GROWTH AND YIELD OF MUNGBEAN AS AFFECTED BY PLANT DENSITY AND METHODS OF WEED CONTROL

SABBIR MAHMUD JOARDER

DEPARTMENT OF AGRONOMY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

DECEMBER, 2014

GROWTH AND YIELD OF MUNGBEAN AS AFFECTED BY PLANT DENSITY AND METHODS OF WEED CONTROL

BY

SABBIR MAHMUD JOARDER

REG. NO. : 08-03145

A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)
IN
AGRONOMY

SEMESTER: JULY-DECEMBER, 2014

APPROVED BY:

Prof. Dr. Md. Hazrat Ali	**Prof. Dr. H. M. M. Tariq Hossain**
Supervisor	**Co-Supervisor**
Department of Agronomy	Department of Agronomy

Prof. Dr. Md. Fazlul Karim
Chairman
Examination Committee

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled **'Growth and Yield of Mungbean as Affected by Plant Density and Methods of Weed Control'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science** in **Agronomy**, embodies the result of a piece of *bonafide* research work carried out by **Sabbir Mahmud Joarder**, Registration number: **08-03145** 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:
Dhaka, Bangladesh

Prof. Dr. Md. Hazrat Ali
Department of Agronomy
Sher-e-Bangla Agricultural University
Dhaka-1207

DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises are due to the Almighty Allah, Who has enabled author to complete the research work and to prepare this thesis for the degree of Master of Science in Agronomy.

The author expresses his heartfelt respect, deepest sense of gratitude and immense indebtedness to his esteemed Supervisor **Dr. Md. Hazrat Ali**, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh for his scholastic guidance, support, encouragement, valuable suggestions and constructive criticism throughout the study period and gratuitous labor in conducting and successfully completing the research work and in the preparation of the manuscript writing including data analysis.

The author also expresses his profound gratitude and indebtedness to honorable Co-Supervisor **Dr. H. M. M. Tariq Hossain**, Professor, Department of Agronomy, SAU, Dhaka for his scholastic guidance, helpful comments and constant inspiration, inestimatable help, valuable suggestions throughout the research work and in preparation of the thesis.

The author sincerely expresses his gratefulness, sincere appreciation and heartiest indebtedness to all the teachers of the Department of Agronomy, SAU, for their valuable suggestions, instructions, cordial help and encouragement during the period of the study.

The author also thankful to all the staff members of Agronomy Department, SAU, Dhaka for their help and cooperation during the experimental period.

The author also expresses sincere appreciation to his brothers, sisters, relatives, well wishers and friends especially Asif, Jewel, Rafiq, Shaheen, Kallol, Tarek, Sukhan and Amit for their inspiration, help and encouragement throughout the study period.

The Author

GROWTH AND YIELD OF MUNGBEAN AS AFFECTED BY PLANT DENSITY AND METHODS OF WEED CONTROL

ABSTRACT

The experiment was conducted at the Agronomy Research Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from April to June, 2014 to find out the growth and yield of mungbean as affected by plant density and methods of weed control. The experiment comprised of two factors; Factor A: Plant density (4 levels)- D_1- 30 cm × continuous, D_2- 30 cm × 5 cm, D_3- 30 cm × 10 cm and D_4- 30 cm × 15 cm; Factor B: Methods of weed control (4 levels)- 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 & 30 DAS). The varieties 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. For plant density, at 20 DAS, the maximum numbers of weed population m^{-2} (7.67) were recorded in D_4 and the minimum (6.08) was recorded in D_1. At 40 DAS, the maximum numbers of weed population m^{-2} (14.00) were recorded in D_1, while the minimum (11.50) was recorded in D_3. The highest number of pods $plant^{-1}$ (18.92), the highest seed yield (1.36 t ha^{-1}) and the highest stover yield (1.75 t ha^{-1}) were observed from D_3, while the lowest number of pods $plant^{1}$ (15.02), the lowest seed yield (1.13 t ha^{-1}) and the lowest stover yield were recorded (1.56 t ha^{-1}) was recorded from D_1. In case of methods of weed control, at 20 and 40 DAS the maximum numbers of weed population m^{-2} (15.92 and 26.58) were found in W_0, while the minimum (3.50 and 7.00) in W_3. The highest number of pods $plant^{-1}$ (18.82), highest seed yield (1.39 t ha^{-1}) and highest stover yield (1.85 t ha^{-1}) were recorded from W_2, again the lowest number of pods $plant^{-1}$ (13.72), lowest seed yield (1.06 t ha^{-1}) and lowest stover yield (1.36 t ha^{-1}) were found from W_0 treatment. Due to the interaction effect of different plant density and methods of weed control at 20 DAS, the maximum number of weed population m^{-2} (16.67) was found from D_4W_0, while the minimum (2.33) from D_1W_3 treatment combination. At 40 DAS, the maximum number of weed population m^{-2} (28.33) was found from D_1W_0, while the minimum (6.00) from D_3W_2. The highest number of pods $plant^{-1}$ (20.63), highest seed yield (1.47 t ha^{-1}) and highest stover yield (1.94 t ha^{-1}) were recorded from D_3W_2 and the lowest number of pod $plant^{-1}$ (12.03), lowest seed yield and (1.02 t ha^{-1}) and lowest stover yield (1.28 t ha^{-1}) were found from D_1W_0. Plant density of 30 cm × 10 cm and pre-emergence herbicide application (application of Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS) can be more beneficial for the farmers to get maximum yield from the cultivation of BARI Mung-6.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

Mungbean (*Vigna radiata* L.) belonging to family Leguminosae 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). It is an important pulse crop of Bangladesh and ranks the third in protein content and fourth position considering both acreage and production (MoA, 2014). It grows well all over the country except the district of Rangamati. Mungbean is a cheap source of easily digestible dietary protein which complements the staple rice in the country. It's seed contains 24.7% protein, 0.6% fat, 0.9 fiber and 3.7% ash (Potter and Hotchkiss, 1997). 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 1.04 t 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 (BBS, 2012). 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). Plant density and method of weed control is prerequisite for increasing the production of mungbean.

The optimum plant density is a pre-requisite for obtaining higher productivity (Rafiei, 2009). Seed yield and yield components of mungbean are markedly influenced by planting density. Plant density affects the plant growth as well as grain yield in mungbean (Jahan and Hamid, 2004). The farmers of our country usually grow mungbean without maintaining proper planting density. Plant density may vary with genotype, time of sowing, growing condition etc. (Sekhon *et al*., 2002). Plant population may not only be defined in terms of number of plants unit^{-1} area (plant density) but also in terms of arrangement of plants on the ground (Kaul and Singh, 2002). The farmers of our country hesitate to grow mungbean in rows, although row planting facilitates easy intercultural operations resulting in higher yield (BARI, 2005). The optimum plant population can be maintained by using adequate seed rate. Regan *et al*. (2003) reported that economic plant density helps in estimating the most profitable seed rate. Row planting with appropriate planting density can help ensure optimum plant population unit^{-1} area of mungbean thereby increasing the yield (BARI, 1998). Various works on spacing of mungbean showed the optimum in plant spacing gave maximum yield (Mondal, 2007; Mansoor *et al*., 2010). The optimum spacing favors the plants to grow in their both aerial and underground parts through efficient utilization of solar radiation and nutrients and thus increase grain yield of mungbean (Miah *et al*., 1990).

Weed is one of the most important factors responsible for low yield of mungbean. The decrease in mungbean productivity due to weed competition is 45.6% (Pandey and Mishra, 2003). Mungbean is very competitive against weed and therefore weed control is essential for mungbean production. Weeds compete with main crop for space, nutrients, water and light. It is also recognized that a low weed population can be beneficial to the crop as it provides food and habitat for a range of beneficial organisms (Bueren *et al.*, 2002). Dry weight of weed increased as the duration of weed competition increased in crop (Islam *et al.,* 1989). Weed crop competition commences with germination of the crop and continues till its maturity. Several Growth stages of mungbean such as emergence, flowering and pod setting are greatly hampered by weed. Weed infestation of these stages causes low pod setting and ultimately yield reduces. Weeds above critical population thresholds can significantly reduce crop yield and quality. Weed problem is becoming more and more acute. Weeds have been reported to harbor the viruses and act as a primary source of inoculums, which causes high incidence of virus-like symptoms. However, the aim of weed management should be to maintain weed population at a manageable level with minimum cost. Timely and economically control of weeds is essential for high yield in mungbean. Significantly more seed yields by weeding have been reported in mungbean by many researchers (Kumar and Kairan, 1990 and Musa *et al*., 1996).

Under the above mention situation and context, the present experiment was conducted to find out the growth and yield of mungbean as affected by plant density and methods of weed control with the following objectives:

- Examine the effect of plant density and methods of weed control on the plant characters, yield and yield attributes of mungbean;
- Compare the efficiency of different weed control methods on the yield of mungbean;
- Study the interaction effect of plant density and weed control methods on the growth and yield of mungbean.

Chapter 2

Review of literature

CHAPTER 2

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 plant densities and methods of weed control play an important role in improving mungbean yield. But research works related to plant densities and methods of weed control 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 the plant densities and methods of weed control in mungbean so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Effects of plant density on growth and yield of mungbean

2.2.1 Plant height

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 tallest plants at all the sampling dates were found in the 30 plants m^{-2}.

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

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

Hassan (2000) reported that in mungbean, plant density and plant height was increased up to 30 kg seed ha^{-1} and plant height also decreased with consequent decrease in seed yield.

El-Habbasha *et al.* (1996) reported that increasing plant density increased plant height but decreased branch number. Tomar and Tiwari (1996) found that plant population (range 300,000-400,000) had no significant effect on plant height.

Plant population has remarkable effect on plant height as reported by many researchers. Singh and Singh (1995) carried out an experiment with four mungbean varieties at 20, 25 and 30 kg ha^{-1} and found that plant height increased with increasing seed rates. Similar result was also reported by Borah (1994) through conducting an experiment with mungbean genotypes sown at 20, 30 and 35 kg ha^{-1}.

Thakuria and Saharia (1990) reported that plant height increased with increasing number of plant population up to 330,000 plants ha^{-1} and further increased plant population will decreased plant height in mungbean.

2.2.2 Number of pods

Zaher *et al.* (2014) conducted an experiment with four row spacing (S_1 = 15 cm, S_2 = 20 cm, S_3 = 25 cm and S_4 = 30 cm) and four weeding treatments (W_0 = No 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 $plant^{-1}$ (43.29) was gained by 30 cm row spacing with three times of weeding.

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

Hassan (2000) reported that different seed rates influenced the pod production significantly. The greater number of pods $plant^{-1}$ was observed in lower seed rates of 20 kg ha^{-1} over 25 and 30 kg ha^{-1}. Similarly, Chowdhury (1999) reported that the number of pods $plant^{-1}$ decreased with increasing plant density in mungbean.

The increasing planting density generally decreased the number of pods as well as grains $plant^{-1}$ as reported by BINA (1998) and Hague (1995). Singh and Singh (1995) obtained the highest number of pods $plant^{-1}$ at lower seed rate than those of higher seed rates. Borah (1994) reported that the number of pods $plant^{-1}$ decreased with increasing seed rate but total number of pods per unit area increased with increasing seed rate up to certain levels.

2.2.3 Pod length

Zaher *et al.* (2014) conducted an experiment with four row spacing (S_1 = 15 cm, S_2 = 20 cm, S_3 = 25 cm and S_4 = 30 cm) and four weeding treatments (W_0 = No 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 observed the highest pod length (6.69 cm) from 30 cm row spacing with three times of weeding.

Mansoor *et al*. (2010) carried out an experiment with row spacings and seed rates and reported that pod length were significantly affected by various seed rates and the pods with maximum length were recorded in plots having 20 cm row spacing and 20 kg ha^{-1}.

Singh *et al.* (2003) conducted an experiment to determine the effect of three seed rates (15, 20 and 25 kg ha^{-1}) on mungbean and reported that seed rate had no significant influenced on pod length. Similar result was reported by Chowdhury (1999) in mungbean who reported that seed rate had no influenced on pod length because of grain size is mainly controlled by gene not by environment.

BINA (1998) conducted an experiment with mungbean to know the effect of seed rate on yield and yield related traits and reported that seed rate had slight effect on pod size. The pod length was greater in low seed rate (25 kg ha^{-1}) than in higher seed rate (30-40 kg ha^{-1}) but non-significant with each other.

Singh and Singh (1995) observed that seed rates had no significant effect on pod length in mungbean. Singh *et al.* (1991) found that seed rates had effect of pod size and reported that pod length decreased with increasing seed rate in mungbean. Similar result was also reported by Singh *et al.* (1985) who reported that pod length was greater in low seed rate than in high seed rates in mungbean.

2.2.4 Number of seeds pod^{-1}

Zaher *et al.* (2014) conducted an experiment with four row spacing (S_1 = 15 cm, S_2 = 20 cm, S_3 = 25 cm and S_4 = 30 cm) and four weeding treatments (W_0 = No 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 recorded the highest number of seeds pod^{-1} (9.43) was recorded by 30 cm row spacing with three times of weeding.

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

Chowdhury (1999) reported that the number of seeds pod^{-1} decreased with increasing plant density in mungbean. The greater number of seeds pod^{-1} was observed with lower seed rates of 20 kg ha^{-1} over 25 and 30 kg ha^{-1}. The increasing planting density generally decreased the number of seeds pod^{-1} but total number of seeds per unit area increased with increasing plant density as reported Miranda *et al.* (1997) in mungbean.

Borah (1994) reported that the number of seeds pod^{-1} decreased with increasing seed rate but total number of seeds per unit area increased with increasing seed rate up to certain levels.

Thakuria and Saharia (1990) conducted a field trial with two mungbean cultivars grown @ 222,000 and 330,000 plants ha^{-1} and observed that wider spacing plants produced greater number seeds pod^{-1} than closer spacing.

Singh and Singh (1988) conducted an experiment involving 4 mungbean cultivars at a density of 400,000, 500,000 and 600,000 plants ha^{-1} and reported that different plant densities gave similar average number of seeds pod^{-1}. The increasing planting density generally decreased the number of seeds pod^{-1} but total number of seeds per unit area increased with increasing plant density as reported by Panwar and Sirohi (1987) in mungbean.

2.2.5 1000-seed weight

Zaher *et al.* (2014) conducted an experiment with four row spacing (S_1 = 15 cm, S_2 = 20 cm, S_3 = 25 cm and S_4 = 30 cm) and four weeding treatments (W_0 = No 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. Results showed that the highest 1000 seed weight (30.49 g) was gained by 30 cm row spacing with three times of weeding.

Mansoor *et al*. (2010) carried out an experiment with row spacings and seed rates and reported that 1000-seed weight were significantly affected by various seed rates as well as plant population.

Hassan (2004) observed that 1000-grain weight was not influenced by seed rate. Similar result was reported by Singh *et al.* (2003) who reported that plant spacing had no influence on grain size because of grain size is mainly controlled by gene not by environment.

Chowdhury (1999) found that seed rate had effect on grain size and reported that 1000 grain weight decreased with increasing seed rate in mungbean. Similarly, BINA (1998) and Tomar and Tiwari (1996) reported that seed rate had no significant effect on 1000-seed weight in mungbean.

Pookpakdi and Pataradilok (1993) conducted an experiment with mungbean to know the effect of plant population on yield and yield related traits and reported that plant population had slight effect on seed size.

2.2.6 Total dry mass production

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 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}).

Mansoor *et al*. (2010) carried out an experiment with row spacings and seed rates and reported that dry matter content in plant was significantly affected by various seed rates as well as plant population.

Singh *et al.* (2003) conducted an experiment to determine the effects of seed rates (15, 20 and 25 kg ha^{-1}) on yield and yield related traits in mungbean and reported that dry matter content increased with increasing seed rate in mungbean.

El-Habbasha *et al.* (1996) conducted an experiment covering two crop seasons and concluded that increasing plant density decreased dry mass production $plant^{-1}$.

Panwar and Sirohi (1987) studied the effect of plant population on grain yield and its components in mungbean and found that DM production ha^{-1} increased with increasing plant density in all cultivars whereas DM and yield $plant^{-1}$ decreased in all cultivars.

Trung and Yoshida (1985) worked with three mungbean cultivars and three plant densities of 25, 35 and 45 plants m^{-2} and found that increasing plant density increased DM production per unit area but decreased DM $plant^{-1}$.

2.2.7 Seed yield

Zaher *et al.* (2014) conducted an experiment with four row spacing (S_1 = 15 cm, S_2 = 20 cm, S_3 = 25 cm and S_4 = 30 cm) and four weeding treatments (W_0 = No 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. Results revealed that 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.

Mansoor *et al*. (2010) carried out an experiment with row spacings and seed rates and reported that grain yield were significantly affected by various seed rates.

Kabir and Sarkar (2008) carried out an experiment to study the effect of variety and planting density on the yield of mungbean in *Kharif*-I season. The experiment comprised five varieties viz. BARIMung-2, BARIMung-3, BARIMung-4, BARIMung-5 and BINAMung-2 and three spacing of planting viz. 30 cm × 10 cm, 20 cm × 20 cm and 40 cm × 30 cm. 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.

Plant density of mungbean may play an important role in interception of solar radiation, which might increase the yield. Many mungbean researchers mentioned that plant density had tremendous effect on growth and yield of mungbean. Singh *et al.* (2003) set up an experiment to determine the effects of seed rates (15, 20 and 25 kg ha^{-1}) on yield and yield related traits in mungbean and reported that seed yield increased with increasing seed rate in mungbean.

Miranda *et al.* (1997) carried out a field trial using five plant population of 100,000, 200,000, 300,000, 400,000 and 500,000 plants ha^{-1} and found that 300000 plants ha^{-1} had the greater seed yield than the others plant densities.

