.35d	8.59ef	39.31def	0.29efg	1.31g	18.66d-g
V_2S_4	14.50fg	6.40hi	8.68def	37.73gh	0.22gh	1.05h	16.66fg
V_2S_5	18.90d-g	7.28de	8.89cde	38.63efg	0.28efg	1.13h	17.66efg
V_3S_1	24.00cdf	7.44d	9.41c	47.92ab	0.51d	1.78d	22.66bcd
V_3S_2	52.56a	10.70a	11.54a	49.11a	1.16a	2.58a	30.66a
V_3S_3	41.50b	7.20de	9.31cd	46.12c	0.35e	1.52f	17.66efg
V_3S_4	26.20cd	6.86fg	8.94cde	37.86gh	0.19h	1.14h	17.66efg
V_3S_5	28.13cd	7.17def	9.02cde	40.02d	0.30ef	1.37g	17.00efg
LSD $_{(0.05)}$	9.37	0.37	0.67	1.28	0.07	0.1	4.42
CV (%)	17.65	2.64	3.31	1.82	9.22	3.90	11.28

In a column, means having similar letter(s) are statistically similar but those having dissimilar letter(s) differ significantly at 0.05 level of significance

V_1: BARI mung 4, V_2: BARI mung 5, V_3: BARI mung 6

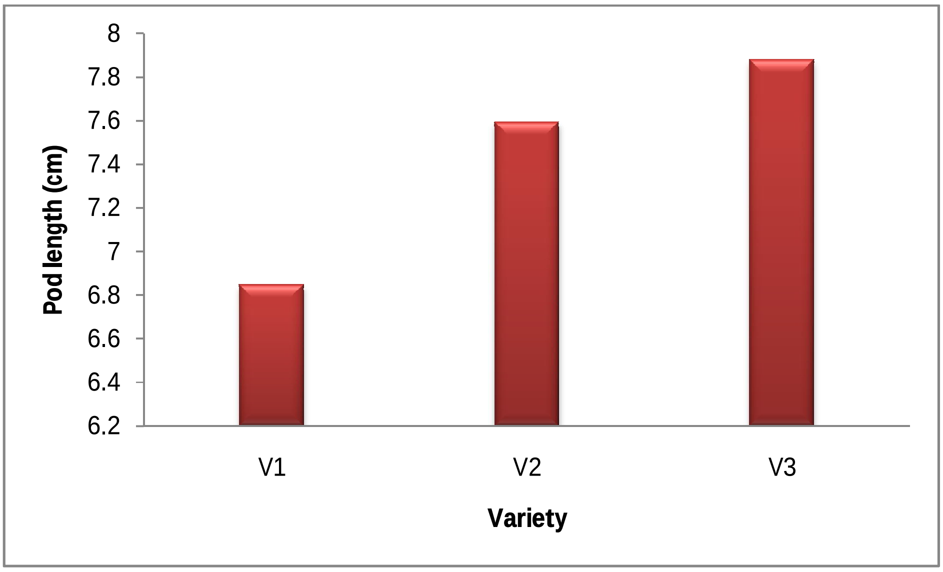
S_1: 30 cm × 10 cm, S_2: 20 cm × 20 cm, S_3: 30 cm × 30 cm, S_4: 40 cm × 40 cm, S_5: 50 cm × 50 cm

4.6 Length of pods

of mungbean due to different cultivar (Figure 11). The highest was found in V_3 (7.87 cm), which was statistically similar to V_2 (7.59 cm). The lowest was found in V_1 (6.84 cm).

of mungbean varied significantly due to spacing(Table 6). The highest was found in S_2 (9.03 cm). The lowest was found in S_4 (6.67 cm), closely followed by S_5 (6.75 cm). Zaher *et al*. (2014) reported that the highest pod length (6.69 cm) was found from 30 cm row spacing.

Interaction effect of cultivar and spacing showed statistically significant differences for (Table 4). The highest was recorded from V_3S_2 (10.70 cm) and the lowest was found in V_1S_5 (7 cm).



