GROWTH AND YIELD PERFORMANCE OF MUNGBEAN VARIETIES UNDER WATERLOGGING CONDITION

MD. ABDUR RAHMAN

Reg. No.: 15-06742

Email: rahmansau3@gmail.com

Mobile: 01701-974880

DEPARTMENT OF SOIL SCIENCE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

JUNE 2022

GROWTH AND YIELD PERFORMANCE OF MUNGBEAN VARIETIES UNDER WATERLOGGING CONDITION

By

MD. ABDUR RAHMAN

REGISTRATION NO.: 15-06742

Email: rahmansau3@gmail.com

Mobile: 01701-974880

A Thesis
submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka-1207,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)

IN

SOIL SCIENCE

SEMESTER: JANUARY-JUNE, 2022

APPROVED BY:

Prof. Mst. Afrose Jahan **Supervisor** **Department of Soil Science** **SAU, Dhaka**	**Prof. Dr. Alok Kumar Paul** **Co-Supervisor** **Department of Soil Science** **SAU, Dhaka**

Prof. Dr. Saiful Islam Bhuiyan
Chairman
Examination Committee
Department of Soil Science

DEPARTMENT OF SOIL SCIENCE

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

*This is to certify that the thesis entitled **'GROWTH AND YIELD PERFORMANCE OF MUNGBEAN GENOTYPES UNDER WATERLOGGING STRESS AT VEGETATIVE STAGE'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS)** in **SOIL SCIENCE**, embodies the result of a piece of bona fide research work carried out by **MD. ABDUR RAHMAN**, Registration number: **15-06742,** 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:
Place: Dhaka, Bangladesh

Prof. Mst. Afrose Jahan
Department of Soil Science
Supervisor

Dedicated to My

Beloved Parents

ACKNOWLEDGEMENTS

*Alhamdulillah, all praises are due to The Almighty **Allah Rabbul Al-Amin** for His gracious kindness and infinite mercy in all the endeavors the author to let him successfully completing the research work and the thesis leading to Master of Science degree.*

*The author would like to express his heartfelt gratitude and most sincere appreciations to his Supervisor **Prof. Mst. Afrose Jahan**, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, for her valuable guidance, advice, immense help, encouragement and support throughout the study. Likewise grateful appreciation is conveyed to Co-supervisor **Prof. Dr. Alok Kumar Paul**, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, for his constant encouragement, cordial suggestions, constructive criticisms and valuable advice to complete the thesis.*

*It is highly appreciating words for **Prof. Dr. Saiful Islam Bhuiyan**, Chairman, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka along with faculties of the Department of Soil Science, Sher-e-Bangla Agricultural University for their rendered novel services towards him as their student.*

The author would like to express his deepest respect and boundless gratitude to all the respected teachers of the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, for their valuable teaching, sympathetic co-operation, and inspirations throughout the course of this study and research work.

The author wishes to extend his special thanks to his classmates and friends for their keen help as well as heartiest co-operation and encouragement during experimentation.

The author is deeply indebted and grateful to his parents and relatives; without whose love, affection, inspiration and sacrifice this work would have not been completed.

Finally the author appreciates the assistance rendered by the staff members of the Department of Soil Science, Sher-e-Bangla Agricultural University Farm staff, Dhaka, who have helped him during the period of study.

The Author

GROWTH AND YIELD PERFORMANCE OF MUNGBEAN VARIETIES UNDER WATERLOGGING CONDITION

ABSTRACT

The experiment was conducted in the research field of Sher-e-Bangla Agricultural University, Dhaka during the period from March 2022 to June 2022 to find out the growth and yield performance of mungbean varieties under waterlogging condition. The experiment comprised of two factors; Factor A: V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8; and Factor B: W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data were recorded and significant variation was observed for most of the characters studied. Mungbean varieties and waterlogging condition had significantly influenced by growth and yield characters. In case of combined effect of variety and different waterlogging condition, significant variation was observed on the growth and yield of mungbean. Results indicated that the tallest plant (56.75 cm at 60 DAS), the maximum leaves plant^{-1} (15.67 at 60 DAS), branches plant^{-1} (4.27 at 60 DAS), pods plant^{-1} (25.25), seeds pod^{-1} (12.80), pod length (13.21 cm), 1000-seed weight (51.85 g), seed yield (1.82 t ha^{-1}), stover yield (3.21 t ha^{-1}), biological yield (5.03 t ha^{-1}), harvest index (36.15%), available phosphorus content (22.75 ppm) and exchangeable potassium content (18.33 meq 100 g^{-1} soil) in post harvest soil was obtained from V_2W_1 (BARI mung-7 growing at well watered condition) treatment combination. On the other hand, the shortest plant (50.00 cm at 60 DAS), minimum leaves plant^{-1} (10.75 at 60 DAS), branches plant^{-1} (3.00 at 60 DAS), pods plant^{-1} (15.75), seeds pod^{-1} (9.15), pod length (9.13 cm), 1000-seed weight (40.23 g), seed yield (1.34 t ha^{-1}), stover yield (2.72 t ha^{-1}), biological yield (4.06 t ha^{-1}), harvest index (33.00%), available phosphorus content (17.82 ppm) and exchangeable potassium content (13.33 meq 100 g^{-1} soil) in post harvest soil was recorded from V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) treatment combination. So, BARI mung-7 variety can be grown at well watered condition for obtaining higher yield of mungbean.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