Tomar *et al.* (1996) worked with other variety to know the effect of seed rate (20, 30 and 40 kg ha^{-1}) on seed yield and observed that seed yield and net return of mungbean was higher with seed rate of 40 kg ha^{-1} than those with seed rate of 20 and 30 kg ha^{-1} despite pods plant^{-1} was higher in 20 and 30 kg ha^{-1}.

Tomar *et al.* (1995) reported that the highest seed yield of mungbean was recorded at a seed rate of 20 kg ha^{-1} and was decreased with increasing seed rate (30 or 40 kg ha^{-1}) due to lesser number of pods plant^{-1} in mungbean *cv.* K-85.

Singh and Singh (1995) conducted a field experiment at Pantnagar, Uttar Pradesh, India using four cultivars of mungbean sown at 20, 25 and 30 kg ha^{-1} and found that yield was increased with increasing seed rate due to increasing number of pod production per unit area. Similar type of result was reported by Hague (1995) who using populations of 250,000, 333,333, 400,000 or 500,000 plants ha^{-1} and found that 333,333 plants ha^{-1} gave the highest seed yield.

Borah (1994) conducted a field experiment to study the performance of green gram genotypes under different seed rates (20, 30 and 35 kg ha^{-1}) during summer season and found that seed yield increased with increasing seed rate i.e. the highest seed yield was recorded in 35 kg ha^{-1}.

Pookpakdi and Pataradilok (1993) investigated the response of genotypes of mungbean on plant population densities sown at 200,000, 400,000 and 800,000 plants ha^{-1} and observed that yield increased with increasing density. Tomar *et al.* (1993) used four cultivars to investigate the effect of seed rates (400,000, 600,000, 800,000 or 1000,000) and found that a population of 1000,000 plants ha^{-1} gave higher seed yield than the other plant populations.

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}.

Panwar and Sirohi (1987) studied the effect of plant population on grain yield and its components in mungbean. They used four cultivars and two plant populations (300,000 and 400,000 plants ha^{-1}) of mungbean and reported that seed yield increased with increasing plant density in all cultivars despite yield attributes $plant^{-1}$ decreased.

Singh *et al.* (1985) reported that different seed rates influenced the seed yield significantly. The higher grain yield obtained with 50 kg seed ha^{-1} over 20, 30 and 40 kg ha^{-1} could be attributed to more number of plants per unit area.

2.2.8 Harvest index

Zaher *et al.* (2014) conducted an experiment with four row spacing (S_1 = 15 cm, S_2 = 20 cm, S_3 = 25 cm and S_4 = 30 cm) and four weeding treatments (W_0 = No 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. The highest harvest index (44.26%) was achieved by 25 cm row spacing with two times of weeding.

Mansoor *et al*. (2010) carried out an experiment with row spacings and seed rates and reported that harvest index % were significantly affected by various seed rates and maximum harvest index % was recorded in plots with 40 cm row spacing and 20 kg ha^{-1}.

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}).

Singh *et al.* (2003) carried out an experiment to determine the effects of seed rates (15, 20 and 25 kg ha^{-1}) on yield and yield related traits in mungbean and reported that seed rates significantly influenced harvest index of mungbean.

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.

Harvest index is a measure of the efficiency of conversion of photosynthate into economic yield of a crop plant (Gautom and Sharma, 1987). Increased harvest index results in increased crop yield, probably because of improved partitioning of dry matter to reproductive parts.

2.2 Effects of methods of weed control on growth and yield of mungbean

2.2.1 Effect of weeding on morphological characters of mungbean

An experiment was conducted by Akter *et al*. (2013) at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh to assess the effect of weeding on growth, yield and yield contributing characters of mungbean *(Vigna radiata* L.) *cv.* BINA mung-4. The trial comprised seven treatments namely, T_1 = no weeding, T_2 = one-stage weeding (Emergence-Flowering), T_3 = one-stage weeding (Flowering-Pod setting), T_4 = one-stage weeding (Pod setting-Maturity), T_5 = two-stage weeding (Emergence-Flowering and Flowering-Pod setting), T_6 = two-stage weeding (Flowering-Pod setting and Pod setting-Maturity) and T_7 = three-stage weeding (Emergence-Flowering and Flowering-Pod setting and Pod setting-Maturity). Three-stage weeding ensured the highest plant height (58.62 cm) as well as the highest number of branches (4.45) and leaves (10.34) plant^{-1}.

Mungbean showed significant increase in plant height and number of pods plant^{-1}. Increase in plant height and number of pods plant^{-1} is inversely proportional to weeds density and dry weight and similar is the case with the number of grains pod^{-1}. Production capacity of mungbean can be determined by the number of pods plant^{-1} (Khan *et al.*, 2008). Data indicated that with the decrease in weeds biomass number of pods plant^{-1} increased.

All crops have a stage during their life cycle when they are particularly sensitive to weed competition. In general, it ranges up to first 25 to 50% of the life time of crops. In Bangladesh, there is a general believed that mungbean does not require any weeding. Hence, the farmers of this country do not use any weed control measure in mungbean field so the problem of weeds and their management such as time of wedding and frequency of weeding is difficult. When the seed bed is not thoroughly prepared and the weeds removed. Weed control is essential during the early growth stage of mungbean. One hand weeding is absolutely essential 20 days after planting and two weeding are economical for successful mungbean production (BARI, 2005).

Khaliq *et al*. (2002) investigated the efficacy of different weed management strategies in mungbean and stated that hoeing treatments resulted in reduced weed dry weight by 79% compared to control and maximum plant height. The decrease in yield in plots with 45 and 60 cm row spacing + tractor might be due to intra-specific plant competition. As we increase row spacing, plant to plant spacing ultimately decreases which initiates competition between the plants which may affect the yield.

Bayan and Saharia (1996) carried out an experiment to Study the weed management and phosphorus on green gram during the *kharif* seasons. They indicated that effective weed management could be achieved with one hand weeding at 20 DAS. Weed free and hand weeding at 20 DAS resulted in a significant increase in plant dry matter compared with no weeding. They also showed that branches plant^{-1}, pods plant^{-1} and seed yields were significantly influenced by weed management.

Sangakkara *et al.* (1995) observed that the adverse effect of weeds was greatest on vegetative growth. The influence on yield components decreased with time. The study indicated vegetative phase as the critical competitive period^{-1}.

The maximum plant height, maximum number of pods plant^{-1} and the highest grain yield were obtained from weed free treatment and the lowest from no weeding control (Naseem, 1982).

2.2.2 Effect of weeding on dry weight of mungbean

An experiment was conducted by Akter *et al*. (2013) at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh to assess the effect of weeding on growth, yield and yield contributing characters of mungbean *(Vigna radiata* L.) *cv.* BINA mung-4. The trial comprised seven treatments namely, T_1 = no weeding, T_2 = one-stage weeding (Emergence-Flowering), T_3 = one-stage weeding (Flowering-Pod setting), T_4 = one-stage weeding (Pod setting-Maturity), T_5 = two-stage weeding (Emergence-Flowering and Flowering-Pod setting), T_6 = two-stage weeding (Flowering-Pod setting and Pod setting-Maturity) and T_7 = three-stage weeding (Emergence-Flowering and Flowering-Pod setting and Pod setting-Maturity). Dry weight plant^{-1} (12.38 g) was highest from three stage weeding and the lowest from no weeding treatment.

Dry weight of weeds is a better criterion of weed crop competition than weeds density; higher fresh and dry weight of weeds reflects more utilization of soil and environmental resources. Data of weeds density, fresh and dry weight in all weed control treatments showed significant decrease as compared to control. These results are in accordance with the findings of Naeem *et al.* (2000) who reported decrease in weeds dry weight resulted in tillage operations.

Ahmed *et al.* (1987) observed that maximum reduction in weed infestation was recorded following their removal at 15 and 30, 30 and 45, and 15, 30 and 45 DAS. Weed removal at 15 and 30, 30 and 45 or 15, 30 and 45 facilitated the production of higher dry matter.

Enyi (1973) suggested that in mungbean weeding 2 weeks after sowing was significantly superior to that at either 4 or 8 weeks after sowing. Plants in the plots weeded 5 weeks after sowing and in the unweeded plots had few or no branches. Late weeding and no weeding reduced the proportion of dry matter diverted into the side stems. The number of pods plant^{-1} at harvest was the highest (30) in the plots where two weeding, 2 and 4 weeks after sowing were done and was the lowest in the unweeded plots.

2.2.3 Effect of weeding on yield and yield component of mungbean

An experiment was conducted by Akter *et al*. (2013) at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh to assess the effect of weeding on growth, yield and yield contributing characters of mungbean *(Vigna radiata* L.) *cv.* BINA mung-4. The trial comprised seven treatments namely, T_1 = no weeding, T_2 = one-stage weeding (Emergence-Flowering), T_3 = one-stage weeding (Flowering-Pod setting), T_4 = one-stage weeding (Pod setting-

Maturity), T_5 = two-stage weeding (Emergence-Flowering and Flowering-Pod setting), T_6 = two-stage weeding (Flowering-Pod setting and Pod setting-Maturity) and T_7 = three-stage weeding (Emergence-Flowering and Flowering-Pod setting and Pod setting-Maturity). The highest number of pods (22.03) plant^{-1}, the longest pod (5.95 cm), the highest number of seeds (17.07) pod^{-1} and the highest seed yield (1.38 t ha^{-1}) were obtained from three-stage weeding (Emergence-Flowering and Flowering-Pod setting and Pod setting-Maturity) in mungbean. On the other hand, the lowest seed yield was obtained under no weeding condition. The highest seed yield resulted in higher biological yield (4.70 t ha^{-1}) and the highest harvest index (37.15%) in three-stage weeding and the lowest from no weeding.

Kundu *et al*. (2009) carried out an experiment to find out the effect of different weed management practices in mungbean and recorded the maximum crop yield was obtained in the treatment receiving quizalofop-p-ethyl 50 g a.i. ha^{-1} at 21 day after emergence (DAE) + hand weeding (HW) at 28 DAE. This was closely followed by the treatment with quizalofop-p-ethyl 50 g a.i. ha^{-1} at 14 DAE + HW at 21 DAE. Weedy check treatment produced lowest yield of mungbean.

Pulses for long time have been grown with poor management practices resulting in poor yields. Proper seed bed, land preparation and weeding are important for adequate germination of seed, crop establishment and good yields. Weeds infestation is one of the major factors lowering yield in pulses in Pakistan (Rehman and Ullah, 2009).

Chattha *et al*. (2007) conducted a field study at National Agricultural Research Centre (NARC), Islamabad to determine the effect of different weed control methods on the yield and yield components of mungbean (*Vigna radiata* L.). In this study different weed control methods (chemical, mechanical, hand-weeding & their integration) were compared for their efficiency to control various weed species under rain-fed conditions of Pakistan. Result revealed that a significant increase (50%) in grain yield of mungbean due to chemical weeding at 2 - 3 leaf stage of weeds + hand-weeding at 50 DAS. Similarly, this treatment out yielded other treatments in terms of number of pods per plant, number of seeds per pod, 1000 grain weight, grain yield.

Mitra and Bhattacharya (2005) reported that application of butachlor along with one hand-weeding (35 days after sowing) resulted in maximum mungbean biomass, yield attributes, seed yield and water use efficiency of the crop along with effective weed suppression. About 69% reduction in mungbean seed yield due to weeds was estimated by Yadav and Singh (2005).

Thousand grain weight was also increased with reduction in weeds dry biomass and found to be maximum (55.0 g) in plots with row spacing 60 cm + tractor followed by 54.67 g in plots with row spacing of 45 cm + tractor. Similarly, it was 51.67 g in case of hand weeding, 51.33 g in *terphali* driven plots and 50.67 g in case of control. These findings were in line with the previous research conducted by Cheema and Akther (2005) who found that 1000-seed weight increased with reduced weed infestation.

Difference in the number of seed might be due to weed suppression which resulted in more translocation and assimilation of photosynthates towards grain formation (Borras *et al.,* 2004). Pod length was recorded maximum in plots where treatments were *terphali* (9.9 cm) and hand weeding (9.7cm); while in plots with 45cm row spacing + tractor and 60cm + tractor, pod length was 9.2 cm and 9.6 cm, respectively compared to control (9.0 cm). This might be due to weed suppression which resulted in more translocation and assimilation of photosynthates towards reproductive growth (Borras *et al.,* 2004).

Seed yield also increased up to 201% using different row spacing and weed control treatments. Increase in grain yield was 100% where weeds were controlled through tractor using 60 cm row spacing and increase in grain yield was about 85% in case of hand weeding and 45 cm row spacing + tractor compared to control. These results were in accordance with Hassan *et al.* (2003) who reported higher grain yield in tillage plots with low weed density compared to control.

Mania e*t al*. (2002) stated that root competition inhibited root proliferation. All else equal, plant should proliferate roots in a nutrient patch devoid of roots rather than one already occupied by roots and this overlapping of roots cause competition among the plants either of the same crop or different.

Lowest number of pods was recorded in weedy check and maximum number of pods was recorded in the plots where weeds were minimum. These results are in certainty with Cheema *et al.* (2000) who reported that the increase in grain yield may be attributed to regulation of plant height and weed control in improving number of pods plant^{-1} and number of seeds pod^{-1}. Minimum number of seed pod^{-1} was recorded in weedy check which was significantly lower in all weed control treatments.

According to Raklia (1999) more weed suppression provides better crop growth for more grain formation. Tessema and Taneer (1997) reported number of grains was affected due to weed infestation.

Jha *et al.* (1997) conducted a field experiment to study the crop weed associations in mungbean and determine the occurrence and frequency distribution of weed species at different time intervals the crop season. They showed that mungbean should be kept weed free during the first 43 days of sowing.

Singh *et al.* (1996) carried out a field experiment on green gram cultivar K851 to determine the crop weed competition in summer green gram and they found that seed yield was decreased by 35% when the crop was infested for the first 30 DAS. Yield increased with increase in weed free duration to the first 45 DAS (0.81 t ha^{-1} compared with 0.88 t ha^{-1} in free plots.

A field experiment was conducted by Singh *et al.* (1996) to study the crop weed competition in summer green gram. They found that grain yield of summer mungbean was reduced by 34.88% due to competition with weed during the first 30 DAS, which increased up to 49.15% when weeds competed with crop for the entire crop season. Seed yield was increased when the initial weed free duration was extended up to 45 days and a further increased in the duration of weed free had no beneficial effect on grain yield. The first 45 days was considered to be the critical period with respect to weed-crop competition in mungbean branches plant^{-1}, pods plant^{-1} and seed yields were significantly influenced by weed management.

By working with different crops and different levels of weeding (at 20, 40 and 60 DAS under no weeding, one weeding at three weeks after sowing and weed free conditions). Das and Yaduraju (1996) found that the weed growth rate (WGR) increased up to 40 DAS in mungbean which was assumed to be the most critical period of weed competition in this crop.

Borah (1994) conducted a field trial at Shillongani, Assam in rainy seasons, using different weed control treatments (no weed control, hand weeding 20 or 30 DAS, or 1.5 kg pendimethalin ha^{-1}) and 0 or 50 kg diammonium phosphate ha^{-1} on mungbean cultivar ML-131. He found that the lowest weed DW at harvest was given by hand weeding 30 DAS in 1990 and 20 DAS in 1991. He also found that mean seed yields over 2 years were 0.37 t ha^{-1} without weed control, 0.72 and 0.69 t ha^{-1} with hand weeding 20 DAS and 30 DAS respectively, and 0.54 t ha^{-1} with pendimethalin.

Meylemans *et al.* (1994) conducted an experiment on the period of weed competition for black gram. They found that the critical most sensitive period for weed control was between 3 and 6 weeks after planting. Weeding before or after this period did not increase yields significantly. Unweeded plots had a yield loss up to 90% compared to weed free plots. Competition by weeds influenced establishment of plant density and number of pods plant^{-1} rather than 1000-seed weight.

A field experiment was conducted by Singh *et al.* (1993) to study the crop weed competition in summer green gram. They found that seed yield of summer mungbean was reduced by 34.88% due to competition with weed during the first 30 DAS, which increased up to 49.15% when weeds competed with crop for the entire crop season. Seed yield was increased when the initial weed free duration was extended up to 45 days and a further increase in the duration of weed free had no beneficial effect on seed yield. The first 45 days was considered to be the critical period with respect to weed-crop competition in mungbean

Talukder *et al.* (1993) reported that the highest yield (1762 kg ha^{-1}) of mungbean was obtained in plots of 33 plants m^{-2} that was weeded at emergence and the lowest yield (1137 kg ha^{-1}) in plots of 50 plants m^{-2} that remained unweeded. Delay in weeding decreased seed yield and yield attributes of mungbean but increased the dry biomass of weeds. The critical period of weed control appeared to be between 7 and 14 DAE. Unrestricted growth of weeds reduced mungbean seed yield by 30% to 33%.

While working with different weeding treatments (not weeded or weeded 1 or 3 times) and different phosphorus levels Bai and Sinha (1993) observed that weed DM yield was decreased by 3 weeding compared with 1 weeding in the first but not in the second year and weed control increased green gram seed yield in both years, with no significance difference between 1 and 3 weeding.

Hossain *et al.* (1990) reported that one hand weeding at 21 DAE was economical for mungbean production. Vaishya and Singh (1989) conducted two field experiments in 1989 and 1986 with various weed management practices on mungbean. They found that seed yield for the weed free control was similar to that obtained with (a) hand weeding 20 DAS, (b) hand weeding 20 and 40 DAS, (c) inter culture + hand weeding 20 DAS and (d) 1.0 kg bentazone ha^{-1} 20 DAS alone or in combination with hand weeding 30 DAS. They further observed that yield reduction in the unweeded control treatments were 63.5% and 38.9% in 1985 and 1986, respectively.

In a trial Uttam (1988) noticed that the yield *Phaseolus radiatus* cultivar PR74 was reduced from 112.11 to 51.16 b m^{-2} by continuous weed competition. The highest yield (125.84 g m^{-2}) was gained from continuous weed control initiated 1 week after sowing. Yield increases for weed control done up to 4 weeks after sowing did not differ significantly. He concluded that the critical time for weed control in this crop was up to 0-4 weeks after sowing. Crop biomass and plant height were not affected by weeding.