V_1: BARI mung 4, V_2: BARI mung 5, V_3: BARI mung 6

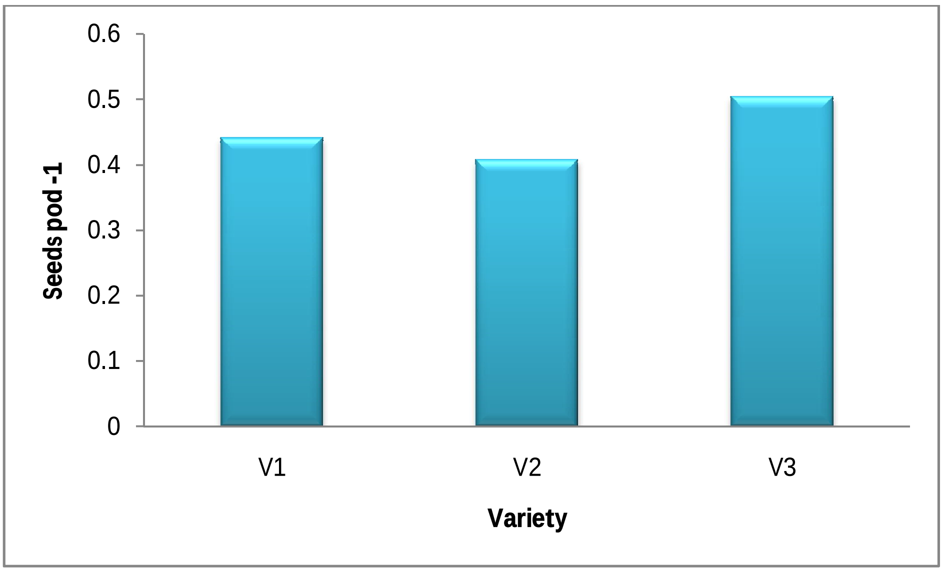
Figure 11. Effect of cultivar on length of pod of mungbean (LSD $_{(0.05)}$ = 2.4003)

4.7 Number of seeds pod^{-1}

seeds pod^{-1} due to different cultivar (Figure 12). The highest number of seeds pod^{-1} was found in V_3 (9.64) The lowest number of seeds pod^{-1} was found in V_1 (9.12), which was statistically similar to V_2 (8.99) .

Number of of mungbean varied significantly due to spacing (Table 5). The highest number of was found in S_2 (10.77). The lowest number of was found in S_4 (8.58). Zaher *et al*. (2014) recorded the highest number of pods per plant (9.43) was recorded by 30 cm row spacing.

Interaction effect of cultivar and spacing showed statistically significant differences for number of (Table 4). The highest number of was recorded from V_3S_2 (11.54) and the lowest was found in V_1S_4 (8.14).



V_1: BARI mung 4, V_2: BARI mung 5, V_3: BARI mung6

Figure 12. Effect of cultivar on seeds pod^{-1} of mungbean (LSD $_{(0.05)}$ = 2.1051)

4.8 1000 seed weight

A statistically significant variation was recorded for 1000 seed weight due to different cultivar. The highest 1000 seed weight was found in V_3 (44.20 g). The lowest 1000 seed weight was found in V_1 (38.17g).

1000 seed weight of mungbean varied significantly due to spacing (Table 5). The highest 1000 seed weight was found in S_2 (45.72 g) The lowest 1000 seed weight was found in S_4 (37.63 g). 1000 seed weight decreased both in closed and wider spacing for mungbean plants and similar results were observed by many other workers (Singh and Singh, 1988; Tomar *et al*. 1996; Chowdhury, 1999, Hassan 2000). On the other hand, BINA (2004) reported that plant density had no influence on 1000 seed weight in mungbean.

Interaction effect of cultivar and spacing showed statistically significant differences for 1000 seed weight (Table 4). The highest 1000 seed weight was recorded from V_3S_2 (49.11 g) and the lowest was found in V_1S_4 (37.3 g).