Acronym		Full meanings
AEZ	=	Agro-Ecological Zone
%	=	Percent
^{0}C	=	Degree Celsius
BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
CV%	=	Percentage of coefficient of variance
cv.	=	Cultivar
DAS	=	Days after sowing
et al.	=	And others
FAO	=	Food and Agriculture Organization
g	=	Gram
ha^{-1}	=	Per hectare
kg	=	Kilogram
LSD	=	Least Significant Difference
MoP	=	Muriate of Potash
N	=	Nitrogen
No.	=	Number
NPK	=	Nitrogen, Phosphorus and Potassium
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resource and Development Institute
t	=	Ton
TSP	=	Triple Super Phosphate
viz.	=	Videlicet (namely)
Wt.	=	Weight

CHAPTER I

INTRODUCTION

CHAPTER I

INTRODUCTION

Mungbean (*Vigna radiata* L.) is an important legume and short duration pulse crop of Bangladesh and other South Asian Countries. Mungbean also known as green gram or golden gram is one of the most important pulse crops in Bangladesh. It belongs to the family Leguminosae. It is native to the Indian subcontinent and mainly cultivated in India, China, Thailand, Philippines, Indonesia, Myanmar, Bangladesh, Laos and Cambodia but also in hot and dry regions of Europe and the United States. It is used as food stuffs in both savory and sweet dishes.

In Bangladesh, daily consumption of pulses is only 17.80 g capita^{-1} (BBS, 2017), while The World Health Organization (WHO) suggested 45 g capita^{-1} day^{-1} for a balanced diet. Due to shortage of production 291 thousands metric ton pulses was imported in Bangladesh in 2016-17 fiscal year (BBS, 2017). Though total pulse production in Bangladesh is 270 thousand metric ton (BBS, 2017), but to provide the abovementioned requirement of 45 g capita^{-1} day^{-1}, the production has to be increased even more than three folds. It has good digestibility and flavor. It contains 48% protein, 1-3% fat, 50.4% carbohydrates, 3.5-4.5% fibers and 4.5-5.5% ash, while calcium and P are 132 and 367 mg per 100 grams of seed, respectively (Frauque *et al.*, 2000). Hence, on the nutritional point of view, mungbean is perhaps the best of all other pulses (Khan, 1981 and Kaul, 1982), contains almost triple amount of protein as compared to rice. It can also minimize the scarcity of fodder because the whole plant or it’s by product can be used as good animal feed. It is a popular crop in the daily diet of the people of Bangladesh. Pulses have been considered as “poor men's meat” since pulses contains more protein than meat and also more economical, they are the best source of protein for the underprivileged people. It is taken mostly in the form of soup which is commonly known as "dal". Generally, there is no complete dish without "dal" in Bangladesh. Green pulse seeds also can be consumed as fried peas or can be used in curry. Cultivation of pulses also can improve the physical, chemical and biological properties of soil as well as increase soil fertility status through N fixation. As a whole, mungbean could be considered as an inevitable component of sustainable agriculture.

The major cropping pattern in Bangladesh consists of two major crops of rice (*i.e.* boro rice-fellow-aman rice). In Bangladesh, more than 75% of the total cropping area is occupied by rice where pulse crop covers only 3.1% of the total cropping area (BBS, 2017). Mungbean is one of the important pulse crops of Bangladesh. It grows well in all over Bangladesh. The majority portion is being produced in southern part of the country. Among the pulse crops the largest area is covered by lentil (40.17%) and mungbean is grown in only 6.34% area (BBS, 2017). The cultivation of mungbean in Bangladesh is tends to increase and it covers 55, 56 and 67 thousand acres respectively in the 2014-15, 2015-16 and 2016-17 fiscal years (BBS, 2017). At present the average yield of mungbean grain in our country is about 281 kg acre^{-1} (BBS, 2017). So, mungbean can be a good solution for the increasing need of plant protein.