In Thailand, Pascua (1988) conducted an experiment on duration of weed control and weed competition on mungbean cultivar KPS 2. He observed that the longer was the weed competition period the greater was the reduction in mungbean yield. Treatments that gave lower fresh weed weight gave higher number of seeds pod^{-1} and longer pod.

Ahmed *et al.* (1987) reported that the highest grain yield of mungbean was obtained when the plot was weeded at 10 DAE but it did not differ significantly from the yield obtained by weeding at 20 DAE.

Sarker and Mondal (1985) showed that grain yield was reduced by 49% to 55% when weeds were allowed to grow undisturbed.

Raghvani *et al.* (1985) conducted an experiment involving three weeding treatments such as (a) weeding once at 15, 30 or 45 DAS, (b) weeding twice at 15 and 30 DAS and (c) weeding thrice at 15, 30 and 45 DAS. Results revealed that a maximum competition was there during the first 30 DAS. They also noticed that weed control during this period gave greater weed control efficiency and higher seed yields and net returns.

Agarcio (1985) reported that grain yield was the highest (511 kg ha^{-1}) cm row spacing; controlling weeds in mungbean within the first 4 weeks after sowing was shaded out by the mungbean canopy and did not reduce seed yield considerably. They concluded that 2 timely weeding during the period of critical competition resulted in optimum yield, 663.8.kg ha^{-1}, as against 782 kg ha^{-1} for weed free controls.

Yadav *et al.* (1983) conducted a field trial in the 1980 and 1981, rainy seasons using different weeding levels and observed that removing weeds at 10, 20 or 30 days after sowing mungbean gave significantly higher seed yields than unweeded control. In both the years the highest seed yields were obtained with clean weeding (88.2 and 155.7 g m^{-2}) and weeding at 20 DAS (75.9 and 144.9 g).

Musa *et al.* (1982) conducted an experiment on weed competition in summer mungbean and black gram at BARI substation at Rajbari. In both mungbean and black gram, seed yield increased considerably due to weeding. They attributed the yield to the increase in the number of pods $plant^{-1}$ and number of seeds pod^{-1}. Two weeding treatment gave maximum net benefit of mungbean.

The crop kept weed free for 60 days after sowing yielded as high as that due to weed free condition for the whole period. On the other hand, weed infestations periods longer than 30 days after sowing significantly reduced yield (AVRDC, 1981). In studies conducted in the Asian Vegetable Research and Development Center (AVRDC) mungbean was kept weed free or allowed to be infested with weeds periods ranging from 15 days after planting to the entire growing season in the spring of 1980.

Panwar and Singh (1980) observed that the average yield of gram was as low as 247 kg ha^{-1} in unweeded control plots. One hand weeding doubled the yield.

As per the above cited reviews, it may be concluded that the plant densities and methods of weed control is important factors for attaining optimum growth and as well as highest yield of mungbean. The literature revealed that the effects of plant densities and methods of weed control have not been studied well and have no definite conclusion for the production of mungbean in the agro climatic condition of Bangladesh.

Chapter 3

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted to find out the growth and yield of mungbean as affected by plant density and methods of weed control. The materials and methods that were used for conducting the experiment have been presented in this chapter. It includes a short 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 data analysis procedure.

3.1 Description of the experimental site

3.1.1 Experimental period

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

3.1.2 Description of the experimental site

The experiment was conducted at the Agronomy Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka. 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.

3.1.4 Characteristics of soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological 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 experiment comprised of two factors

Factor A: Plant densities (4 levels)

i) D_1 - 30 cm × continuous
ii) D_2 - 30 cm × 5 cm
iii) D_3 - 30 cm × 10 cm
iv) D_4 - 30 cm × 15 cm

Factor B: Methods of weed control (4 levels)

i) W_0 - No weeding (control)
ii) W_1 - Two hand weedings (at 15 and 30 DAS)
iii) W_2 - Pre emergence herbicide application (application of Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS)
iv) W_3 - Post emergence herbicide application (application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS)

There were in total 16 (4×4) treatment combinations such as D_1W_0, D_1W_1, D_1W_2, D_1W_3, D_2W_0, D_2W_1, D_2W_2, D_2W_3, D_3W_0, D_3W_1, D_3W_2, D_3W_3, D_4W_0, D_4W_1, D_4W_2 and D_4W_3.

3.2.2 Planting material

The varieties of mungbean BARI Mung-6 was used as the test crop for this study. The seeds of BARI Mung-6 were collected 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

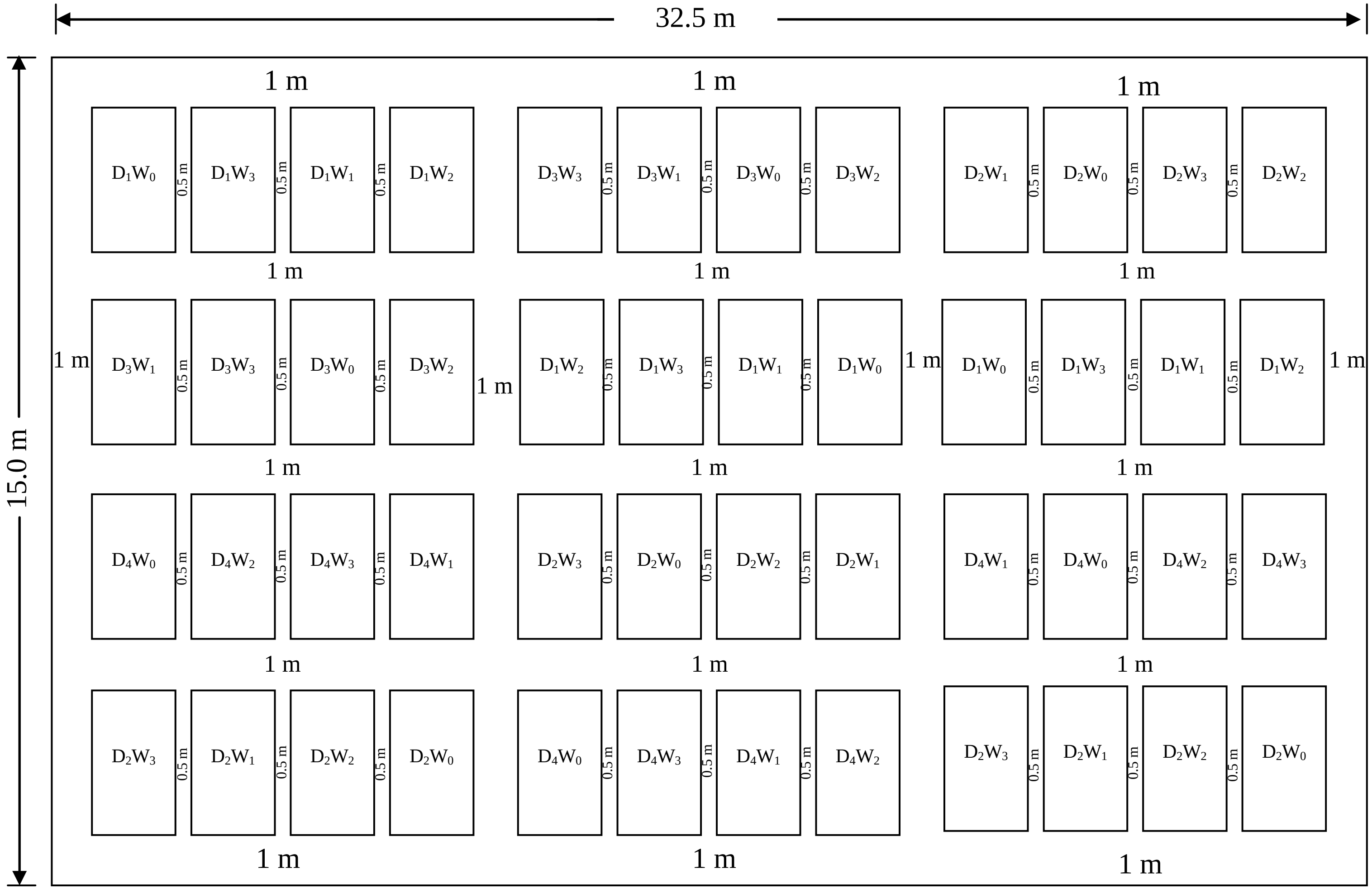
The land was first opened at 6^{th} April, 2014 with the tractor drawn disc plough. Ploughed soil was brought into desirable fine tilth by ploughing and cross-ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 15^{th} and 24^{th} April, 2014, respectively. Experimental land was divided into unit plots following the experimental design.

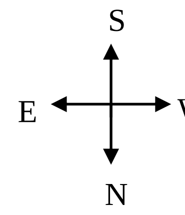
3.2.4 Fertilizer application

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, 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.

3.2.5 Experimental design and layout

The two factors experiment was laid out in split plot design with three replications. An area of 32.5 m × 15.0 m was divided into blocks. Plant densities were assigned in the main plot and four weed control methods in sub-plot. The size of the each unit plot was 2.5 m × 2.0 m. The space between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experimental plot is shown in Figure 1.





Plot size: 2.5 m × 2.0 m

Plot spacing: 0.50 m

Between block: 1.00 m

Factor A: Plant densities (4 levels)

D_1 - 30 cm × continuous

D_2 - 30 cm × 5 cm

D_3 - 30 cm × 10 cm

D_4 - 30 cm × 15 cm

Factor B: Methods of weed control (4 levels)

W_0 - No weeding (control)

W_1 - Two hand weeding s(at 15 and 30 DAS)

W_2 - Pre emergence herbicide application (application of Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS)

W_3 - Post emergence herbicide application (application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS)

Figure 1. Layout of the experimental plot

3.3 Growing of crops

3.3.1 Sowing of seeds in the field

The seeds of mungbean were sown on April 24, 2014 in solid rows in the furrows 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 provided before 15 and 30 DAS for optimizing the vegetative growth of mungbean for the all experimental plots equally. Proper drain also made for drained out excess water from irrigation and also rainfall from the experimental plot. The crop field was weeded and herbicides were applied as per treatment of weed control methods.

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 control in proper way. Before sowing seeds were treated with Bavistin 50 WP to protect seed borne disease.

3.4 Crop sampling and data collection

Ten 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 20 days started from 20 DAS (days after sowing) to 60 DAS and final harvesting of pod at 75 DAS.

3.5 Harvest and post harvest operations

Harvesting was done 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. Weed species in the experimental plot
ii. Weed population
iii. Dry weight of weed biomass
iv. Plant height at 20, 40, 60 DAS and at harvest (75 DAS)
v. Number of branches plant^{-1} at 20, 40, 60 DAS and at harvest
vi. Number of leaves plant^{-1} at 20, 40, 60 DAS and at harvest
vii. Dry matter content plant^{-1} at 20, 40, 60 DAS and at harvest
viii. Days to 1st flowering
ix. Number of pods plant^{-1}
x. Number of seeds pod^{-1}
xi. Pod length
xii. Weight of 1000 seeds
xiii. Seed yield hectare^{-1}
xiv. Stover yield hectare^{-1}
xv. Biological yield hectare^{-1}
xvi. Harvest index

3.7 Procedure of data collection

3.7.1 Weeds parameters

3.7.1.1 Weed population

From the 1 m^2 area of every plot, the total weeds were uprooted and the species were identified and counted at 20 DAS and 40 DAS.

3.7.1.2 Dry weight of weed biomass/m^2

Fresh weeds were collected from 1 m^2 in each plot at 20 DAS and 40 DAS and then washed by tap water. Then weeds sample from each plot were oven dried for 24 hours at 80^{0}C temperature. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight of the sample was taken by electric balance.

3.7.2. Crop growth characters

3.7.2.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at 20, 40, 60 DAS and at harvest. Data were recorded from 10 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 20, 40, 60 DAS and at harvest. Data were recorded from 10 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 20, 40, 60 DAS and at harvest. Data were recorded from 10 plants from each plot and average number of leaves plant^{-1} was recorded as per treatment.

3.7.2.4 Dry matter content plant^{-1}

Ten plants were collected randomly from each plot at 20, 40, 60 DAS and harvest. Fresh plant samples from each plot were put into envelop 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 Days to 1st flowering

Days to 1st flowering were recorded by counting the number of days required to start flower initiation of mungbean plant in each plot.

3.7.3.2 Number of pods plant^{-1}

Numbers of total pods of 10 plants from each plot were counted and the mean numbers were expressed as plant^{-1} basis.

3.7.3.3 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 10 pods from each plot.

3.7.3.4 Pod length

Pod length was taken of randomly selected 10 pods and the mean length was expressed on per pod basis.

3.7.3.5 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 5 (2.5 m ×2 m) 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 5 (2.5 m ×2 m) 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:

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

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 plant density and methods of weed control. 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 Duncan Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

CHAPTER 4

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 plant density and methods of weed control. The analyses of variance (ANOVA) of the data on different weed parameters, 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 Weed control

4.1.1 Weed species in the experimental field

Plants compete with numerous weeds under favorable condition which is the common phenomenon of crop cultivation. Plant-weed competition increased when the density of weeds increased. Thirteen weed species belongs to 6 families were found infested with crops in the experimental field. The local name, common name, scientific name, family, life cycle and type of those weed species are shown in Table 1. Among the observed 13 weed species *Cynodon dactylon*, *Cyperus rotundus*, *Echinochloa colonum*, *Alternanthera philoxeroides* and *Eleusine indica* were found as major population of weed species in the experimental plot. Among the weed species 6 weed species belong to the family Gramineae, 2 weed species were under Amaranthaceae family, and 2 weed species under Cyperaceae and only 1 weed specie belongs to the family respectively to Oxalidaceae Leguminosae and Compositae family. Among the thirteen weed species eleven species were annual in life cycle and two were perennial. Weed was one of the worst enemies of mungbean as it competed with the crop for space, nutrient, water and light and finally reduced its yield. About 69% reduction in mungbean grain yield due to weeds was estimated by Yadav and Sing (2005). Besides causing a considerable reduction in yield, weeds deplete soil fertility and increase incidence of insect pests, weeding at proper time can suppress weeds in the crop field.

Table 1. List of weeds with common name, scientific name, family, life cycle and type that were available in the experimental plot

Sl. No.	Local Name	Common Name	Scientific Name	Family	Life Cycle
1.	Anguli ghas	Scrab grass	*Digitaria sanguinalis*	Gramineae	Annual
2.	Chapra	Goose grass	*Eleusine indica*	Gramineae	Perennial
3.	Choto Anguli	Small Crabgrass	*Digitaria ischaemum*	Gramineae	Annual
4.	Choto Shama	Jungle rice	*Echinochloa colonum*	Gramineae	Annual
5.	Durba	Bermuda grass	*Cynodon dactylon*	Gramineae	Perennial
6.	Kata Notae	Spiny Pig Weed	*Amaranthus spinosus*	Amaranthaceae	Annual
7.	Malancha	Alligator weed	*Alternanthera philoxeroides*	Amaranthaceae	Annual
8.	Mutha	Nut sedge	*Cyperus rotundus*	Cyperaceae	Annual
9.	Amrul Shak	Creeping wood sorrel	*Oxalis europea*	Oxalidaceae	Annual
10.	Arachye	Tora weed	*Cassia tora*	Leguminosae	Annual
11.	Keshuti	White eclipta	*Edipta prostrata*	Compositae	Annual
12.	Gaicha	Paspalum grass	*Paspalum commersonii*	Gramineae	Annual
13.	Chechra	Bog bulrush	*Scirpus mucronatus*	Cyperaceae	Annual

4.1.2 Weed Population

Weed population m^{-2} at 20 and 40 DAS varied significantly due to different plant density under the present trial (Appendix III). At 20 DAS, the maximum numbers of weed population m^{-2} (7.67) were recorded in D_4 (30 cm × 15 cm) which was closely followed (7.00 and 6.58) by D_3 (30 cm × 10 cm) and D_2 (30 cm × 5 cm), respectively. On the other hand, the minimum number of weed population m^{-2} (6.08) were observed in D_1 (30 cm × continuous) treatment (Table 2). At 40 DAS, the maximum numbers of weed population m^{-2} (14.00) were recorded in D_1 which was closely followed (12.67 and 12.58) by D_2 and D_4, respectively and they were statistically similar, while the minimum number (11.50) in D_3 treatment.

Statistically significant variation was recorded in terms of weed population m^{-2} at 20 and 40 DAS for different methods of weed control (Appendix III). Data revealed that at 20 DAS, the maximum numbers of weed population m^{-2} (15.92) were found in W_0 (No weeding i.e. control), while the minimum (3.50) in W_3 (Post emergence herbicide application: application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 DAS & 30 DAS) which was closely followed (3.92 and 4.00) by W_1 (Two hand weeding: at 15 DAS and 30 DAS) and W_2 (Pre emergence herbicide application: application of Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS), respectively and they were statistically similar (Table 2). At 40 DAS, the maximum numbers of weed population m^{-2} (26.58) were recorded in W_0, while the minimum (7.00) in W_2 which were closely followed (7.92) by W_1 treatment. Naeem *et al.* (2000) reported that weeds density showed significant decrease for different weed management as compared to control.

Interaction effect of different plant density and methods of weed control showed significant differences on weed population m^{-2} at 20 and 40 DAS (Appendix III). At 20 DAS, the maximum number of weed population m^{-2} (16.67) was found from D_4W_0, while the minimum (2.33) was recorded from D_1W_3 treatment combination (Table 3). At 40 DAS, the maximum number of weed population m^{-2} (28.33) was found from D_1W_0, while the minimum (6.00) was recorded from D_3W_2 treatment combination.