Table 5 . Effect of spacing on length of pod, number of seeds per pod and 1000 seed eight (g) of mungbean

Treatment	Length of pod (cm)	Number of seeds per pod	1000 seed weight (g)
S_1	7.48b	9.11b	44.29b
S_2	9.03a	10.77a	45.72a
S_3	7.11c	8.96b	41.17c
S_4	6.50d	8.58c	37.63e
S_5	7.06c	8.82bc	38.72d
$LSD_{(0.05)}$	0.19	0.29	0.73
CV (%)	2.64	3.31	1.82

In a column, means having similar letter(s) are statistically similar but those having dissimilar letter(s) differ significantly at 0.05 level of significance

S_1: 30 cm × 10 cm, S_2: 20 cm × 20 cm, S_3: 30 cm × 30 cm, S_4: 40 cm × 40 cm, S_5: 50 cm × 50 cm

4.9 Seed yield

A statistically significant variation was recorded for grain yield of mungbean due to different cultivar (Figure 14). The highest seed yield was found in V_3 (0.515 t ha^{-1}), closely followed by V_1 (0.45 tha^{-1}). The lowest seed yield was found in V_1 (0.40 t ha^{-1}). Tickoo *et al*. (2006) recorded highest seed yield (1.63 t ha^{-1}) from cultivar Pusa Vishal.

Seed yield of mungbean varied significantly due to spacing (Table 6). The highest grain yield was found in S_2 (0.8989 t ha^{-1}). The lowest seed yield was found in S_4 (0.21 t ha^{-1}). Spacing of mungbean play an important role in intercepting solar radiation, which in turn may influence the yield. Kabir and Sarkar (2008) reported that 30 cm × 10 cm produced the highest seed yield. Similar results were also reported by other workers (Hassan, 2000; Singh *et al*., 2003).

Interaction effect of cultivar and spacing showed statistically significant differences for grain yield (Table 4). The highest grain yield was recorded from V_3S_2 (1.16 t ha^{-1}) and the lowest was found in V_1S_4 (0.23 t ha^{-1}).

4.10 Stover Yield

Statistically non significant variation was recorded for stover yield of mungbean due to different cultivar. The highest stover yield was found in V_3 (1.69 t ha^{-1}). The lowest stover yield was found in V_2 (1.47 t ha^{-1}).

Stover yield of mungbean varied significantly due to spacing (Table 7). The highest stover yield was found in S_2 (2.19 t ha^{-1}). The lowest stover yield was found in S_4 (1.09 t ha^{-1}).

Interaction effect of cultivar and spacing showed statistically significant differences for stover yield (Table 4). The highest stover yield was recorded from V_3S_2 (2.58 t ha^{-1}) and the lowest was found in V_1S_4 (1.05 t ha^{-1}).

Table 6. Effect of cultivar on seed yield, stover yield and harvest index of mungbean

Treatment	Seed yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
V_1	0.44b	1.64a	20.60a
V_2	0.40b	1.39b	20.26a
V_3	0.50a	1.67a	21.13a
LSD $_{(0.05)}$	0.03	0.04	2.76
CV (%)	9.22	3.90	11.28

In a column, means having similar letter(s) are statistically similar but those having dissimilar letter(s) differ significantly at 0.05 level of significance

V_1: BARI mung 4, V_2: BARI mung 5, V_3: BARI mung 6

4.11 Harvest Index

Harvest index of mungbean showed non-significant differences due to different cultivar. The highest harvest index was attained from V_3 (21.133%) and the lowest was observed from V_2(20.267%) which was closely followed by V_1 (20.6%).

Differences in spacing showed non-significant variations in terms of harvest index of mungbean. The higest harvest index was found from S_2 (28.4%)

whereas the lowest value was recorded from S_3 (17.11%) treatment, which was similar to S_4 (17.44%) and S_5 (17.89%).

Interaction effect of different cultivars and spacing showed non-significant variation in terms of harvest index (Table 4) . the highest havest index was found from V_3S_2 (30.667%) and the lowest was observed from V_1S_3 (15.00%) treatment combination.