It is recognized that pulses offer the most practical means of solving protein malnutrition in Bangladesh but there is an acute shortage of grain legumes in relation to its requirements, because the yield of legumes in farmer's field is usually less than 1 t ha^{-1} against the potential yield of 2 to 41 ha^{-1} (Ramakrishna *et al.,* 2000). Low yields of grain legumes, including mungbean make the crop less competitive with cereals and high value crops. Therefore, to meet the situation it is necessary to boost up the production through varietal development and proper management practices as well as summer mungbean cultivation. The possibilities of growing mungbean in summer are being experimented and some successes have already been made in Bangladesh. Bangladesh Agricultural Research Institute (BARI), Bangladesh Institute of Nuclear Agriculture (BINA), Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) developed 17 mungbean varieties with yield potentials in recent years. Very recently, with the introduction of some high yielding varieties like BARI MUNG-5, BARI MUNG-6, BARI MUNG-7 and BARI MUNG-8 increasing attention is being paid to the cultivation of this crop in order to mitigate the alarmingly protein shortage in the diet of our people.

Mungbean cannot withstand waterlogging, particularly during the early stages of growth (Singh and Singh, 2011). Extensive grain yield losses have also been observed when the plants are young. Flooding or waterlogging reduces oxygen concentrations around the roots of the submerged plants and restricts nodule activity and nitrogen fixation. Thus, mungbean is not suited to the wet tropics, where the annual precipitation is above 1,000 mm (Fernandez and Shanmugasundaram, 1988).

Waterlogging stress is a global constraint limiting crop yield (Borrego-Benjumea *et al.*, 2021). It is ranked second to drought based on severe damage to crop production and substantial economic losses (Olorunwa *et al.*, 2022). Among all the abiotic stresses, 65% of agricultural crop losses were attributed directly to waterlogging stress, costing the global economy an estimated USD 74 billion each year (FAO, 2017). Recent data suggests that over 16 percent of the world's cultivated land is affected by transient waterlogging (PLoSchuk *et al.*, 2018) and over 17 million km^2 of land is at risk of flooding (Voesenek and Sasidharan, 2013). According to the current climate change forecast, waterlogging events are predicted to increase, and to become a great challenge for sustainable mungbean cultivation (IPCC, 2021).

Waterlogging tolerance is a highly complex phenomenon, and plants have evolved a variety of tolerance mechanisms that include changes in morphological and physiological parameters such as adventitious root production (Lambers and Oliveira, 2019; Qi *et al.*, 2019), parenchyma development, and alteration in leaf (epinasty) and shoot morphology (Wu *et al.*, 2018), maintaining higher levels of gas exchange (Barickman *et al.*, 2019) and chlorophyll a fluorescence parameters (Smethurst and Shabala, 2003). Moreover, under waterlogging stress, plants adapt various other mechanisms which involve higher acquisition of soluble sugars, enhanced fermentation activity, and reactive oxygen (ROS)-scavenging enzymes (Anee *at al.*, 2019; Armstrong *et al.*, 2019), along with responses involving hormones such as ethylene and abscisic acid. Waterlogging has been shown to cause a variety of morpho-physiological alterations in mungbean genotypes depending on the growth stage, duration, and soil type (Islam *et al.*, 2007; Sharma and Dhanda, 2014). Various studies have reported a reduction in stomatal conductance accompanied by CO_2 assimilation under waterlogged situations in the mungbean (Wagner ansd Dreyer, 1997; Valentini *et al.*, 1995), resulting in reduced growth (Musgrave and Ding, 1998). The more pronounced early effects found in sensitive genotypes included a drop in photosynthesis and stomatal conductance. In mungbean, several growth parameters including root growth, leaf area, leaf chlorophyll content, photosynthesis, stomatal conductance, water use efficiency, and total biomass are severely impacted by waterlogging and predate the effect on yield, and thus could be used in screening for waterlogging tolerance (Ahmed *et al.*, 2002; Kumar *et al.*, 2013).