Table 2. Effect of plant density and methods of weed control on weed population and dry matter content in weed

Treatments	Weeds population (No.) at		Dry weight of weed biomass (gm^{-2})	
	20 DAS	40 DAS	20 DAS	40 DAS
Plant density				
D_1	6.08 c	14.00 a	3.92 b	4.88 b
D_2	6.58 b	12.67 b	3.95 b	4.92 b
D_3	7.00 b	11.50 c	3.93 b	4.91 b
D_4	7.67 a	12.58 b	4.21 a	5.24 a
SE	0.142	0.108	0.029	0.024
CV(%)	7.21	2.94	4.99	2.80
Methods of weed control				
W_0	15.92 a	26.58 a	4.72 a	6.46 a
W_1	3.92 bc	7.92 c	3.81 b	4.54 b
W_2	4.00 b	7.00 d	3.72 b	4.47 b
W_3	3.50 c	9.25 b	3.77 b	4.48 b
SE	0.158	0.219	0.040	0.048
CV(%)	8.00	5.98	6.92	5.61

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

D_1: 30 cm × continuous

D_2: 30 cm × 5 cm

D_3: 30 cm × 10 cm

D_4: 30 cm × 15 cm

W_0: No weeding (control)

W_1: Two hand weeding (at 15 DAS and 30 DAS)

W_2: Pre emergence herbicide application (application of Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS)

W_3: Post emergence herbicide application (application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 DAS & 30 DAS)

Table 3. Interaction effect of plant density and methods of weed control on weed population and dry matter content in weed

Treatments	Weeds population (No.) at		Dry weight of weed biomass (g m^{-2})	
	20 DAS	40 DAS	20 DAS	40 DAS
D_1W_0	15.33 b	28.33 a	4.81 a	6.65 a
D_1W_1	3.33 de	9.33 de	3.69 d-f	4.34 f-h
D_1W_2	3.33 de	8.00 ef	3.62 d-f	4.30 f-h
D_1W_3	2.33 e	10.33 d	3.58 ef	4.22 gh
D_2W_0	16.33 a	27.33 ab	4.68 a	6.33 b
D_2W_1	3.67 cd	7.33 fg	3.69 d-f	4.44 e-h
D_2W_2	3.33 de	6.67 fg	3.73 c-e	4.52 d-g
D_2W_3	3.00 de	9.33 de	3.68 d-f	4.40 f-h
D_3W_0	15.33 b	24.33 c	4.58 a	6.28 b
D_3W_1	4.00 cd	7.67 f	3.86 b-d	4.60 c-f
D_3W_2	4.67 c	6.00 g	3.44 f	4.15 h
D_3W_3	4.00 cd	8.00 ef	3.84 b-e	4.59 c-f
D_4W_0	16.67 a	26.33 b	4.79 a	6.58 ab
D_4W_1	4.67 c	7.33 fg	3.98 bc	4.78 cd
D_4W_2	4.67 c	7.33 fg	4.09 b	4.90 c
D_4W_3	4.67 c	9.33 de	3.99 bc	4.72 c-e
SE	0.922	0.438	0.080	0.097
CV(%)	8.00	5.98	6.92	5.61

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

D_1: 30 cm × continuous — W_0: No weeding (control)

D_2: 30 cm × 5 cm — W_1: Two hand weeding (at 15 DAS and 30 DAS)

D_3: 30 cm × 10 cm — W_2: Pre emergence herbicide application (application of Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS)

D_4: 30 cm × 15 cm — W_3: Post emergence herbicide application (application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 DAS & 30 DAS)

4.1.3 Dry weight of weed biomass

Different plant density showed statistically significant variation in terms of dry weight of weed biomass m^{-2} at 20 and 40 DAS (Appendix III). At 20 DAS, the highest dry weight of weed biomass m^{-2} (4.21 g) were observed in D_4, while the lowest (3.92 g) were found in D_1 treatment which was statistically similar (3.93 g and 3.95 g) to D_3 and D_2, respectively (Table 2). At 40 DAS, the highest dry weight of weed biomass m^{-2} (5.24 g) were recorded in D_4, whereas the lowest (4.88 g) were found in D_1 treatment which was statistically similar (4.91 g and 4.92 g) to D_3 and D_2, respectively.

Dry weight of weed biomass m^{-2} at 20 and 40 DAS varied significantly due to different methods of weed control (Appendix III). At 20 DAS, the highest dry weight of weed biomass m^{-2} (4.72 g) were recorded in W_0, while the lowest (3.72 g) were found in W_2 which was statistically similar (3.77 g and 3.81 g) to W_3 and W_1, respectively (Table 2). At 40 DAS, the highest dry weight of weed biomass m^{-2} (6.46 g) were observed in W_0, while the lowest (4.47 g) were found in W_2 which was statistically similar (4.48 g and 4.54 g) to W_3 and W_1, respectively. Khaliq *et al*. (2002) investigated the efficacy of different weed management strategies in mungbean and stated that hoeing treatments resulted in reduced weed dry weight by 79% compared to control. Naeem *et al.* (2000) reported that weeds dry weight in all weed control treatments showed significant decrease as compared to control.

Statistically significant variation was recorded due to the interaction effect of different plant density and methods of weed control in terms of dry weight of weed biomass m^{-2} at 20 and 40 DAS (Appendix III). At 20 DAS, the highest dry weight of weed biomass m^{-2} (4.81 g) was recorded from D_1W_0, while the lowest (3.44 g) was found from D_3W_2 treatment combination (Table 3). At 40 DAS, the highest dry weight of weed biomass m^{-2} (6.65 g) was observed from D_1W_0, whereas the lowest (4.15 g) was attained from D_3W_2 treatment combination.

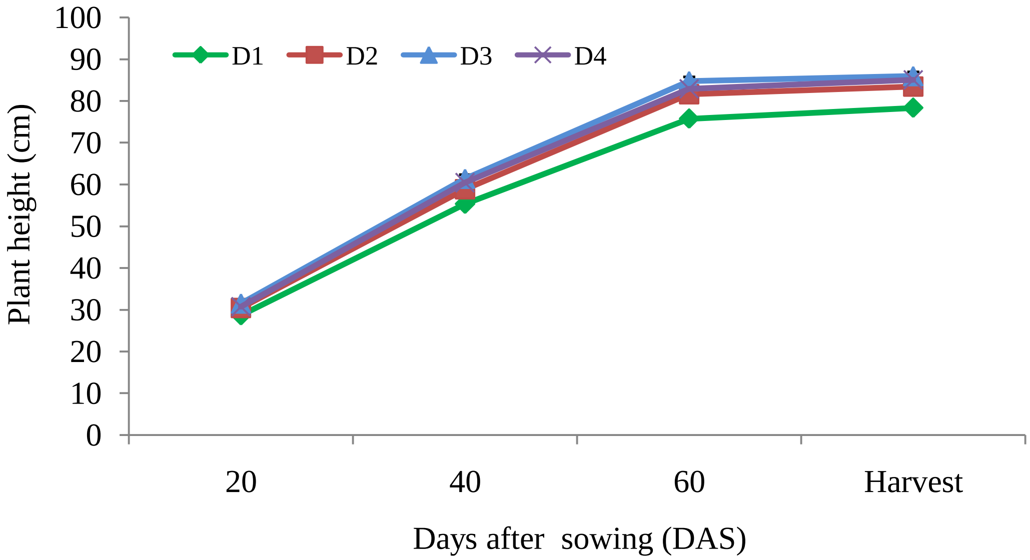
4.2 Crop Growth Characters

4.2.1 Plant height

Plant height of mungbean at 20, 40, 60 DAS and harvest varied significantly due to different plant density (Appendix IV). At 20, 40, 60 DAS and at harvest, the tallest plant (31.46, 61.34, 84.75 and 85.95 cm, respectively) were observed from D_3 which were statistically similar (30.69, 60.39, 82.87 and 85.02 cm, respectively) to D_4, whereas the shortest plant (28.62, 55.32, 75.74 and 78.34 cm, respectively) from D_1 (Figure 2). It was revealed that with the increases of plant density plant height showed increasing trend upto certain level than decreases. In case of lower plant density plant compete for light and nutrients than higher density which greatly affect plant growth that produced comparatively shorter plant. On the other way excess wider density does not create and competition within the species and produce comparatively shorter plant than the suitable plant density. Mansoor *et al*. (2010) reported the tallest plants in 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.

Methods of weed control showed significant variation for plant height of mungbean at 20, 40, 60 DAS and at harvest (Appendix IV). At 20, 40, 60 DAS and at harvest, the tallest plant (31.69, 61.42, 83.55 and 87.22 cm, respectively) were recorded from W_2, which were statistically similar (31.10, 60.22, 82.48 and 84.90 cm, respectively) to W_1 and followed (29.99, 58.93, 81.60 and 82.13 cm, respectively) by W_3, while the shortest plant (28.43, 55.33, 77.32 and 78.50 cm, respectively) were observed from W_0, respectively (Figure 3). Akter *et al*. (2013) reported that three-stage weeding ensured the highest plant height (58.62 cm).

Interaction effect of different plant density and methods of weed control showed significant variation in terms of plant height at 20, 40, 60 DAS and at harvest (Appendix IV). At 20, 40, 60 DAS and at harvest, the tallest plant (34.32, 65.07, 87.60 and 89.50 cm, respectively) were observed from D_3W_2, while the shortest plant (24.86, 51.96, 73.58 and 74.28 cm, respectively) were found from D_1W_0 treatment combination (Table 4).



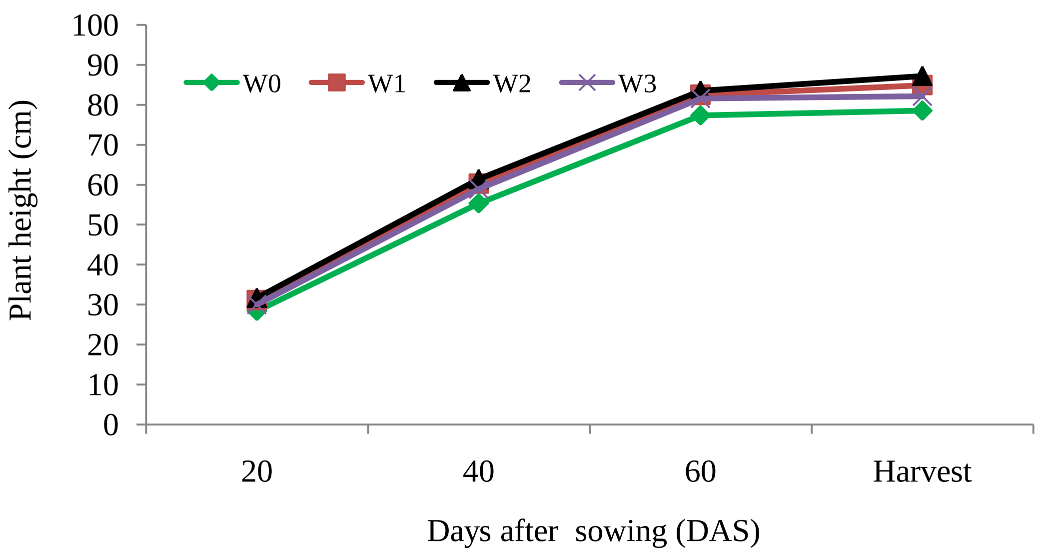
D_1: 30 cm × continuous

D_2: 30 cm × 5 cm

D_3: 30 cm × 10 cm

D_4: 30 cm × 15 cm

Figure 2. Effect of different plant density on plant height (SE = 0.522, 0.518, 0.890 and 0.734 for 20, 40, 60 DAS and harvest).



W_0: No weeding (control)

W_1: Two hand weeding (at 15 and 30 DAS)

W_2: Pre emergence herbicide application (Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS)

W_3: Post emergence herbicide application (Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS)

Figure 3. Effect of different methods of weed control on plant height (SE = 0.730, 0.560, 1.063 and 0.874 for 20, 40, 60 DAS and harvest)

Table 4. Interaction effect of plant density and methods of weed control on plant height

Treatments	Plant height (cm) at			
	20 DAS	40 DAS	60 DAS	Harvest
D_1W_0	24.86 e	51.96 i	73.58 e	74.28 fg
D_1W_1	32.10 a-c	58.36 e-g	76.85 c-e	81.71 c-e
D_1W_2	29.74 a-d	56.59 f-h	76.58 c-e	84.53 a-d
D_1W_3	27.77 c-e	54.39 hi	75.93 de	72.83 g
D_2W_0	31.89 a-c	58.14 e-g	79.32 b-e	77.91 e-g
D_2W_1	28.99 b-e	58.68 d-g	82.43 a-d	84.95 a-c
D_2W_2	30.87 a-d	60.12 c-f	83.28 a-c	86.82 a-c
D_2W_3	30.01 a-d	58.43 e-g	81.35 a-d	84.03 a-d
D_3W_0	26.66 de	55.22 g-i	77.95 b-e	78.82 d-f
D_3W_1	33.24 ab	62.98 a-c	86.52 a	87.40 a-c
D_3W_2	34.32 a	65.07 a	87.60 a	89.50 a
D_3W_3	31.62 a-c	62.10 a-d	86.95 a	88.09 ab
D_4W_0	30.29 a-d	56.00 gh	78.43 b-e	82.98 b-e
D_4W_1	30.07 a-d	60.85 b-e	84.13 ab	85.53 a-c
D_4W_2	31.82 a-c	63.92 ab	86.75 a	88.03 ab
D_4W_3	30.56 a-d	60.79 b-e	82.17 a-d	83.56 b-d
SE	1.460	1.119	2.126	1.749
CV(%)	8.34	5.29	4.53	5.64

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

D_1: 30 cm × continuous — W_0: No weeding (control)

D_2: 30 cm × 5 cm — W_1: Two hand weeding (at 15 and 30 DAS)

D_3: 30 cm × 10 cm — W_2: Pre emergence herbicide application (application of Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS)

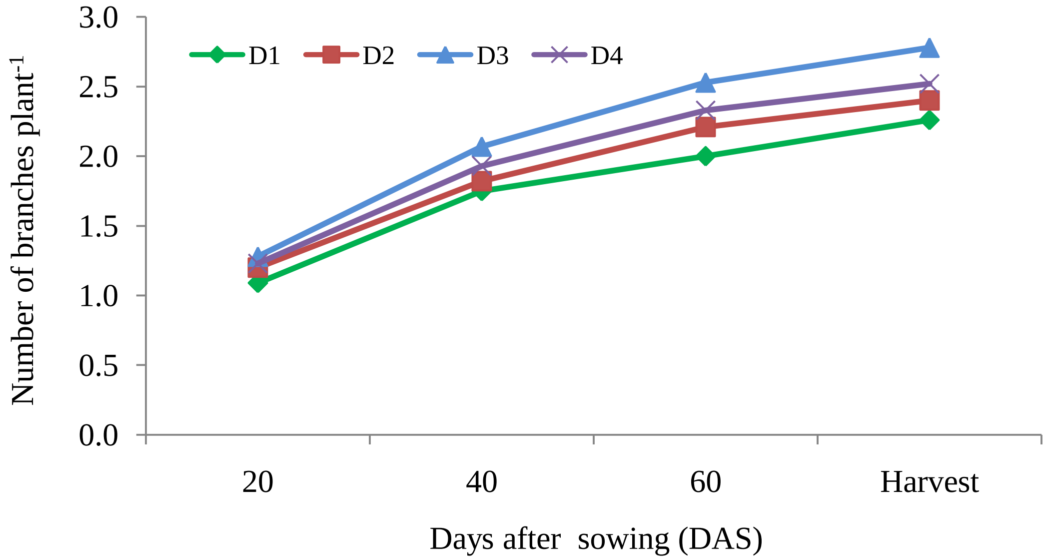
D_4: 30 cm × 15 cm — W_3: Post emergence herbicide application (application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS)

4.2.2 Number of branches plant^{-1}

Different plant density varied significantly in terms of number of branches plant^{-1} of mungbean at 20, 40, 60 DAS and at harvest (Appendix V). At 20, 40, 60 DAS and at harvest, the highest number of branches plant^{-1} (1.28, 2.07, 2.53 and 2.78, respectively) were recorded from D_3 which were statistically similar (1.23, 1.93, 2.33 and 2.52, respectively) to D_4 which were followed (1.20, 1.82, 2.21 and 2.40, respectively) by D_1. On the other hand, the lowest number of branches plant^{-1} (1.09, 1.75, 2.00 and 2.26, respectively) were obtained from D_1 at 20, 40, 60 DAS and at harvest (Figure 4). In general, number of branches plant^{-1} increased in optimum plant density and it were probably due to availability of suitable space, nutrition and environment viz. air, dry and moisture, humidity, water, dark and light intensity etc. for the plant. The present result is in agreement with the results of El-Habbasha *et al*. (1996).

Number of branches plant^{-1} of mungbean at 20, 40, 60 DAS and at harvest showed significant differences due to methods of weed control (Appendix V). At 20, 40, 60 DAS and at harvest, the highest number of branches plant^{-1} (1.27, 2.08, 2.47 and 2.74, respectively) were found from W_2, which were statistically similar (1.23, 2.02, 2.39 and 2.68, respectively) to W_1 and followed (1.18, 1.96, 2.32 and 2.54, respectively) by W_3, whereas the lowest number (1.12, 1.51, 1.90 and 2.00, respectively) were recorded from W_0 at 20, 40, 60 DAS and at harvest, respectively (Figure 5). Akter *et al*. (2013) reported that three-stage weeding ensured the highest number of branches (4.45). Bayan and Saharia (1996) reported that branches plant^{-1} were significantly influenced by weed management.