Table 7. Effect of spacing on seed yield, stover yield and harvest index of mungbean

Treatment	Seed yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
S_1	0.51b	1.66b	22.44b
S_2	0.89a	2.19a	28.44a
S_3	0.32c	1.55c	17.11c
S_4	0.21d	1.08e	17.44c
S_5	0.30c	1.36d	17.88c
$LSD_{(0.05)}$	0.04	0.05	2.26
CV (%)	17.65	3.90	11.28

In a column, means having similar letter(s) are statistically similar but those having dissimilar letter(s) differ significantly at 0.05 level of significance

S_1: 30 cm × 10 cm, S_2: 20 cm × 20 cm, S_3: 30 cm × 30 cm, S_4: 40 cm × 40 cm, S_5: 50 cm × 50 cm

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period from March to June 2015 at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh to study the effect of variety and spacing. Three varieties (V_1= BARI mung 4, V_2= BARI mung 5 and V_3= BARI mung 6) and five row spacing (S_1 = 30 cm × 10 cm, S_2 = 20 cm × 20 cm, S_3 = 30 cm × 30 cm, S_4 = 40cm × 40 cm, S_5 = 50 cm × 50 cm) were used. There were fifteen treatment combinations under the study. The two factor experiment was laid out in Split plot design with three replications. Data on different yield contributing characters and yield was recorded and found significant variation for different treatments.

The tallest plants were found in V_3 (8.11 cm, 17.86cm, 26.31cm, 48.737cm) at all the stages studied. The shortest plant was found in V_1 (6.55cm, 15.515 cm, 23.74cm, 40.492) . The highest number of branches per plant was obtained from V_3 (2.14, 2.85, 3.68), while the lowest number of branches per plant was found in V_2 (1.80, 2.71, 3.46). The highest dry matter per plant was obtained from V_3 (1.06 g, 7.68 g, 13.57g, 17.87g) while the lowest dry matter per plant was found in V_1 (0.70g, 7.25g, 10.91g, 15.98g). The highest number of nodules per plant was obtained from V_3 (6.5, 9.94, 5.45) while the lowest number of nodules per plant was found in V2 (4.71, 8.82, 5.00), which was statistically similar to V1 (4.88, 9.47, 4.52).

The highest number of pods per plant was found in V_2 (36.04).The lowest number of pods per plant was found in V_1 (22.03), which were statistically similar to V_3 (27.97). The highest length of pods was found in V_3 (7.87 cm), which was statistically similar to V_2 (7.59 cm). The lowest length of pods was found in V_1 (6.84 cm). The highest number of seeds pod^{-1} was found in V_3 (9.64) The lowest number of seeds pod^{-1} was found in V_1 (9.12), which was statistically similar to V_2 (8.99) . The highest 1000 seed weight was found in V_3 (44.20 g). The lowest 1000 seed weight was found in V_1 (38.17g). The highest seed yield was found in V_3 (0.515 t ha^{-1}), closely followed by V_1 (0.45 tha^{-1}). The lowest seed yield was found in V_1 (0.40 t ha^{-1}). The highest stover yield was found in V_3 (1.69 t ha^{-1}). The lowest stover yield was found in V_2 (1.47 t ha^{-1}). The highest harvest index was attained from V_3 (21.133%) and the lowest was observed from V_2(20.267%) which was closely followed by V_1 (20.6%).

On the other hand, the tallest plant was found in S_2 (8.59cm, 20.09cm, 30.57cm, 49.290cm) spacing, whereas the shortest plant was found in S_5 (6.46, 14.15cm, 36.844cm,) spacing. At 30, 45 and 60 DAE the highest number of branches per plant was found in S_2 (2.84, 4.15, 5.07) and the lowest number of branches per plant was obtained from S_4 (1.53, 2.16, 2.81). At 15, 30, 45 and 60 DAE the highest dry matter per plant was found in S_2 (2.23g,13.15g, 17.02g, 22.77g) and the lowest dry matter per plant was obtained from S_4 (0.56 g, 3.29g, 8.488g, 13.566g). . At 30, 45 and 60 DAE the highest number of nodules per plant was found in S_2 (8.22, 13.11, 5.522) and the dry matter per plant was obtained from S_4 (3.24, 7.02, 4.35).