Keeping in the view of the importance of mungbean genotypes in Bangladesh and in relation to waterlogging tolerance under different levels of waterlogging at vegetative growth stages, this experiment was undertaken to achieve the following objectives.

Objectives:

1. Compare the growth and yield of mungbean variety under waterlogging condition.
2. To find out suitable waterlogging stress-tolerant variety based on morpho-physiological traits.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Although many research works on mungbean have been performed extensively in several countries in the world, in Bangladesh, little attention has so far been given for the improvement of mungbean variety or its cultural management. Currently Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) have started extensive research work on varietal development and improvement of this crop. A very few studies related to yield and development of mungbean have been carried out in our country as well as many other countries of the world, which is not adequate and conclusive. In this chapter, an attempt has been made to review the available information at home and abroad regarding the yield performance of mungbean genotypes under water logging stress at vegetative stages.

2.1 Effect of variety on growth and yield of mungbean

Hossain *et al.* (2016) conducted an experiment to find out the performance of different mungbean varieties in summer season at the field laboratory of the Sher-e-Bangla Agricultural University, Bangladesh during March to June, 2014. Seven mungbean varieties were laid out in a Randomized Complete Block Design (RCBD) with three replications. BARI mung-3 showed the highest plant height whereas maximum leaves per plant found for BINA moog-8. The early flowering or days to first flowering was found in BINA moog-8 and the late flowering was recorded in BARI mung-6. The minimum days to attainment of the highest length of pod was found in BINA moog-8 and the maximum time were recorded in BARI mung-2 and BARI mung-6. The highest number of fertile seeds per pod was recorded in BINA moog-8 and the lowest number of fertile seeds per pod was observed in BARI mung-4. The highest number infertile seeds per pod were recorded in BARI mung-4 and the lowest number of infertile seeds per pod was observed in BINA moog-8. BINA moog-8 showed the maximum pod length and 1000-seed weight while the minimum was observed in BARI mung-4. The highest yield was recorded in BINA moog-8 and the lowest in BINA moog-5. Most of the morphological and yield contributing characters of BINA moog-8 was favorable for better yield in summer cultivation. So the production of mungbean can be increased by the cultivation of BINA moog-8 in summer season.

Uddin *et al.* (2009) carried out an experiment in experimental field of the department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to investigate the interaction effect of variety and fertilizers on the growth and yield of summer mungbean during the summer season of 2007. Five levels of fertilizer viz. control, N + P +K, Biofertilizer, Biofertilizer + N + P + K and Bio-fertilizer + P + K. and three varieties BARI mung-5, BARI mung-6 and BINA mung-5 were also used as experimental variables. The experiment was laid out in Randomized Block Design with fifteen treatments where each treatment was replicated three times. Results showed that most of the growth and yield component of mungbean *viz.* plant height, branch plant, number of nodules plant^{-1}, total dry matter plant^{-1}, pods plant^{-1}, seed plant^{-1}, seed pod^{-1}, weight of 1000-seeds, seed yield and stover yield were significantly influence by the bio-fertilizer (*Bradyrhyzobium* inoculums) treatment except number of leaves and dry weight of nodule. These are influenced by chemical fertilizer and biofertilizer also. All the parameters performed better in case of *Bradyrhyzobium* inoculums. BARI mung-6 obtained highest number of nodule plant and higher dry weight of nodule. It also obtained highest number of pod plant^{-1}, seed plant^{-1}, 1000 seed weight and seed yield. Interaction effect of variety and bio-fertilizer (*Bradyrhyzobium*) inoculation was significant of all the parameters. BARI mung-6 with *Bradyrhyzobium* inoculums produced the highest number of nodule and pod plant. It also showed the highest seed yield, stover yield and 1000-seed weight.