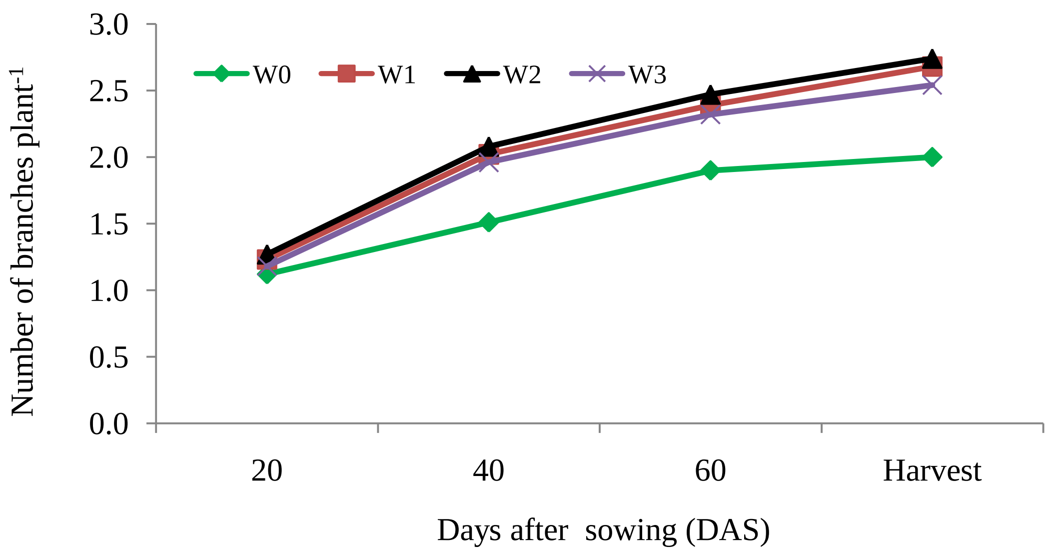
Statistically significant variation were recorded for the interaction effect of different plant density and methods of weed control in terms of number of branches plant^{-1} at 20, 40, 60 DAS and harvest (Appendix V). At 20, 40, 60 DAS and at harvest, the highest number of branches plant^{-1} (1.37, 2.37, 2.83 and 3.03, respectively) were observed from D_3W_2 and the lowest (1.00, 1.43, 1.77 and 1.87, respectively) were found from D_1W_0 treatment combination (Table 5).



D_1: 30 cm × continuous D_2: 30 cm × 5 cm

D_3: 30 cm × 10 cm D_4: 30 cm × 15 cm

Figure 4. Effect of different plant density on number of branches plant^{-1} (SE = 0.018, 0.029, 0.036 and 0.040 for 20, 40, 60 DAS and harvest)



W_0: No weeding (control) W_1: Two hand weeding (at 15 and 30 DAS)

W_2: Pre emergence herbicide application (Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS)

W_3: Post emergence herbicide application (Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS)

Figure 5. Effect of different methods of weed control on number of branches plant^{-1} (SE = 0.018, 0.026, 0.046 and 0.033 for 20, 40, 60 DAS and harvest)

Table 5. Interaction effect of plant density and methods of weed control on number of branches plant^{-1}

Treatments	Number of branches plant^{-1} at			
	20 DAS	40 DAS	60 DAS	Harvest
D_1W_0	1.00 e	1.43 g	1.77 f	1.87 h
D_1W_1	1.20 bc	1.90 ef	2.13 de	2.40 e-g
D_1W_2	1.13 cd	1.90 ef	2.13 de	2.57 c-e
D_1W_3	1.03 de	1.77 f	1.97 ef	2.20 g
D_2W_0	1.20 bc	1.57 g	1.83 f	1.93 h
D_2W_1	1.13 cd	1.90 ef	2.33 b-d	2.63 b-d
D_2W_2	1.27 ab	1.93 d-f	2.37 b-d	2.60 c-e
D_2W_3	1.20 bc	1.87 ef	2.30 b-d	2.43 d-f
D_3W_0	1.13 cd	1.53 g	2.20 c-e	2.27 fg
D_3W_1	1.33 a	2.20 b	2.60 ab	3.00 a
D_3W_2	1.37 a	2.37 a	2.83 a	3.03 a
D_3W_3	1.27 ab	2.17 bc	2.50 bc	2.83 ab
D_4W_0	1.13 cd	1.50 g	1.80 f	1.93 h
D_4W_1	1.27 ab	2.07 b-d	2.50 bc	2.67 bc
D_4W_2	1.33 a	2.13 bc	2.53 b	2.77 bc
D_4W_3	1.20 bc	2.03 c-e	2.50 bc	2.70 bc
SE	0.035	0.052	0.092	0.067
CV(%)	5.10	4.74	7.03	4.65

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

D_1: 30 cm × continuous
D_2: 30 cm × 5 cm
D_3: 30 cm × 10 cm
D_4: 30 cm × 15 cm

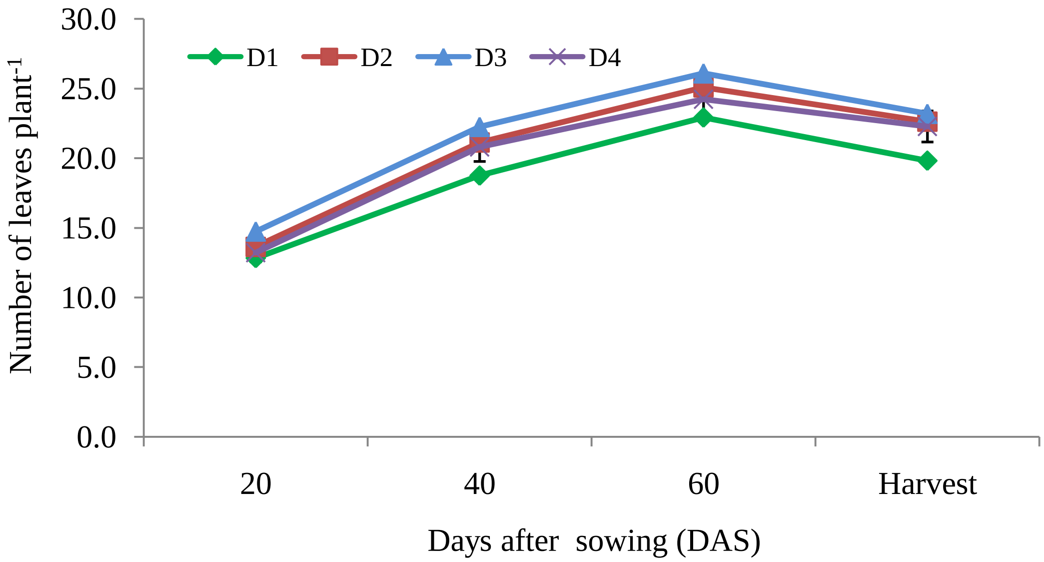
W_0: No weeding (control)
W_1: Two hand weeding (at 15 and 30 DAS)
W_2: Pre emergence herbicide application (application of Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS)
W_3: Post emergence herbicide application (application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS)

4.2.3 Number of leaves plant^{-1}

Number of leaves plant^{-1} of mungbean at 20, 40, 60 DAS and at harvest varied significantly due to different plant density (Appendix VI). Data revealed that at 20, 40, 60 DAS and at harvest, the highest number of leaves plant^{-1} (14.75, 22.26, 26.10 and 23.20, respectively) were found from D_3 which were statistically similar (13.65, 21.13, 25.08 and 22.63, respectively) to D_2 and followed (13.22, 20.81, 24.24 and 22.28, respectively) by D_4, whereas the lowest (12.83, 18.75, 22.92 and 19.82, respectively) were recorded from D_1 at 20, 40, 60 DAS and at harvest (Figure 6). It appears that the increase in number of leaves plant^{-1} the increase in plant density were related to the increase in the inter-plant competition over light and the disruption of the balance of growth regulators. Kabir and Sarkar (2008) reported that plant spacing of 30 cm × 10 cm produced the maximum number of leaves plant^{-1} of mungbean.

Statistically significant variation were recorded in terms of number of leaves plant^{-1} of mungbean at 20, 40, 60 DAS and at harvest due to methods of weed control (Appendix VI). At 20, 40, 60 DAS and at harvest, the highest number of leaves plant^{-1} (15.32, 22.44, 26.94 and 24.23, respectively) were obtained from W_2, which were statistically similar (14.38, 21.33, 25.98 and 23.27, respectively) to W_1 and followed (13.08, 20.93, 24.80 and 22.11, respectively) by W_3, whereas the lowest (11.67, 18.24, 20.62 and 18.33, respectively) were found from W_0 at 20, 40, 60 DAS and at harvest, respectively (Figure 7). Akter *et al.* (2013) reported that three-stage weeding ensured the highest number of leaves (10.34) plant^{-1}.

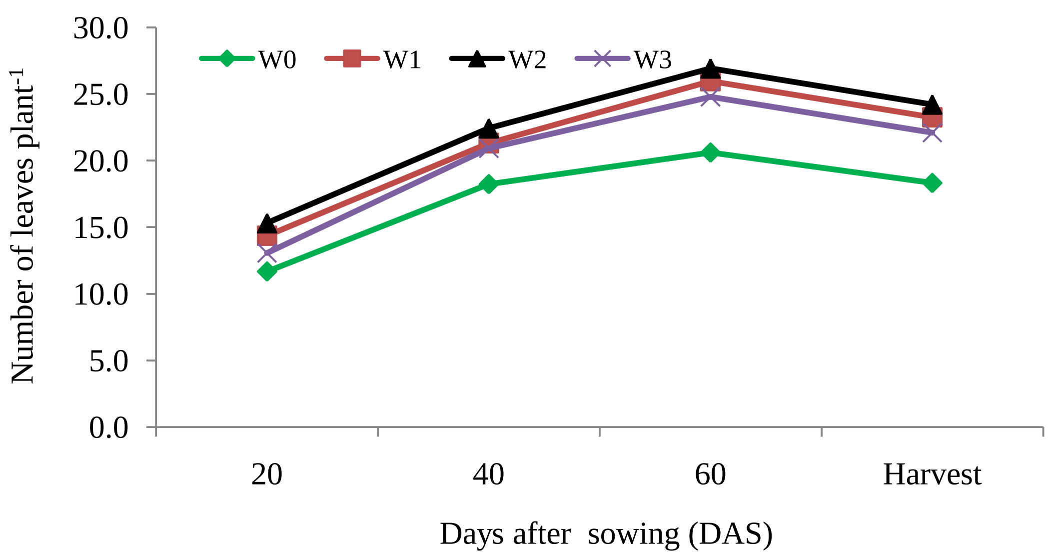
Number of leaves plant^{-1} at 20, 40, 60 DAS and harvest showed significant variation for the interaction effect of different plant density and methods of weed control (Appendix VI). At 20, 40, 60 DAS and at harvest, the highest number of leaves plant^{-1} (16.40, 24.87, 28.40 and 25.50, respectively) were recorded from D_3W_2, again the lowest (11.00, 16.73, 19.70 and 17.47, respectively) were recorded from D_1W_0 treatment combination (Table 6).



D_1: 30 cm × continuous D_2: 30 cm × 5 cm

D_3: 30 cm × 10 cm D_4: 30 cm × 15 cm

Figure 6. Effect of different plant density on number of leaves plant^{-1} (SE = 0.337, 0.252, 0.243 and 0.423 for 20, 40, 60 DAS and harvest)



W_0: No weeding (control) W_1: Two hand weeding (at 15 and 30 DAS)

W_2: Pre emergence herbicide application (Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS)

W_3: Post emergence herbicide application (Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS)

Figure 7. Effect of different methods of weed control on number of leaves plant^{-1} (SE = 0.293, 0.302, 0.314 and 0.520 for 20, 40, 60 DAS and harvest)

Table 6. Interaction effect of plant density and methods of weed control on number of leaves plant^{-1}

Treatments	Number of leaves plant^{-1} at			
	20 DAS	40 DAS	60 DAS	Harvest
D_1W_0	11.00 h	16.73 h	19.70 f	17.47 e
D_1W_1	15.20 a-c	19.83 d-f	24.33 e	20.97 b-d
D_1W_2	13.70 b-e	19.93 d-f	26.43 a-d	22.80 ab
D_1W_3	11.40 f-h	18.50 f-h	21.20 f	18.03 de
D_2W_0	12.40 e-h	19.47 ef	21.33 f	19.37 c-e
D_2W_1	13.30 d-f	20.70 c-e	26.77 a-d	24.27 ab
D_2W_2	15.90 a	22.40 bc	26.77 a-d	24.37 ab
D_2W_3	13.00 e-g	21.93 bc	25.47 c-e	22.53 a-c
D_3W_0	12.10 e-h	19.27 e-g	20.93 f	17.83 de
D_3W_1	15.60 a	23.17 ab	27.77 ab	24.83 a
D_3W_2	16.40 a	24.87 a	28.40 a	25.50 a
D_3W_3	14.90 a-d	21.73 b-d	27.30 a-c	24.63 a
D_4W_0	11.20 gh	17.50 gh	20.50 f	18.63 de
D_4W_1	13.40 c-e	21.60 b-d	25.07 de	23.03 ab
D_4W_2	15.30 ab	22.57 bc	26.17 b-e	24.23 ab
D_4W_3	13.00 e-g	21.57 b-d	25.23 c-e	23.23 ab
SE	0.587	0.605	0.627	1.041
CV(%)	7.46	5.05	4.42	8.20

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

D_1: 30 cm × continuous — W_0: No weeding (control)

D_2: 30 cm × 5 cm — W_1: Two hand weeding (at 15 and 30 DAS)

D_3: 30 cm × 10 cm — W_2: Pre emergence herbicide application (application of Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS)

D_4: 30 cm × 15 cm — W_3: Post emergence herbicide application (application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS)

4.2.4 Dry matter content plant^{-1}

Statistically significant variation were recorded in terms of dry matter content plant^{-1} of mungbean at 20, 40, 60 DAS and at harvest for different plant density (Appendix VII). At 20, 40, 60 DAS and at harvest, the highest dry matter content plant^{-1} (1.59, 5.29, 9.40 and 11.04 g, respectively) were found from D_3 which were statistically similar (1.52, 5.12, 8.73 and 10.76 g, respectively) to D_4 and followed (1.49, 4.78, 8.25 and 10.62 g, respectively) by D_2, while the lowest (1.29, 4.55, 7.96 and 10.14 g, respectively) were obtained from D_1 at 20, 40, 60 DAS and at harvest (Table 7). The wider plant density produced highest dry matter than the closer plant density. Mansoor *et al*. (2010) reported that dry matter content in plant were significantly affected by various seed rates as well as plant population.

Dry matter content plant^{-1} of mungbean at 20, 40, 60 DAS and at harvest showed significant variation due to methods of weed control (Appendix VII). At 20, 40, 60 DAS and at harvest, the highest dry matter content plant^{-1} (1.61, 5.17, 9.00 and 11.01 g, respectively) were recorded from W_2, which were statistically similar (1.58, 5.01, 8.82 and 10.81 g, respectively) to W_1 and followed (1.49, 4.95, 8.59 and 10.57 g, respectively) by W_3. On the other hand, the lowest dry matter content plant^{-1} (1.20, 4.62, 7.92 and 10.17 g, respectively) were found from W_0 at 20, 40, 60 DAS and at harvest, respectively (Table 7). Ahmed *et al.* (1987) observed that weed removal at 15 and 30, 30 and 45 or 15, 30 and 45 facilitated the production of higher dry matter.

Interaction effect of different plant density and methods of weed control showed significant variation in terms of dry matter content plant^{-1} at 20, 40, 60 DAS and harvest (Appendix VII). At 20, 40, 60 DAS and at harvest, the highest dry matter content plant^{-1} (1.89, 5.84, 10.24 and 11.37 g, respectively) were observed from D_3W_2 and the lowest (1.05, 4.36, 7.48 and 9.63 g, respectively) were found from D_1W_0 treatment combination (Table 8).

Table 7. Effect of plant density and methods of weed control on dry matter content plant^{-1}

Treatments	Dry matter content plant^{-1} (g) at			
	20 DAS	40 DAS	60 DAS	Harvest
Plant density				
D_1	1.29 b	4.55 d	7.96 c	10.14 c
D_2	1.49 a	4.78 c	8.25 c	10.62 b
D_3	1.59 a	5.29 a	9.40 a	11.04 a
D_4	1.52 a	5.12 b	8.73 b	10.76 b
SE	0.035	0.026	0.097	0.059
CV(%)	8.33	3.04	7.33	3.63
Methods of weed control				
W_0	1.20 b	4.62 b	7.92 c	10.17 c
W_1	1.58 a	5.01 a	8.82 ab	10.81 a
W_2	1.61 a	5.17 a	9.00 a	11.01 a
W_3	1.49 a	4.95 a	8.59 b	10.57 b
SE	0.043	0.093	0.092	0.071
CV(%)	10.03	11.02	6.94	4.35

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

D_1: 30 cm × continuous

D_2: 30 cm × 5 cm

D_3: 30 cm × 10 cm

D_4: 30 cm × 15 cm

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 gm ha^{-1} at 3 DAS)

W_3: Post emergence herbicide application (application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS)

Table 8. Interaction effect of plant density and methods of weed control on dry matter content plant^{-1}

Treatments	Dry matter content plant^{-1} (g) at			
	20 DAS	40 DAS	60 DAS	Harvest
D_1W_0	1.05 f	4.36 g	7.48 h	9.63 h
D_1W_1	1.51 b-d	4.84 c-g	8.57 c-f	10.51 e-g
D_1W_2	1.27 d-f	4.44 g	7.86 gh	10.69 d-f
D_1W_3	1.33 c-e	4.55 e-g	7.94 gh	9.75 h
D_2W_0	1.39 cd	4.81 c-g	8.06 f-h	10.17 g
D_2W_1	1.48 b-d	4.60 e-g	8.01 f-h	10.74 c-f
D_2W_2	1.58 bc	4.99 b-g	8.76 cd	10.91 b-e
D_2W_3	1.50 b-d	4.74 d-g	8.16 e-g	10.66 d-f
D_3W_0	1.11 ef	4.49 fg	7.86 gh	10.37 fg
D_3W_1	1.74 ab	5.47 ab	10.02 a	11.19 a-c
D_3W_2	1.89 a	5.84 a	10.24 a	11.37 a
D_3W_3	1.61 bc	5.34 a-d	9.47 b	11.22 ab
D_4W_0	1.27 d-f	4.82 c-g	8.29 d-g	10.52 e-g
D_4W_1	1.60 bc	5.12 b-f	8.67 c-e	10.81 b-f
D_4W_2	1.69 ab	5.39 a-c	9.15 bc	11.06 a-d
D_4W_3	1.53 b-d	5.16 b-e	8.80 cd	10.66 d-f
SE	0.086	0.187	0.184	0.141
CV(%)	10.03	11.02	6.94	4.35

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

D_1: 30 cm × continuous — W_0: No weeding (control)

D_2: 30 cm × 5 cm — W_1: Two hand weeding (at 15 and 30 DAS)

D_3: 30 cm × 10 cm — W_2: Pre emergence herbicide application (application of Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS)

D_4: 30 cm × 15 cm — W_3: Post emergence herbicide application (application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS)

4.3 Yield contributing characters

4.3.1 Days to 1st flowering

Days to 1st flowering of mungbean varied significantly due to different plant density (Appendix VIII). The maximum days to flowering (39.08) was found from D_1 which was statistically similar (37.50 and 36.75) to D_2 and D_4, whereas the minimum days to 1st flowering (34.67) was recorded from D_3 (Table 9). Days to 1st flowering varied due to genetical and environmental influences as well as management practices. El-Habbasha *et al.* (1996) reported that increasing plant density decreased days to 1st flowering.