The highest number of pods per plant was found in S_2 (35.71). The lowest number of pods per plant was found in S_4 (19.1), which was statistically similar to S_5 (22.55). The highest length of pods was found in S_2 (9.03 cm). The lowest length of pods was found in S_4 (6.67 cm), closely followed by S_5 (6.75 cm). The highest number of seeds per pod was found in S_2 (10.77). The lowest number of seeds per pod was found in S_4 (8.58). The highest 1000 seed weight was found in S_2 (45.72 g). The lowest 1000 seed weight was found in S_4 (37.63 g). The highest seed yield was found in S_2 (0.8989 t ha^{-1}). The lowest seed yield was found in S_4 (0.21 t ha^{-1}). The highest stover yield was found in S_2 (2.19 t ha^{-1}). The lowest stover yield was found in S_4 (1.09 t ha^{-1}). The higest harvest index was found from S_2 (28.4%) whereas the lowest value was recorded from S_3 (17.11%) treatment, which was similar to S_4 (17.44%) and S_5 (17.89%).

The tallest plant was recorded for V_3S_2 (9.61cm, 21.98cm, 33.593cm, 54.990cm) and the shortest plant was recorded from V_1S_5 (5.70 cm, 12.90cm, 21.090cm, 34.157cm) . The most number of branches was observed in the treatment combination V_3S_2 (3.16, 4.33, 5.46) whereas the lowest number of branches was observed in the combination V_2S_3 (1.23, 1.96, 2.8). The highest dry matter was observed in the treatment combination V_3S_2 (2.93g, 15.54g, 19.98g, 24.46 g), whereas the lowest dry matter was observed in the combination V_1S_4 (0.36g, 2.85g, 7.99g, 13.04g). The highest number of nodules per plant was observed in the treatment combination V_3S_2 (10.4, 13.93, 6.40) whereas the lowest number of nodules per plant was observed in the combination V_1S_4 (3.06, 6.66, 3.93).

The highest number of pods per plant was recorded from V_3S_2 (52.56) and the lowest was found in V_1S_4 (14.00). The highest length of pods was recorded from V_3S_2 (10.70 cm) and the lowest was found in V_1S_5 (6.750cm). The highest 1000 seed weight was recorded from V_3S_2 (49.11 g) and the lowest was found in V_1S_4 (37.3 g). The highest seed yield was recorded from V_3S_2 (1.16 t ha^{-1}) and the lowest was found in V_1S_4 (0.23 t ha^{-1}). The highest stover yield was recorded from V_3S_2 (2.58 t ha^{-1}) and the lowest was found in V_1S_4 (1.05 t ha^{-1}). the highest havest index was found from V_3S_2 (30.667%) and the lowest was observed from V_1S_3 (15.00%) treatment combination.

It may be concluded that BARI mung 6 along with spacing 20 cm × 20 cm gave maximum seed yield which was 77.8% higher than control.

Recommendations:

Considering the results of the present experiment, further studies in the following areas may be suggested-

- Such study needs to be repeated in different agro-ecological zones (AEZ) of Bangladesh for the evaluation of regional adaptability,
- Other cultivars may be used for further study, and
- Different spacing arrangements may be used for further study.