Parvez *et al.* (2013) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from October to January 2011 to study the performance of mungbean as affected by variety and level of phosphorus. The experiment comprised four varieties *viz.* BARI Mung-6, Binamoog-4, Binamoog-6 and Binamoog-8 and four levels of phosphorus viz. 0, 20, 40 and 60 kg P_2O_5 ha^{-1}, and laid out in a Randomized Complete Block Design with three replications. Results revealed that the longest plant, highest number of branches plant^{-1}, number of total pods plant^{-1}, seeds plant^{-1} and seed weight plant^{-1} were obtained from BARI Mung-6. The longest plant, highest number of branches plant^{-1}, number of total pods plant^{-1}, number of mature pods plant^{-1}, length of pod, seed weight plant^{-1}, 1000-seed weight, seed yield, stover yield and harvest index were obtained when 60 kg P_2O_5 was applied. Binamoog-6 produced the highest seed yield which was as good as Binamoog-8. The second highest and the lowest seed yield were recorded from Binamoog-4 and BARI Mung-6, respectively. The highest stover yield was obtained from Binamoog-8 followed by Binamoog-4. The lowest stover yield was recorded from BARI Mung-6. The highest seed yield was recorded when phosphorus was applied at the rate of 60 kg P_2O_5 ha^{-1} which was statistically identical to 40 kg P_2O_5 ha^{-1}. The intermediate and the lowest seed yield were obtained when phosphorus was applied at the rate of 20 kg P_2O_5 ha^{-1} and control treatment, respectively. The highest stover yield was obtained when 60 kg P_2O_5 ha^{-1} was applied but the lowest stover yield was recorded in control treatment (0 kg P_2O_5 ha^{-1}). The highest plant height, number of branches plant^{-1}, number of total pods plant^{-1} and seeds pod^{-1} were obtained from BARI Mung-6 in combination with 60 kg P_2O_5 ha^{-1}. The highest seed yield was obtained from Binamoog-6 when 60 kg P_2O_5 ha^{-1} was applied which was as good as Binamoog-8 in combination with 60 kg P_2O_5 ha^{-1} and the highest stover yield was recorded from Binamoog-8 with 60 kg P_2O_5 ha^{-1}. It can be concluded that mungbean variety Binamoog-6 or Binamoog-8 can be grown with higher dose of phosphorus (60 kg P_2O_5 ha^{-1}) for higher seed yield.

Miah *et al.* (2009) conducted an experiment to identify the suitable variety (s) and optimum sowing date for getting maximum yield of summer mungbean. Four mungbean [*Vigna radiata* (L.) Wilczek] varieties viz. BINA moog2, BINA moog5, BINA moog6 and BINA moog7 were sown at 10 day intervals starting from 20 February to 11 April. Among the varieties BINA moog7 was ranked first in terms of seed yield (938.40 kg ha^{-1}) followed in order of BINA moog6 (711.72 kg ha^{-1}), BINA moog5 (684.00 kg ha^{-1}) and BINA moog2 (547.80 kg ha^{-1}). BINA moog6 matured earlier than the other three varieties. The highest seed yield (969.62 kg ha^{-1}) was obtained from 2 March sowing followed by 20 February (917.54 kg ha^{-1}) and 12 March sowing (869.52 kg ha^{-1}). Sowing after 2 March gradually decreased the seed yield producing the lowest value (388.87 kg ha^{-1}) at 11 April sowing. In general, delayed sowing enhanced the maturity. BINA moog7 yielded the highest (1201.32 kg ha^{-1}) when sown on 2 March, which was statistically similar to 20 February and 12 March sowing. Therefore, summer mungbean variety BINA moog7 may be sown during the period from 20 February to 12 March for higher seed yield and for late sowing, BINA moog6 may be considered as it matures earlier than others.

Buriro *et al.* (2015) examined the growth and yield response of two mungbean (Mung-06 and NM-92) varieties to different application rates of potassium was evaluated under field condition. Plants were fertilized with five K (00, 50, 75, 100 and 125 kg ha^{-1}) levels. The data obtained from the study indicated that there was significant effect of potassium levels on growth, yield and yield components of both varieties. Compared to Mung-06, the variety NM-92 performed well by displaying maximum seed germination, taller plants with more branches, pods, seeds and biological yield. In addition to the recommended rates of nitrogen and phosphorus, the K applied @ 125 kg ha^{-1} significantly increased seed germination, plant height, number of branches per plant, number of pods, seed index and biological yield of mungbean (kg ha^{-1}) as well. The difference between 125 and 100 kg K ha^{-1} rates for majority of the growth and yield parameters under study remained non-significant. However, the plants given 75, 50 and 00 kg K ha^{-1} ranked 3rd, 4th and 5th, respectively for all the recorded yield parameters. It is, therefore, concluded that 100 kg K ha^{-1} can be the effective rate for achieving economically higher mungbean yield.