Methods of weed control showed significant variation in terms of days to 1st flowering of mungbean (Appendix VIII). The maximum days to flowering (38.92) was found from W_3, which was statistically similar (38.67) to W_1, while the minimum days to 1st flowering (34.17) was recorded from W_2 which was statistically similar (36.25) to W_1 (Table 9).

Interaction effect of different plant density and methods of weed control showed significant variation in terms of days to 1st flowering (Appendix VIII). The maximum days to 1st flowering (42.33) was found from D_1W_0, while the minimum days to 1st flowering (32.67) was recorded from D_3W_2 treatment combination (Table 10).

4.3.2 Number of pods plant^{-1}

Different plant density varied significantly in terms of number of pods plant^{-1} of mungbean (Appendix VIII). The highest number of pods plant^{-1} (18.92) was observed from D_3 which was closely followed (17.63 and 17.47) by D_4 and D_2 and they were statistically similar, while the lowest (15.02) was recorded from D_1 treatment (Table 9). This increased number of plants unit^{-1} area exerted competition among plants for nutrients and light that might be caused lower crop growth rate which consequence a reduction in the number of pods plant^{-1}. Similar result was also reported by many workers (Singh and Singh, 1988; Chowdhury, 1999; Hassan, 2000; Singh *et al.,* 2003).

Table 9. Effect of plant density and methods of weed control on yield contributing characters

Treatments	Days to 1st flowering	Number of pods $plant^{-1}$	Number of seeds pod^{-1}	Weight of 1000-seeds (g)
Plant density				
D_1	39.08 a	15.02 c	10.63 c	41.17 b
D_2	37.50 a	17.47 b	11.70 b	42.54 ab
D_3	34.67 b	18.92 a	12.23 a	45.36 a
D_4	36.75 ab	17.63 b	11.83 b	44.39 a
SE	0.719	0.163	0.090	0.830
CV(%)	6.73	3.27	2.69	6.62
Methods of weed control				
W_0	38.67 a	13.72 c	10.38 b	40.92 b
W_1	36.25 ab	18.63 a	12.02 a	44.12 a
W_2	34.17 b	18.82 a	12.17 a	44.74 a
W_3	38.92 a	17.87 b	11.81 a	43.68 a
SE	0.948	0.188	0.119	0.565
CV(%)	8.87	4.76	3.56	4.51

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

D_1: 30 cm × continuous

D_2: 30 cm × 5 cm

D_3: 30 cm × 10 cm

D_4: 30 cm × 15 cm

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 gm ha^{-1} at 3 DAS)

W_3: Post emergence herbicide application (application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS)

Table 10. Interaction effect of plant density and methods of weed control on yield contributing characters

Treatments	Days to 1st flowering	Number of pods plant^{-1}	Number of seeds pod^{-1}	Weight of 1000-seeds (g)
D_1W_0	42.33 a	12.03 h	10.07 e	40.06 d
D_1W_1	38.33 a-e	16.40 e	10.97 d	42.97 b-d
D_1W_2	35.33 b-e	16.17 e	10.80 de	40.63 d
D_1W_3	40.33 a-d	15.47 ef	10.67 de	41.02 d
D_2W_0	41.67 ab	14.43 fg	10.63 de	42.81 b-d
D_2W_1	33.00 e	18.63 cd	12.07 bc	42.13 cd
D_2W_2	34.00 de	18.90 b-d	12.27 a-c	42.95 b-d
D_2W_3	41.33 ab	17.90 d	11.83 c	42.28 cd
D_3W_0	33.67 e	14.57 fg	10.50 de	40.34 d
D_3W_1	39.00 a-e	20.50 a	12.80 ab	46.50 ab
D_3W_2	32.67 e	20.63 a	12.90 a	48.35 a
D_3W_3	33.33 e	19.97 ab	12.70 ab	46.26 ab
D_4W_0	37.00 a-e	13.83 g	10.33 de	40.47 d
D_4W_1	34.67 c-e	18.97 b-d	12.27 a-c	44.90 a-c
D_4W_2	34.67 c-e	19.57 a-c	12.70 ab	47.01 a
D_4W_3	40.67 a-c	18.13 d	12.03 bc	45.18 a-c
SE	1.895	0.375	0.238	1.129
CV(%)	8.87	4.76	3.56	4.51

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

D_1: 30 cm × continuous — W_0: No weeding (control)

D_2: 30 cm × 5 cm — W_1: Two hand weeding (at 15 and 30 DAS)

D_3: 30 cm × 10 cm — W_2: Pre emergence herbicide application (application of Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS)

D_4: 30 cm × 15 cm — W_3: Post emergence herbicide application (application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS)

Number of pods plant^{-1} of mungbean showed statistically significant variation due to methods of weed control (Appendix VIII). The highest number of pods plant^{-1} (18.82) was observed from W_2, which was statistically similar (18.63) to W_1 and closely followed (17.87) by W_3, again the lowest number (13.72) was found from W_0 treatment (Table 9). Bayan and Saharia (1996) reported that pods plant^{-1} was significantly influenced by weed management. Akter *et al*. (2013) reported the highest number of pods (22.03) plant^{-1} from three-stage weeding in mungbean.

Statistically significant variation was recorded in terms of number of pods plant^{-1} due to the interaction effect of different plant density and methods of weed control (Appendix VIII). The highest number of pods plant^{-1} (20.63) was recorded from D_3W_2 and the lowest (12.03) was recorded from D_1W_0 treatment combination (Table 10).

4.3.3 Number of seeds pod^{-1}

Statistically significant variation was recorded in terms of number of seeds pod^{-1} of mungbean due to different plant density (Appendix VIII). The highest number of seeds pod^{-1} (12.23) was obtained from D_3 which was closely followed (11.83 and 11.70) by D_4 and D_2 and they were statistically similar, whereas the lowest (10.63) from D_1 treatment (Table 9). Zaher *et al.* (2014) recorded the highest number of seeds pod^{-1} (9.43) was recorded by 30 cm row spacing.

Methods of weed control varied significantly in terms of number of seeds pod^{-1} of mungbean (Appendix VIII). The highest number of seeds pod^{-1} (12.17) was found from W_2, which was statistically similar (12.02 and 11.81) to W_1 and W_3, while the lowest (10.38) from W_0 (Table 9). Akter *et al*. (2013) reported the highest number of seeds (17.07) pod^{-1} from three-stage weeding in mungbean.

Number of seeds pod^{-1} showed significant variation due to the interaction effect of different plant density and methods of weed control (Appendix VIII). The highest number of seeds pod^{-1} (12.90) was found from D_3W_2, while the lowest number (10.07) was attained from D_1W_0 treatment combination (Table 10).

4.3.4 Pod length

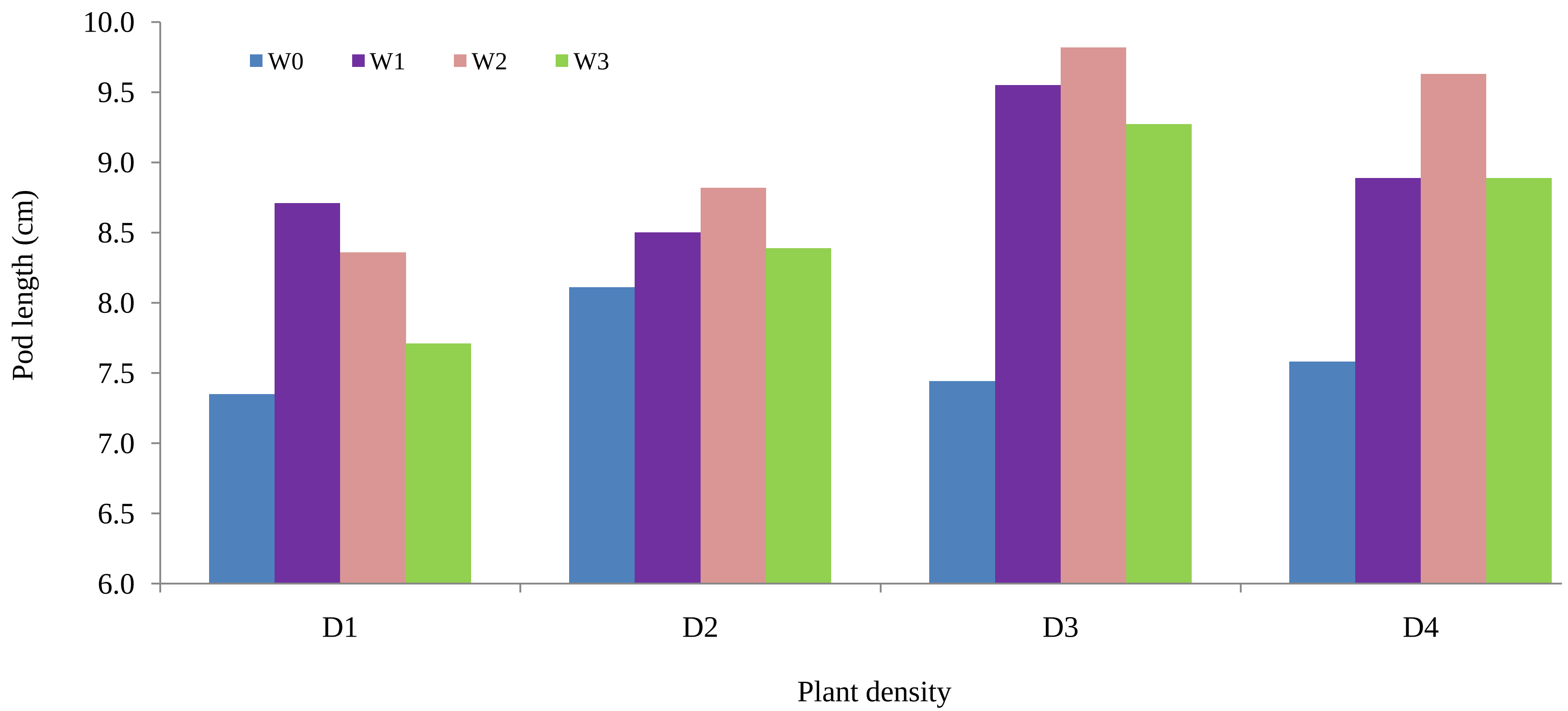
Pod length of mungbean varied significantly due to different plant density (Appendix VIII). The longest pod (9.02 cm) was recorded from D_3 which was statistically similar (8.74 cm) to D_4 and closely followed (8.45 cm) by D_2, while the shortest pod (8.03 cm) was obtained from D_1 treatment (Figure 8). Zaher *et al.* (2014) reported that the highest pod length (6.69 cm) from 30 cm row spacing.

Methods of weed control showed statistically significant variation in terms of pod length of mungbean under the present trial (Appendix VIII). It was revealed that the longest pod (9.15 cm) was observed from W_2, which was statistically similar (8.91 cm) to W_1 and closely followed (8.57 cm) by W_3, whereas the shortest pod (7.62 cm) was found from W_0 treatment (Figure 9). Akter *et al*. (2013) reported the longest pod (5.95 cm) from three-stage weeding in mungbean.

Statistically significant variation was recorded due to the interaction effect of different plant density and methods of weed control in terms of pod length of mungbean (Appendix VIII). The longest pod (9.82 cm) was observed from D_3W_2 and the shortest pod (7.35 cm) was found from D_1W_0 treatment combination (Figure 10).

4.3.5 Weight of 1000-seeds

Different plant density showed significant differences in terms of weight of 1000-seeds of mungbean (Appendix VIII). The highest weight of 1000-seeds (45.36 g) was observed from D_3 which was statistically similar (44.39 g and 42.54 g) by D_4 and D_2, again the lowest weight (41.17 g) was found from D_1 treatment (Table 9). Lowest 1000-seed weight at and lower and higher plant density might be due to lower amount of assimilate translocation from leaf to grain. Similar result was also reported by many workers (Singh and Singh, 1988; Tomar *et al.*, 1996; Chowdhury, 1999; Hassan, 2000; Singh *et al.*, 2003). They observed that 1000-seed weight decreased both in closed and wider spacing for plant in mungbean. On the broad leaf hand, BINA (2004) reported that plant density had no influenced on 1000-seed weight in mungbean.



D_1: 30 cm × continuous D_2: 30 cm × 5 cm W_0: No weeding (control) W_1: Two hand weeding (at 15 and 30 DAS)

D_3: 30 cm × 10 cm D_4: 30 cm × 15 cm W_2: Pre emergence herbicide application (Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS)

W_3: Post emergence herbicide application (Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS)

Figure 10. Interaction effect of plant density and methods of weed control on pod length (SE = 0.253)

Methods of weed control varied significantly in terms of weight of 1000-seeds of mungbean (Appendix VIII). The highest weight of 1000-seeds (44.74 g) was recorded from W_2, which was statistically similar (44.12 g and 43.68 g) to W_1 and W_3, whereas the lowest (40.92 g) from W_0 (Table 9). Cheema and Akther (2005) reported that 1000-grain weight increased with reduced weed infestation.

Interaction effect of different plant density and methods of weed control showed significant variation in terms of weight of 1000-seeds (Appendix VIII). The highest weight of 1000-seeds (48.35 g) was recorded from D_3W_2 and the lowest weight (40.06 g) was recorded from D_1W_0 treatment combination (Table 10).

4.4 Yield characters

4.4.1 Seed yield

Different plant density showed statistically significant variation in terms of seed yield of mungbean (Appendix IX). The highest seed yield (1.36 t ha^{-1}) was recorded from D_3 which was statistically similar (1.33 t ha^{-1}) to D_4 and closely followed (1.26 t ha^{-1}) by D_2, while the lowest (1.13 t ha^{-1}) was observed from D_1 treatment (Table 11). Plant density of mungbean may play an important role in interception of solar radiation, which might increase the yield. Kabir and Sarkar (2008) reported that 30 cm × 10 cm produced the highest seed yield. Similar result was also reported by many workers (Thakuria and Saharia, 1990; Tomar and Tiwari, 1996; Hassan, 2000; Singh *et al.,* 2003).

Statistically significant variation was recorded due to methods of weed control in terms of seed yield of mungbean under the present trial (Appendix IX). The highest seed yield (1.39 t ha^{-1}) was found from W_2, which was statistically similar (1.34 t ha^{-1}) to W_1 and closely followed (1.30 t ha^{-1}) by W_3, again the lowest seed yield (1.06 t ha^{-1}) was recorded from W_0 treatment (Table 11). Bayan and Saharia (1996) reported that seed yields were significantly influenced by weed management. Weeds infestation is one of the major factors lowering yield in pulses (Rehman and Ullah, 2009). About 69% reduction in mungbean grain yield due to weeds was estimated by Yadav and Sing (2005).

Table 11. Effect of plant density and methods of weed control on seed, stover, biological yield and harvest index

Treatments	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
Plant density				
D_1	1.13 c	1.56 c	2.69 c	42.04
D_2	1.26 b	1.65 b	2.91 b	43.36
D_3	1.36 a	1.75 a	3.11 a	43.86
D_4	1.33 a	1.70 ab	3.02 a	43.84
SE	0.016	0.024	0.032	0.427
CV(%)	4.31	5.02	3.73	3.42
Methods of weed control				
W_0	1.06 c	1.36 d	2.41 d	42.77
W_1	1.34 ab	1.78 b	3.12 b	42.84
W_2	1.39 a	1.85 a	3.24 a	43.87
W_3	1.30 b	1.67 c	2.97 c	43.61
SE	0.022	0.026	0.033	0.629
CV(%)	6.04	5.48	3.94	5.04

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

D_1: 30 cm × continuous

D_2: 30 cm × 5 cm

D_3: 30 cm × 10 cm

D_4: 30 cm × 15 cm

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 gm ha^{-1} at 3 DAS)

W_3: Post emergence herbicide application (application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS)

Seed yield of mungbean showed statistically significant variation due to the interaction effect of different plant density and methods of weed control (Appendix IX). The highest seed yield (1.47 t ha^{-1}) was observed from D_3W_2. On the other hand, the lowest seed yield (1.02 t ha^{-1}) was obtained from D_1W_0 treatment combination (Table 12).

4.4.2 Stover yield

Stover yield of mungbean varied significantly due to different plant density under the present trial (Appendix IX). The highest stover yield (1.75 t ha^{-1}) was observed from D_3 which was statistically similar (1.70 t ha^{-1}) to D_4 and closely followed (1.65 t ha^{-1}) by D_2, while the lowest (1.56 t ha^{-1}) was obtained from D_1 treatment (Table 11).