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APPENDICES

Appendix I. Morphological characteristic of the soil of experimental field

Morphological characteristics of the soil of experimental field

Morphological features	Characteristics
Location	Experimental 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
Flood level	Above flood level
Drainage	Well drained

Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
%Silt	43
%Clay	30
Textural class	Silty-clay
pH	6.1
Organic matter (%)	1.13
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100g soil)	0.10
Available S (ppm)	23

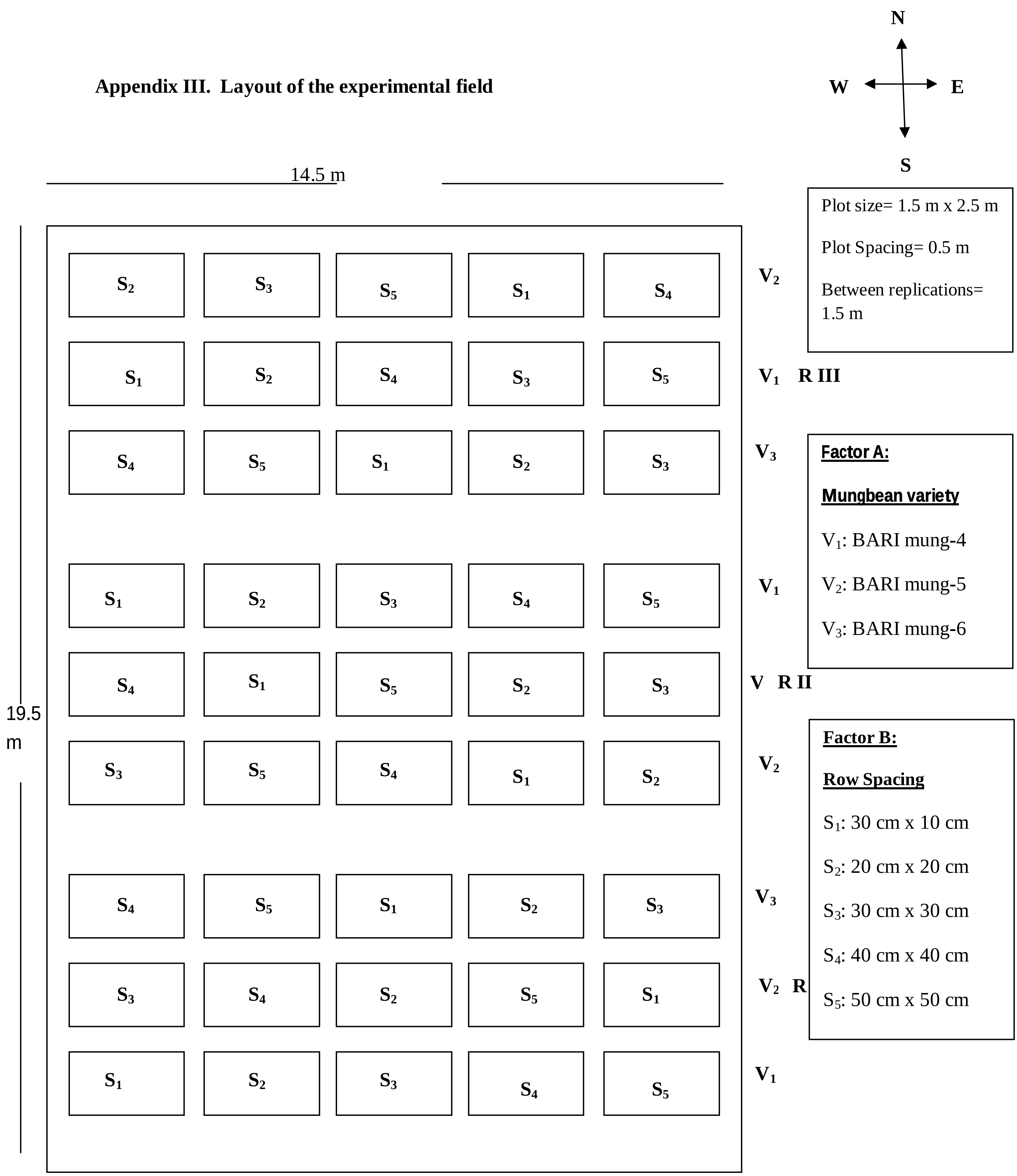
Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

Appendix II. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from March to June 2015

Month (2015)	Air temperature (degrees Celsius)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
March	32.10	20.56	45.11	4
April	32.79	23.38	63.48	166
May	34.07	25.42	67.83	185
June	32.75	26.70	74.57	375