Kaysha *et al.* (2020) a field trial was conducted to evaluate the effects of inter-row spacing and fertilizer rate on the performance of mungbean varieties at Kindo Koysha district, in 2018. The experiment comprised factorial combinations of two varieties (Shewarobit, N-26), three inter-row spacing of planting (20, 30 and 40 cm) and four NPS fertilizer rate (0, 50, 100 and 150 kg ha^{-1}) was laid out using randomized complete block design with three replications. The results indicated that the three-way interaction effect of variety, fertilizer and row spacing significantly influenced above-ground dry biomass. Further, the two-way interaction effect of variety with fertilizer rate significantly ($P < 0.05$) influenced yield and yield attributing traits. Accordingly, the maximum number of pod per plant (14.7), grain yield ha^{-1} (1294.7 kg ha^{-1}) and harvest index were recorded for N-26 variety at 150 kg NPS ha^{-1}. Moreover, economic analysis also indicated that the highest net benefit of 33168.00 ETB ha^{-1} was recorded for mungbean variety N-26 grown at 100 kg NPS ha^{-1}. Based on the result of this study, it can be tentatively concluded that producing variety N-26 at the rate of 100 kg NPS ha^{-1} found to be promising treatment combination for better productivity and higher economic return in the study area.

Tehulie *et al.* (2021) conducted an experiment to determine the effect of inter and intra row spacing on growth, yield components and yield of mung bean varieties under irrigation. The treatments consisted of factorial combinations of three inter row spacing (30, 40, and 50 cm), three-intra row spacing (5, 10 and 15 cm) and two mung bean varieties (N-26 and MH-97) laid out in randomized complete block design with three Replications. The main effect of varieties, inter row spacing and intra row spacing was highly significant and significant on plant height, secondary branch and where the longest plant height (41.71 cm) was for variety MH-97 and from 5 cm intra row spacing, respectively and maximum number of secondary branch was recorded for variety MH-97 (8.91) and from 15 cm intra row and 50 cm inter row spacing, respectively. The interaction effect of the variety, inter and intra row spacing was highly significant on number of primary branch per plant, number of pod per plant and crop stand count percentage where the highest number of primary branches (7.00) was recorded from variety MH-97 at 50 cm inter row spacing and highest number pods per plant (30.15) were recorded for variety MH-97 at 40 cm inter row and (31.34) at 15 cm intra row spacing. Where the highest crop stand count at harvest was recorded from variety MH-97 (97.00%) at 40 cm inter row spacing. The main effect of inter row spacing and intra row spacing were highly significant and significant on above ground dry biomass and the highest above ground dry biomass at inter row spacing of 30 cm (5968.8 kg ha^{-1}) and intra row spacing 5 cm 6145.9 kg ha^{-1}). The main effect of variety, inter-row and intra-row spacing were highly significant on harvest index and grain yield where the highest harvest index was from variety MH-97 (20.91%), inter row spacing of 40 cm which give (21.18%) and intra row spacing 10 cm which give (20.30%) and the highest grain yield from Variety MH-97 (1117.94 kg ha-1), inter row spacing 40 cm (1213.75 kg ha^{-1}) and intra row spacing 10 cm which give (1151.67 kg ha^{-1}). However, this tentative generalization based one season at one location requires further studies over years and locations to give a valid recommendation.

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

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

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

Kabir and Sarker (2008) carried out an experiment was to study the effect of variety and planting density on the yield of mungbean in *Kharif*- I season (February to June) of 2003. The experiment comprised five varieties *viz.* BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5 and BINA Mung-2 and three spacing of planting *viz.* 30 cm × 10 cm, 20 cm × 20 cm and 40 cm × 30 cm. The experiment was laid out in a randomized complete block design with three replications. It was observed that BARI Mung-2 produced the highest seed yield and BINA Mung-2 did the lowest. 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. BARI Mung-2 planted at a spacing of 30 cm × 10 cm gave the maximum seed yield.

Jahan *et al.* (2020) conducted a field experiment comprising two varieties of mungbean, BARI Mung-5 (V_1) and BARI Mung-6 (V_2), and five levels of phosphorus fertilizer: triple super phosphate [$Ca(H_2PO_4)$] *viz.* T_1 (control), T_2 (42.5 kg P ha^{-1}), T_3 (85 kg P ha^{-1}), T_4 (127.5 kg P ha^{-1}), and T_5 (170 kg P ha^{-1}). The experiment was organized in a randomized complete block design with three replications. V_1 produced the highest number of pods per plant (7.65), whereas the maximum 1,000-seed weight (49 g) was produced by V_2. The maximum plant height (30.89 cm), number of branches per plant (8.55), number of leaves per plant (19.05), number of pods per plant (10.25), pod length (8.95 cm), number of seeds per pod (9.11), 1,000-seed weight (48.17 g), and yield (1.05 t ha^{-1}) were obtained from the T_4 treatment. The interaction of phosphorus levels and varieties had a considerable effect on the growth, yield, and yield attributes of mungbean. The highest number of leaves (20.44) and number of pods (10.39) were obtained from V_1 when 127.5 kg P ha^{-1} (T_4) was applied, whereas the maximum number of seeds per pod (9.25) and maximum pod length (9.09 cm) were obtained when 85 kg P ha^{-1} and 42.5 kg P ha^{-1}, respectively, were used. The highest number of branches per plant (8.87), 1,000-seed weight (52.83 g), and the maximum seed yield (1.14 t ha^{-1}) were achieved from the treatment V_2T_4 owing to the interactive effect of phosphorus dose and mungbean variety.