Methods of weed control showed significant variation in terms of stover yield of mungbean (Appendix IX). The highest stover yield (1.85 t ha^{-1}) was recorded from W_2, which was closely followed (1.78 t ha^{-1}) by W_1, while the lowest (1.36 t ha^{-1}) was observed from W_0 which was followed (1.67 t ha^{-1}) by W_3 treatment (Table 11).

Interaction effect of different plant density and methods of weed control showed significant variation in terms of stover yield (Appendix IX). The highest stover yield (1.94 t ha^{-1}) was found from D_3W_2, while the lowest (1.28 t ha^{-1}) was recorded from D_1W_0 treatment combination (Table 12).

4.4.3 Biological yield

Statistically significant variation were recorded in terms of biological yield of mungbean due to different plant density (Appendix IX). Data revealed that the highest biological yield (3.11 t ha^{-1}) was found from D_3 which was statistically similar (3.02 t ha^{-1}) to D_4 and closely followed (2.91 t ha^{-1}) by D_2, while the lowest (2.69 t ha^{-1}) was recorded from D_1 treatment (Table 11). Zaher *et al.* (2014) recorded the highest biological yield (3964 kg ha^{-1}) were gained by 30 cm row spacing.

Table 12. Interaction effect of plant density and methods of weed control on seed, stover, biological yield and harvest index

Treatments	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
D_1W_0	1.02 c	1.28 d	2.30 f	44.27
D_1W_1	1.16 c	1.71 bc	2.86 d	40.27
D_1W_2	1.29 b	1.84 ab	3.13 bc	41.33
D_1W_3	1.04 c	1.42 d	2.47 ef	42.27
D_2W_0	1.05 c	1.36 d	2.40 ef	43.62
D_2W_1	1.32 ab	1.81 a-c	3.13 bc	42.26
D_2W_2	1.35 ab	1.79 a-c	3.13 bc	42.98
D_2W_3	1.33 ab	1.66 c	2.99 cd	44.59
D_3W_0	1.08 c	1.36 d	2.44 ef	44.52
D_3W_1	1.45 a	1.86 ab	3.32 ab	43.83
D_3W_2	1.47 a	1.94 a	3.41 a	43.13
D_3W_3	1.44 ab	1.84 ab	3.28 ab	43.94
D_4W_0	1.08 c	1.44 d	2.52 e	43.07
D_4W_1	1.42 ab	1.74 bc	3.16 bc	44.99
D_4W_2	1.43 ab	1.85 ab	3.29 ab	43.64
D_4W_3	1.37 ab	1.76 bc	3.14 bc	43.65
SE	0.044	0.053	0.067	1.258
CV(%)	6.04	5.48	3.94	5.04

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

D_1: 30 cm × continuous — W_0: No weeding (control)

D_2: 30 cm × 5 cm — W_1: Two hand weeding (at 15 and 30 DAS)

D_3: 30 cm × 10 cm — W_2: Pre emergence herbicide application (application of Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS)

D_4: 30 cm × 15 cm — W_3: Post emergence herbicide application (application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS)

Biological yield of mungbean showed significant variation due to methods of weed control in terms (Appendix IX). The highest biological yield (3.24 t ha^{-1}) was recorded from W_2, which was closely followed (3.12 t ha^{-1}) by W_1, whereas the lowest (2.41 t ha^{-1}) was found from W_0 which was followed (2.97 t ha^{-1}) by W_3 treatment (Table 11).

Interaction effect of different plant density and methods of weed control varied significantly in terms of biological yield (Appendix IX). The highest biological yield (3.41 t ha^{-1}) was observed from D_3W_2 and the lowest (2.30 t ha^{-1}) was found from D_1W_0 treatment combination (Table 12).

4.4.4 Harvest index

Harvest index of mungbean showed significantly non significant differences due to different plant density (Appendix IX). The highest harvest index (43.86%) was attained from D_3 and the lowest (42.04%) was observed from D_1 treatment (Table 11). This result was supported by Hague (1995) in mungbean who observed that harvest index increased till 25 kg seeds ha^{-1} followed by decreased with increased seed rates.

Methods of weed control showed non significant variation in terms of harvest index of mungbean (Appendix IX). The highest harvest index (43.87%) was found from W_2, whereas the lowest value (42.77%) was recorded from W_0 treatment (Table 11).

Interaction effect of different plant density and methods of weed control showed non significant variation in terms of harvest index (Appendix IX). The highest harvest index (44.59%) was found from D_2W_3 and the lowest (40.27%) was observed from D_1W_1 treatment combination (Table 12).

Chapter 5

Summary and conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy Research Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from April to June, 2014 to find out the growth and yield of mungbean as affected by plant density and methods of weed control. The experiment comprised of two factors; Factor A: Plant density (4 levels)- D_1- 30 cm × continuous, D_2- 30 cm × 5 cm, D_3- 30 cm × 10 cm and D_4- 30 cm × 15 cm; Factors B: Methods of weed control (4 levels)- 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 gm ha^{-1} at 3 DAS) and W_3- Post emergence herbicide application (application of Whip Super 9 EC @ 750 ml ha^{-1} at 15 & 30 DAS). The varieties 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 different weed parameters, yield contributing characters and yield of mungbean showed statistically significant differences for plant density and methods of weed control.

For plant density, at 20 DAS, the maximum numbers of weed population m^{-2} (7.67) was recorded in D_4 and the minimum (6.08) in D_1. At 40 DAS, the maximum numbers of weed population m^{-2} (14.00) was recorded in D_1, while the minimum number (11.50) in D_3. At 20 DAS, the highest dry weight of weed biomass m^{-2} (4.21 g) was observed in D_4, while the lowest (3.92 g) in D_1 treatment. At 40 DAS, the highest dry weight of weed biomass m^{-2} (5.24 g) was recorded in D_4, whereas the lowest (4.88 g) in D_1.

At 20, 40, 60 DAS and at harvest, the tallest plant (31.46, 61.34, 84.75 and 85.95 cm, respectively) were observed from D_3, whereas the shortest (28.62, 55.32, 75.74 and 78.34 cm, respectively) from D_1. At 20, 40, 60 DAS and at harvest, the highest number of branches $plant^{-1}$ (1.28, 2.07, 2.53 and 2.78, respectively) were recorded from D_3 and the lowest (1.09, 1.75, 2.00 and 2.26, respectively) from D_1.

At 20, 40, 60 DAS and at harvest, the highest number of leaves plant^{-1} (14.75, 22.26, 26.10 and 23.20, respectively) were found from D_3, whereas the lowest (12.83, 18.75, 22.92 and 19.82, respectively) from D_1. At 20, 40, 60 DAS and at harvest, the highest dry matter content plant^{-1} (1.59, 5.29, 9.40 and 11.04 g, respectively) were found from D_3, while the lowest (1.29, 4.55, 7.96 and 10.14 g, respectively) from D_1.

The maximum days to flowering (39.08) was found from D_1, whereas the minimum days (34.67) from D_3. The highest number of pods plant^{-1} (18.92) was observed from D_3, while the lowest (15.02) from D_1. The highest number of seeds pod^{-1} (12.23) was obtained from D_3, whereas the lowest (10.63) from D_1. The longest pod (9.02 cm) was recorded from D_3, while the shortest pod (8.03 cm) from D_1. The highest weight of 1000-seeds (45.36 g) was observed from D_3 again the lowest weight (41.17 g) from D_1. The highest seed yield (1.36 t ha^{-1}) was recorded from D_3, while the lowest (1.13 t ha^{-1}) from D_1. The highest stover yield (1.75 t ha^{-1}) was observed from D_3, while the lowest (1.56 t ha^{-1}) from D_1 treatment. The highest biological yield (3.11 t ha^{-1}) was found from D_3, while the lowest (2.69 t ha^{-1}) from D_1. The highest harvest index (43.86%) was attained from D_3 and the lowest (42.04%) from D_1.

In case of methods of weed control, at 20 DAS the maximum numbers of weed population m^{-2} (15.92) was found in W_0, while the minimum number (3.50) in W_3. At 40 DAS, the maximum numbers of weed population m^{-2} (26.58) was recorded in W_0, while the minimum (7.00) in W_2. At 20 DAS, the highest dry weight of weed biomass m^{-2} (4.72 g) was recorded in W_0, while the lowest (3.72 g) in W_2. At 40 DAS, the highest dry weight of weed biomass m^{-2} (6.46 g) was observed in W_0, while the lowest (4.47 g) in W_2.

At 20, 40, 60 DAS and at harvest, the tallest plant (31.69, 61.42, 83.55 and 87.22 cm, respectively) were recorded from W_2, while the shortest (28.43, 55.33, 77.32 and 78.50 cm, respectively) from W_0. At 20, 40, 60 DAS and at harvest, the highest number of branches plant^{-1} (1.27, 2.08, 2.47 and 2.74, respectively) were found from W_2, whereas the lowest (1.12, 1.51, 1.90 and 2.00, respectively) from W_0. At 20, 40, 60 DAS and at harvest, the highest number of leaves plant^{-1} (15.32, 22.44, 26.94 and 24.23, respectively) were obtained from W_2, whereas the lowest number (11.67, 18.24, 20.62 and 18.33, respectively) from W_0. At 20, 40, 60 DAS and at harvest, the highest dry matter content plant^{-1} (1.61, 5.17, 9.00 and 11.01 g, respectively) were recorded from W_2 and the lowest dry matter (1.20, 4.62, 7.92 and 10.17 g, respectively) from W_0.

The maximum days to flowering (38.92) was found from W_3, while the minimum days (34.17) from W_2. The highest number of pods plant^{-1} (18.82) was observed from W_2, again the lowest number (13.72) from W_0 treatment. The highest number of seeds pod^{-1} (12.17) was found from W_2, while the lowest number (10.38) from W_0. The longest pod (9.15 cm) was observed from W_2, whereas the shortest (7.62 cm) from W_0. The highest weight of 1000-seeds (44.74 g) was recorded from W_2, whereas the lowest (40.92 g) from W_0. The highest seed yield (1.39 t ha^{-1}) was found from W_2 and the lowest (1.06 t ha^{-1}) from W_0. The highest stover yield (1.85 t ha^{-1}) was recorded from W_2, while the lowest (1.36 t ha^{-1}) from W_0. The highest biological yield (3.24 t ha^{-1}) was recorded from W_2, while the lowest (2.41 t ha^{-1}) from W_0. The highest harvest index (43.87%) was found from W_2, whereas the lowest (42.77%) from W_0.

Due to the interaction effect of different plant density and methods of weed control at 20 DAS, the maximum number of weed population m^{-2} (16.67) was found from D_4W_0, while the minimum (2.33) from D_1W_3 treatment combination. At 40 DAS, the maximum number of weed population m^{-2} (28.33) was found from D_1W_0, while the minimum (6.00) from D_3W_2. At 20 DAS, the highest dry weight of weed biomass m^{-2} (4.81 g) was recorded from D_1W_0, while the lowest (3.44 g) was found from D_3W_2. At 40 DAS, the highest dry weight of weed biomass m^{-2} (6.65 g) was observed from D_1W_0, whereas the lowest dry weight (4.15 g) was attained from D_3W_2.

At 20, 40, 60 DAS and at harvest, the tallest plant (34.32, 65.07, 87.60 and 89.50 cm, respectively) were observed from D_3W_2, while the shortest (24.86, 51.96, 73.58 and 74.28 cm, respectively) from D_1W_0. At 20, 40, 60 DAS and at harvest, the highest number of branches plant^{-1} (1.37, 2.37, 2.83 and 3.03, respectively) were observed from D_3W_2 and the lowest (1.00, 1.43, 1.77 and 1.87, respectively) from D_1W_0. At 20, 40, 60 DAS and at harvest, the highest number of leaves plant^{-1} (16.40, 24.87, 28.40 and 25.50, respectively) were recorded from D_3W_2, again the lowest number (11.00, 16.73, 19.70 and 17.47, respectively) from D_1W_0. At 20, 40, 60 DAS and at harvest, the highest dry matter content plant^{-1} (1.89, 5.84, 10.24 and 11.37 g, respectively) were observed from D_3W_2 and the lowest (1.05, 4.36, 7.48 and 9.63 g, respectively) from D_1W_0.

The maximum days to 1st flowering (42.33) was found from D_1W_0, while the minimum days (32.67) from D_3W_2. The highest number of pods plant^{-1} (20.63) was recorded from D_3W_2 and the lowest (12.03) from D_1W_0. The highest number of seeds pod^{-1} (12.90) was found from D_3W_2, while the lowest (10.07) from D_1W_0. The longest pod (9.82 cm) was observed from D_3W_2 and the shortest (7.35 cm) from D_1W_0. The highest weight of 1000-seeds (48.35 g) was recorded from D_3W_2 and the lowest (40.06 g) from D_1W_0. The highest seed yield (1.47 t ha^{-1}) was observed from D_3W_2 and the lowest (1.02 t ha^{-1}) from D_1W_0. The highest stover yield (1.94 t ha^{-1}) was found from D_3W_2, while the lowest (1.28 t ha^{-1}) from D_1W_0. The highest biological yield (3.41 t ha^{-1}) was observed from D_3W_2 and the lowest biological yield (2.30 t ha^{-1}) from D_1W_0. The highest harvest index (44.59%) was found from D_2W_3 and the lowest (40.27%) from D_1W_1.

Conclusion

It may be concluded that plant density of 30 cm × 10 cm and pre-emergence herbicide application (application of Topstar 80 WP @ 75 gm ha^{-1} at 3 DAS) can be more beneficial for the farmers to get maximum yield from the cultivation of BARI Mung-6.

References

REFERENCES

Agarcio, B. C. (1985). Effect of row spacing and time of weeding on the growth and yield of mungbean. *Annals Trop. Res.* 5(2): 83-90.

Ahmed, A., Karim, F., Shamdane, G. and Maniruzzaman, A. F. M. (1987). Effect of time of weeding and plant density on the growth and yield of mungbean. *Bangladesh J. Res*. **16**(2): 56-62.

Akter, R., Samad, M. A., Zaman, F. and Islam, M. S. (2013). Effect of weeding on the growth, yield and yield contributing characters of mungbean (*Vigna radiata* L.). *J. Bangladesh Agril. Univ*. **11**(1): 53–60.

AVRDC (Asian Vegetable Research and Development centre). (1981). Mungbean report for 1980. Shanhua, Taiwan. p. 76.

Bai, E. K. L. and Sinha, M. N. (1993). Effect of phosphorus and weed management on green gram (*Phaseolus radiatus*) and its residual effect on mustard. *Indian J. Agron*. **38**(l): 37-41.

BARI (Bangladesh Agricultural Research Institute). (1998). *Bangladesh-e Moog Daler Chash* (in Bangla)-Mungbean Cultivation in Bangladesh. Pulse Res. Sta., Bangladesh Agril. Res. Inst., Joydebpur, Gazipur-1701, Bangladesh. p. 45.

BARI (Bangladesh Agricultural Research Institute). (2005). *Krishi Projukti Hat Boi* (in Bangla)-Handbook on Agro-technology. Rashid *et al.* (Eds.). Bangladesh Agril. Res. Inst., Joydebpur, Gazipur-1701, Bangladesh. p. 100.

BARI (Bangladesh Agricultural Research Institute). (2005). Mungbean Cultivation in Bangladesh, p. 33.

Bayan, H. C. and Saharia, P. (1996). Effect of weed management and phosphorus and kharif greengram. *J. Agril. Sci. Soc.* **9**(2): 151-154.

BBS (Bangladesh Bureau of Statistics). (2012). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Govt. of Peoples Republic of Bangladesh. Dhaka. Bangladesh. p. 79.

BINA (Bangladesh Institute of Nuclear Agriculture). (1998). Annual Report of 1997-98. Bangladesh Inst. Nuclear Agric., Mymensingh. p. 23.

Borah, M. C. (1994). Effect of Rhizobium inoculation on mungbean varieties as affected by chemical fertilizers. *Botanical Conf., Dhaka. Bangladesh*. p. 9

Borras, L. Slafer, G. A. and Otegui, M. E. (2004). Seed dry weight response to source-sink manipulations in wheat, maize and soybean: a quantitative reappraisal. *Field Crop Res.* **86**: 131-146.

Bueren, E. T. L., Struik, P. C. and Jacobsen, E. (2002). Ecological concepts in organic farming and their consequences for an organic crop ideotype. *J. Life Sci*. **50**: 1-26.

Chattha, M. R., Jamil, M. and Mahmood, T. Z. (2007). Yield and Yield components of Mungbean as Affected by Various Weed Control Methods under Rain-fed Conditions of Pakistan. *Intl. J. Agric. & Biol*. **9**(1): 114–119.

Cheema, M. S. and Akther, H. (2005). Efficacy of different post emergence herbicides and their application methods in controlling weeds in wheat. Pakistan *J. Weed Sci. Res.* 11: 23-30.

Cheema, Z. A., Rakha, A. and Khaliq, A. (2000). Use of sorgaab and sorghum mulch for weed management in mungbean. Pakistan *J. Agric. Sci.* 37: 140-144.

Chowdury, A. S. (1999). Effect of seed rate and weeding regime on the yield and yield contributing characters of summer mungbean. M. S. Thesis, Dept. Agron., Bangladesh Agric. Univ., Mymensingh. P. 38.

Das, P. K. and Yaduraju, C. (1996). Response of molybdenum on the growth and yield of summer mungbean with and without inoculation. M.S. Thesis, Dept. Soil Sci., Bangladesh Agril. Univ., Mymensingh. p. 72.

El-Habbasha, K. M., Adam, S. M. and Rizk, F. A. (1996). Growth and yield of pea plant affected by plant density and foliar potassium application. *Egyptian J. Hort*. **23**: 35-41.

Enyi, A. K. (1973). Response of biofertilizer to nodulation, growth and yeild of different varieties of summer mungbean (*Vigna radiata* L.). M.S. Thesis, Dept. Soil Sci., Bangladesh Agril. Univ., Mymensingh. p. 59.