Source: Bangladesh Meteorological Department (Climate & Weather division), Agargaon, Dhaka- 1212

Appendix III. Layout of the experimental field



Appendix IV. Analysis of variance of the data on plant height of mungbean as influenced

by different cultivars, planting geometry and their interaction

Source of variation	Degrees of freedom	Mean square			
		Plant height (cm) at			
		15 DAE	30 DAE	45 DAE	60 DAE
Replication	2	2.49	1.62	8.18	76.14
Factor A (cultivar)	2	9.81*	25.39*	28.616*	259.36*
Error	4	0.62276	1.3830	3.081	35.035
Factor B (Spacing)	4	8.48*	39.06*	106.65*	204.10*
Interaction (A x B)	8	0.33*	0.71*	2.97*	6.77*
Error	24	0.31	0.70	0.57	6.22

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

Appendix V. Analysis of variance of the data on number of branches of mungbean as influenced by different cultivars, planting geometry and their interaction

Source of variation	Degrees of freedom	Mean square		
		Number of branches at		
		30 DAE	45 DAE	60 DAE
Replication	2	0.71667	0.18600	0.77222
Factor A (cultivar)	2	0.46667*	0.07400^{NS}	0.19822^{NS}
Error	4	0.07033	0.10900	0.28222
Factor B (Spacing)	4	3.32756*	6.30300*	9.06256*
Interaction (A x B)	8	0.14389*	0.10150*	0.23156*
Error	24	0.17661	0.12467	0.22306

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

Appendix VI. Analysis of variance of the data on dry matter content of mungbean as influenced by different cultivars, planting geometry and their interaction

Source of variation	Degrees of freedom	Mean square			
		Dry matter (gm) at			
		15 DAE	30 DAE	45 DAE	60 DAE
Replication	2	0.02805	0.899	2.4332	29.251
Factor A (cultivar)	2	0.60099*	0.813*	26.7561*	3.395*
Error	4	0.02299	2.368	13.3645	8.960
Factor B (Spacing)	4	4.78106*	121.455*	87.0018*	101.462*
Interaction (A x B)	8	0.33947*	3.632*	4.1006*	2.421*
Error	24	0.02404	0.763	2.2814	2.146

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

Appendix VII. Analysis of variance of the data on number of nodules of mungbean as influenced by different cultivars, planting geometry and their interaction

Source of variation	Degrees of freedom	Mean square		
		Number of nodules at		
		30 DAE	45 DAE	60 DAE
Replication	2	0.7980	0.4667	4.21400
Factor A (cultivar)	2	14.5627*	4.6887^{NS}	3.22067*
Error	4	0.3887	0.9003	0.35667
Factor B (Spacing)	4	30.4511*	49.9124*	2.10978^{NS}
Interaction (A x B)	8	1.5238*	0.5248*	1.49344*
Error	24	0.3996	0.4213	1.21189

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

Appendix VIII. Analysis of variance of the data on yield contributing characters and yield of mungbean as influenced by different cultivars, planting geometry and their interaction

Source of variation	Degrees of freedom	Mean square						
		Pods per plant	Pod length (cm)	Seed per pod	Weight of 1000 seeds (g)	Seed yield (t/ha)	Stover yield	Harvest index (%)
Replication	2	103.62	1.27780	1.69334	1.500	0.00454	0.02375	7.267
Factor A (Cultivar)	2	1222.65*	2.70988*	1.78884*	141.120*	0.04278*	0.20478*	2.867^{NS}
Error	4	132.90	0.18264	0.24763	0.363	0.00594	0.07242	7.433
Factor B (Spacing)	4	410.69*	8.60212*	6.87711*	108.940*	0.61998*	1.46099*	212.389*
Interaction (A x B)	8	52.56*	1.41288*	0.20108*	21.315*	0.03206*	0.08052*	6.756*
Error	24	20.26	0.11489	0.09396	0.572	0.00342	0.01680	5.433

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