Belay *et al.* (2019) carried out a field experiment during the 2016 and 2017 main cropping seasons using a randomized complete block design with three replications in order to evaluate eight characteristics viz., days to 50% flowering, seed filling period, 90% physiological maturity, plant height, number of pod per plant, number of seeds per pod, seed yield and thousand seed weight for six mung bean varieties under rain-fed conditions at Abergelle Agricultural Research Center on station in Ethiopia. Analysis of variance showed that, differences varietal was observed for traits studied ($p \leq 0.05$) except number of pods per plant. The variety Rasa had better performance than the other varieties with the highest seed yield (1776 kg ha^{-1}), while the lowest seed yield was obtained from local Sheraro (889 kg ha^{-1}). Thus, Rasa is recommended as promising variety to the farmers of Abergelle areas.

Rabbani *et al.* (2013) carried out a field experiment was at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh during the period from January to May 2010 to study the effect of sowing date on the performance of mungbean varieties. Four mungbean [*Vigna radiata* (L.) Wilczek] varieties *viz.* BINA moog2, BINA moog5, BINA moog6 and BINA moog7 were sown at 15-day intervals starting from 31 January to 2 March 2010 to identify the suitable variety and optimum sowing date for getting maximum yield. Among the varieties BINA moog7 was ranked first in terms of seed yield (1.85 t ha^{-1}) which was statistically similar to BINA moog6 (1.84 t ha^{-1}) followed by the variety BINA moog5 (1.51 t ha^{-1}). BINA moog6 matured earlier than the other three varieties. The highest seed yield (1.77 t ha^{-1}) was obtained from 2 March sowing followed by 15 February (1.67 kg ha^{-1}) and 31 January sowing produced the lowest seed yield (1.44 kg ha^{-1}). BINA moog7 yielded the highest (1.95 kg ha^{-1}) when sown on 2 March which was statistically identical with BINA moog6 with 2 March (1.92 t ha^{-1}) and BINA moog7 sown in 15 February (1.92 t ha^{-1}). Therefore, summer mungbean varieties BINA moog7 or BINA moog6 may be sown during the period from 15 February to 2 March for obtaining higher seed yield.

Rahman *et al.* (2016) conducted a study was at Bangladesh Agricultural University, Mymensingh during March-June, 2013 to evaluate the performance of mungbean varieties and to determine the optimum seed rate under strip tillage system. Three mungbean varieties (BARI Mung-6, Binamung-5 and Binamung-8) were tested against five seeding rates (20, 25, 30, 35 and 40 kg ha^{-1}). The experiment was laid out in split-plot design with three replications. The study revealed that variety and seed rate had significant effect on plant population, pods $plant^{-1}$, pod length, seeds pod^{-1}, seed yield and stover yield of mungbean. The highest seed yield was obtained from Binamung-5 at 35 kg seed ha^{-1} while the highest stover yield was obtained from 40 kg seed ha^{-1}. For BARI Mung-6 and Binamung-8, 35 kg seed ha^{-1} also provided higher seed yield than other seeding rates. Nevertheless, the lowest seed and stover yields were obtained from Binamung-8 with 20 kg seed ha^{-1}. Therefore, the study concluded that machine seeding of mungbean at 35 kg seed ha^{-1} ensure optimum seed yield for tested varieties under strip tillage system and cultivation of Bina mung-5 at 35 kg seed ha^{-1} can produce the maximum seed yield under this system.