FAO (Food and Agriculture Organization). (1999). FAO Production Yearbook. Basic Data Unit. Statistic Division, FAO. Rome, Italy.

FAO (Food and Agriculture Organization). (2013). FAO Yearbook Production. p. 53.

Gautam, R. C. and Sharma, K. C. (1987). Dry matter accumulation under different planting schemes and plant densities of rice. Indian J. Agric. Res. 21: 101109.

Gomez, A. K. and Gomez, A. A. (1984). Statistical procedures for agricultural research. 2nd edn. John Wiley and Sons, New York. pp. 207-215.

Hague, M. M. (1995). Effect of plant population on the growth and yield of mungbean. *Bangladesh J. Sci. and Indus. Res.* **30**: 63-69.

Hasan, S. M. M. (2004). Effect of seed rate on the yield and quality of mungbean. M. S. Thesis, Dept. Agron., Bangladesh Agric. Univ., Mymensingh. p. 39.

Hassan, G. (2000). Effect of optimum plant population of mungbean. *Pakistan J. Agric. Sci*. **37**: 31-38.

Hassan. G., Khan, N. and Khan, H. (2003). Effect of zero tillage and herbicides on the weed density and yield of chickpea under rice based conditions of *Pakistan J. Weed Sci. Res*. **9**: 193-200.

Hossain, M. A., Karim, M. F. and Maniruzzaman, A. F. M. (1990). Response of summer mungbean to levels of field management. *Appl. Agric. Res*. **5**: 289-92.

Hussain, N., Khan, M.B. and Ahmad, R. (2008). Improving mungbean productivity in calcareous soils through band replacement of farmyard manure with phosphorus. *Internl. J. Agri Biol*. **10**: 709-714.

Islam, M. A., Mamun, A. A., Bhuiyan, M. S. U. and Hossain, S. M. A. (1989). Weed biomass and grain yield in wheat as affected by seed rate and duration of weed competition. *Bangladesh J. Agri*. **14**: 213-224

Jahan, M. S. and Hamid, A. (2004). Effect of population density and planting configuration on dry matter allocation and yield in mungbean (*Vigna* radiate (L). *Pakistan J. Biol. Sci*. **7**: 1493-1498.

Jeswani, L. M. and Saini, S. R. (1981). Summer Mung Technology. *Indian Farming*. 30: 73-74.

Jha, G. V., Santos, L. C. D., Peluzio, J. M. and Santos, G. R. D. (1997). Effect of different plant densities on mungbeans and rice beans. *Ohwi and Ohashi Revista*. **44**(252): 241-248.

Kabir, M. H. and Sarkar, M.A.R. (2008). Seed yield of mungbean as affected by variety and plant spacing in *Kharif*-I season . *J. Bangladesh Agril. Univ*. **6**(2): 239–244.

Kaulm J. N. and Singh, H. (2002). Role of Agronomy in Food Security. *In:* Recent Advances in Agronomy. Singh, Guriqbal, J. S. Kolar and H. S. Sekhon, (Eds.) Indian Society of Agronomy, New Delhi, pp. 1-36.

Khaliq, A., Aslam, Z. and Cheema, Z. A. (2002). Efficacy of different weed management strategies in mungbean (*Vigna radiata L.).* Intl. *J. Agric. and Biol*. **4**: 237-239.

Khan, F. S., Zammurad, I. A., Muhammad, A. and Hussain, S. (2008). Response of mungbean genotypes to rhizobium inoculum and varying levels of nitrogen fertilizer. *Pakistan J. Agric. Res*. **21**: 1-4.

Kumar, S. and Kairon, M. S. (1990). Studies on crop weed competition in summer mungbean. *Legume Res*. **13**: 110-112.

Kundu, R., Bera, P. S. and Brahmachari, K. (2009). Effect of different weed management practices in summer mungbean [*Vigna radiata* L.] under new alluvial zone of West Bengal. *J. Crop and Weed*. **5**(2): 117-121.

Mania, G. G., Joel, S. B. and Mordechai, G. (2002). Intra-plant versus inter-plant root competition in beans: avoidance, resources matching or tragedy of commons. *Plant Eco*. **160**: 235-247.

Mansoor, M., Khan, H., Ayaz, M., Zubair, M. and Nadim, M. A. (2010). Effect of different planting densities on some physiological parameters of mungbean. *Gomal Uni. J. Res*. **26**(2): 1-8.

Meylemans, B., Sangakkara, U. R. and Damme, Van, P. (1994). Critical period of weed competition for blackgram in Sri Lanka. In 46th Intl. Plant density and number of per hill on growth and yield of mungbeans cultivar *Walet. Agrivita*. **16**(2): 7882.

Miah, M. H. N., Karin, M. A., Rahman, M. S. and Islam, M. S. (1990). Performance of Nizershail under different row spacing. *J. Training Dev*. **3**: 31-34.

Miranda, G. V., Santos, I. C., Pleuzio, J. M. and Santos, G. R. (1997). Effect of different plant densities on mungbeans and rice beans. *Ohwi and Ohashi Revista*. **44**: 241-248.

Mitra, S. and Bhattacharya, B. K. (2005). Water use and productivity of green gram (Vigna radiate) as influenced by spacing, mulching and weed control under rain-fed upland situation of Tripura. *Indian J. Agric. Sci*. **75**: 52–4.

MoA (Ministry of Agriculture). (2014). *Monthly Hand Book of Agricultural Statistics, June.* p. 57.

Mondal, M. M. A. (2007). A study of source-sink relation in mungbean. A Ph.D Dissertation, Dept. Crop Bot., Bangladesh Agric. Univ., Mymensingh. P. 237.

Musa, M. A., Islam, M. B. and Rahman, M. M. (1982). Weed management studies on summer mungbean and blackgram. Paper presented at the internal review of E & R Project and RARS, BARI, Ishurdi, Pabna. 20-22 December, 1982.

Musa, M., Chawdhury, G. A., Khalid, A. H., Shahzad, M. A. and Cheema, N. M. (1996). Weed competition studies in mungbean. Absts. 5^{th}. *Pakistan weed Sci. Conf.* March 3-5.

Naeem, M., Saeed, A. and Hakoomat, A. (2000). Efficacy of faluazifop. Butyl (fusillade 25 EC) and fenoxaprop-P- ethyl (pumas 69 EW) for weed control in mungbean. *Pakistan J. Agric. Sci*. **37**: 1-2.

Naseem, S. M. (1982). Performance of mungbean as influenced by different seeding technique under varying cultural practices. Unpublished M.S. Thesis, University of the Philippines, Los Banos, Philippines. *Bangladesh J. Sci. Ind. Res*. **30**(l): 63-69.

Pandey, J. and Mishra, B. N. (2003). Effect of weed management practices in rice mustard-mungbean cropping system on weeds and yield of crops. *Annals Agric. Res*. **24**: 737–42.

Panwar, D. K. and Singh, R. (1980). Response of cowpea rhizobia on nodulation and yield of mungbean (*Vigna radiata L.* Wilczek). *J. Mycopathol. Res*. **36**(l): 17-23.

Panwar, J. D. S. and Sirohi, G. S. (1987). Studies on the effect of plant population of grain yield and its components in mungbean. *Indian J. Plant Physiol*. **30**: 412-414.

Pascua, H. M. (1988). Effect of row spacing and plant population density on two varieties of mungo. Ann. Rep. 1971-1972. UPCA, BPI, Philippines. pp. 30-34.

Pookpakdi, A. and Pataradilok, H. (1993). Response of genotypes of mungbean and blackgram to planting dates and plant population densities. *Kesetsart J. Natural Sci*. **27**: 395-400.

Potter, N. N. and Hotchkiss, J. H. (1997). Food Science. CBS publishers, New Delhi,India. pp: 403.

Rafiei, M. (2009). Influence of tillage and plant density on mungbean. *Eurasian J. Sust. Agric*. 3: 877-880.

Raghvani, M. S., Eunus, M. and Awal, M. A. (1985). Dry matter production and partitioning of mungbean (*Vigna radiata L.). Bangladesh J. Training and Dev*. **15**(1&2): 193-199.

Raklia, D. (1999). Efficacy of Sorghum allelopathy as weed control strategy. *Kasetsart J. Natural Sci*. **40**: 195-200.

Rana, M. M., Chowdhury, A. K. M. S. H. and Bhuiya, M. S. U. (2011). Effects of plant population and bio-fertilizer on the growth parameters of three summer mungbean cultivars. *Bangladesh J. Agril. Res*. **36**(3): 537-542.

Regan, K. L., Siddique, K. H. M. and Martin, L. D. (2003). Response of *Kabuli* chickpea (*Cicer arietinum* L.) to sowing rate in Mediterranean-type environments of south-western Australia. *Australian J. Expt. Agric*. **43**: 87-97.

Rehman, A. and Ullah, E. (2009). Model farming. Dawn the internet edition; May 13, 2009.

Sangakkara, U. R., Meylemans, B., Damme, P. and Van-Damme, P. (1995). Impact of different weed types on growth and yield of mungbean. *Agron. Crop Sci*. **175**(1): 15-23.

Sarker, A. K. and Mondal, M. H. (1985). A study on the effect of weeding on yield and yield attributes of several varieties /strains of mungbean. *Bangladesh J. Agril. Res*. **10**(1): 34-40.

Sekhon, H. S., Singh, G. and Brar, J. S. (2002). Effect of population density and planting geometry on the growth and yield of mungbean (*Vigna radiata* L.) genotypes. *Environ. Ecol*. **20**: 897-901.

Sharma, A. R. and Behera, U. K. (2009). Nitrogen contribution through *Sesbania* green manure and dual-purpose legumes in maize-wheat cropping system: Agronomic and economic considerations. *Plant Soil*. **325**: 289-304.

Singh, A. K. and Singh, N. P. (1995). Effect of varieties and seed rates on yield of mungbean and urdbean during summer. *Indian J. Pulses Res*. **8**: 90-92.

Singh, A. N., Singh, S. and Bhan, V. M. (1993). Crop weed competition in summer green gram. *Indian J. Agron*. **39**(3): 475-478.

Singh, A., Singh, S. and Bhan, V. M. (1996). Crop weed competition in summer green gram. *Indian J. Agron*. **14**(4): 616-619.

Singh, C. P. and Singh, H. P. (1988). Response of mungbean to plant population and planting pattern. *J. Agron*. **33**: 344-345.

Singh, G., Sekon, H. S., Sandhu, J. S. and Randhawa, A. S. (2003). Effect of location and seed rate on three genotypes of mungbean. *Trop. Sci*. **43**: 116-120

Singh, R. C., Singh, M., Dahira, D. R. and Phogat, S. B. (1985). Effect of dates of sowing and seed rates on summer season mungbean. *Indian J. Agron*. **31**: 187-188.

Talukader, M. A. M., Hashem, A. and Hamid, A. (1993). Effect of crop density and time of weeding on the performance of mungbean. *Annls. Bangladesh Agric*. **3**(2): 883-891.

Tessema, T. and Tanner, D. G. (1997). Grass weed competition and calculated economic threshold densities in bread wheat in Ethiopia. *African Crop Sci. J*. **5**: 371-384.

Thakuria, K. and Saharia, P. (1990). Response of greengram genotypes to plant density and phosphorus levels in summer. *Indian J. Agron*. **35**: 431-432.

Tomar, S. S. and Tiwari, A. S. (1996). Response of green gram and blackgram genotypes to plant density. *Gurjrat Agril. Univ. Res. J*. **21**: 88-92.

Tomar, S. S., Sharma, R. K., Verma, 0. P., Bhadouria, S. S. and Tomar, A. S. (1996). Effect of seed rate, irrigation and phophorus levels on the yield attrributes and net return of summer mungbean. *Bhartiya Krishi Anusandhan Patrika*. **11**(3): 136-140.

Tomar, S. S., Shrivastava, U. K., Sharma, R. K., Bhadouria, S. S. and Tomar, A. S. (1995). Physiological parameters of summer mungbean as affected by seed rate, moisture regime and phosphorus. *Legume Res.* **18**: 125-128.

Trung, B. C., Yoshida, S. and Kobayashi, Y. (1985). Influence of excess soil moisture on the nitrogen nutrition grain productivity mungbean. *Japanese J. Crop Sci*. **54**: 79-83.

USDA-ARS, Germplasm resources information network (GRIN). (2012). http://www.ars-grin.gov.

Uttam, I. H. (1988). Critical period of mungbean to weed competition. *Biotropia*. **2**(8-11).

Vaishya, R. D. and Singh, S. P. (1989). Integrated weed management in summer mungbean. *Indian J. Pulses Res*. **2**(2): 129-132.

Yadav, S. K., Bhan, V. M. and Singh, S. T. (1983). Crop weed competition studies in mungbean. *Expt. Agric*. **19**(4): 337-340.

Yadav, V. K. and S. P. Singh. (2005). Losses due to weeds and response to pendimethalin and fluchloralin in varieties of summer sown *Vigna radiate*. *Annals Pl. Protect. Sci*. **13**: 454–457.

Zaher, M. A. B., Roy, T. S., Rahman, M. M., Ali, M. O. and Haque, M. N. (2014). Row spacing and number of weeding on the yield performance of mungbean. *Intl. J. Sustain. Agril. Tech*. **10**(10): 01-07.

APPENDICES

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

Months	*Air temperature (^oC)		*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 Meteorological Department (Climate & 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
pH	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 weed population and dry matter content in weed as influenced by different plant density and methods of weed control

Sources of variation	Degrees of freedom	Mean squares			
		Weeds population (No.) at		Dry weight of weed biomass (g m^{-2})	
		20 DAS	40 DAS	20 DAS	40 DAS
Replication	2	0.021	0.000	0.003	0.002
Plant density (A)	3	5.389**	12.576**	0.234**	0.355**
Error	6	0.243	0.139	0.010	0.007
Methods of weed control (B)	3	440.611**	1040.076**	2.718**	11.546**
Interaction (A×B)	9	0.667*	1.299*	0.061**	0.105**
Error	24	0.299	0.576	0.019	0.028

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

Appendix IV. Analysis of variance of the data on plant height as influenced by different plant density and methods of weed control

Sources of variation	Degrees of freedom	Mean squares			
		Plant height (cm) at			
		20 DAS	40 DAS	60 DAS	Harvest
Replication	2	0.038	0.066	5.141	0.194
Plant density (A)	3	17.382*	83.795**	181.696**	138.366**
Error	6	3.267	3.223	9.495	6.456
Methods of weed control (B)	3	24.671*	83.255**	89.546**	169.156**
Interaction (A×B)	9	14.781*	9.573*	41.684*	19.220*
Error	24	6.391	3.756	13.562	9.175

** 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 plant^{-1} as influenced by different plant density and methods of weed control

Sources of variation	Degrees of freedom	Mean squares			
		Number of branches plant^{-1} at			
		20 DAS	40 DAS	60 DAS	Harvest
Replication	2	0.001	0.001	0.008	0.008
Plant density (A)	3	0.074**	0.232**	0.600**	0.594**
Error	6	0.004	0.010	0.016	0.019
Methods of weed control (B)	3	0.057**	0.815**	0.770**	1.361**
Interaction (A×B)	9	0.010*	0.025**	0.143*	0.842*
Error	24	0.004	0.008	0.025	0.013

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

Appendix VI. Analysis of variance of the data on number of leaves plant^{-1} as influenced by different plant density and methods of weed control

Sources of variation	Degrees of freedom	Mean squares			
		Number of leaves plant^{-1} at			
		20 DAS	40 DAS	60 DAS	Harvest
Replication	2	0.562	0.159	0.006	0.171
Plant density (A)	3	8.266*	25.673**	21.772**	26.749**
Error	6	1.363	0.762	0.711	2.151
Methods of weed control (B)	3	30.247**	38.067**	93.216**	80.370**
Interaction (A×B)	9	2.563*	5.313*	3.300*	37.437*
Error	24	1.032	1.098	1.180	3.248

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

Appendix VII. Analysis of variance of the data on dry matter content plant^{-1} as influenced by different plant density and methods of weed control

Sources of variation	Degrees of freedom	Mean squares			
		Dry matter content plant^{-1} (g) at			
		20 DAS	40 DAS	60 DAS	Harvest
Replication	2	0.006	0.012	0.024	0.001
Plant density (A)	3	0.197**	1.319**	4.721**	1.671**
Error	6	0.015	0.008	0.113	0.042
Methods of weed control (B)	3	0.412**	0.629**	2.674**	1.563**
Interaction (A×B)	9	0.052*	0.243*	0.723**	0.126*
Error	24	0.022	0.105	0.101	0.060

** 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 as influenced by different plant density and methods of weed control

Sources of variation	Degrees of freedom	Mean squares				
		Days to 1st flowering	Number of pods plant^{-1}	Number of seeds pod^{-1}	Pod length (cm)	Weight of 1000-seeds (g)
Replication	2	0.063	0.092	0.021	0.005	3.554
Plant density (A)	3	40.389*	31.812**	5.623**	2.135**	42.113*
Error	6	6.201	0.319	0.097	0.168	8.258
Methods of weed control (B)	3	60.167**	68.839**	8.101**	5.440**	34.186**
Interaction (A×B)	9	26.926*	3.996*	0.396*	0.537*	10.163*
Error	24	10.778	0.422	0.170	0.192	3.825

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

Appendix IX. Analysis of variance of the data on seed, stover, biological yield and harvest index as influenced by different plant density and methods of weed control

Sources of variation	Degrees of freedom	Mean squares			
		Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest Index (%)
Replication	2	0.001	0.006	0.010	0.943
Plant density (A)	3	0.128**	0.076**	0.400**	8.787
Error	6	0.003	0.007	0.012	2.186
Methods of weed control (B)	3	0.258**	0.575**	1.598**	3.660
Interaction (A×B)	9	0.013*	0.020*	0.054**	3.642
Error	24	0.006	0.008	0.013	4.748

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