2.1 Effect of waterlogging condition on growth and yield of mungbean

Islam *et al.* (2014) examined the growth and yield responses of three mungbean genotypes viz. VC3950-88, VC6173A and BARI Mung-5 to three different environmental stresses viz. wet puddling, soil flooding and saturated soil culture. Wet puddling significantly reduced the field emergence and vigor index of seedlings. Height of plants was also adversely affected due to the stresses, although recovery was comparatively better in flooded situation. Irrespective of growing conditions, leaf chlorophyll index reduced significantly and recovered almost completely. The extraordinary responses of plants to all the stresses were the damaging of roots and/or impairing of root and shoot growth. The subsequent recovery of root and shoot growth significantly varied depending on the types of stresses. The development of numerous adventitious roots and the production of greater amount of root nodules were the most important recovery mechanisms of plants to withstand flooding situation and saturated soil culture, respectively. As a result, seed production was less affected under these two conditions. In contrast, wet puddling situation performed the worst, showing depressed plant growth throughout the growing period and thus seed production was affected the most. Among the genotypes, VC6173A was best adapted under the three stresses, giving the highest seed yield by producing higher amount of pods, increased seed size and longer pod.

Ullah (2006) carried out three experiments were at Sher-e-Bangla Agricultural University during July, 2000. In experiment I, seeds were drowned in water for 12, 24, 36, 48, 60, 72, 84, 96 and 108 hours and then set in pertridishes to evaluate germination performance. In experiment 2, seeds were soaked in water for 12, 24, 36, 48, 60 and 72 hours and then were sown in soil of polythene bags to evaluate seedling emergence. In experiment 3, seeds were sown in soils of earthen pots and then the pots along with soil were drowned in water for 12, 24, 36 and 48 hours. The results showed that water logging over 24 hours delayed germination significantly. Water logging over 48 hours reduced the germination significantly and that over 60 hours reduced germination drastically. Water logging over 72 hours caused failure in germination. Water logging over 12 hours delayed seedling emergence significantly. But, water logging up to 48 hours significantly improved the emergence percentage of seedlings and that over 48 hours caused drastic reduction in seedling emergence. In experiment 3, it was seen that significantly lower values of almost all the physiological parameters were found with successive increase in duration of water logging over 12 hours.

Kumar *et al.* (2013) conducted a study to examine the physiological response of contrasting mung bean (*Vigna radiata*) genotypes viz., T 44 & MH–96–1 (tolerant) and Pusa Baisakhi & MH–1K–24 (sensitive) under waterlogging conditions. Plants were waterlogged at vegetative stages (30 days after sowing) for 3, 6 and 9 days. Waterlogging resulted in decreased leaf area, crop growth rate, root growth and nodules number, membrane stability index, photosynthesis rate, chlorophyll and carotenoid contents, flowering rate, pod setting, yield and altered dry matter partitioning. Sensitive genotypes showed large reductions in aforementioned physiological traits and slow recovery in photosynthesis rate. On the other hand, tolerant genotypes maintained higher photosynthetic rate, chlorophylls and carotenoids, growth rate, membrane stability and fast photosynthetic recovery under waterlogging. After 9 days of exposure to waterlogging, photosynthetic rate and yield losses in most sensitive genotype (MH-1K-24) were 83 and 85 %, respectively. On an average, photosynthetic loss at 3, 6 and 9 days of waterlogging was 43, 51, and 63 %, respectively, while grain yield loss was 20, 34 and 52 % respectively.

Nahar *et al.* (2020) revealed that waterlogging is a major constraint of mungbean production in the tropical and subtropical regions of the world and can cause a significant yield loss. The study evaluated 100 mungbean genotypes for tolerance to waterlogging employing rigorous field screening procedures. Three-week-old seedlings of 100 mungbean genotypes were subjected to waterlogging for 3 days maintaining a waterlogging depth of 2.5 cm. Waterlogging tolerance was evaluated during the periods of recovery and final harvest considering relative performance (values of waterlogging relative to non-waterlogging controls) of 18 plant traits. All the genotypes showed a wide range of variation in relative values. Some genotypes subjected to waterlogging produced plenty of adventitious roots that contributed to foliage development and chlorophyll increment, which resulted in better shoot growth, and eventually yield of mungbean increased. Nine plant traits highly associated in waterlogged conditions were used in cluster analysis. The genotypes within cluster 6 and cluster 7 performed better regarding almost all plant traits whereas cluster 4 performed very poorly. Discriminant function analysis showed that function 1 and function 2 explained 54.5% and 32.2%, respectively and altogether 86.7% variation in the genotypes. The harvest index and straw dry matter mostly explained the total variance in function 1. Dry matter of root, shoot and straw explained the maximum variance in function 2. Root dry matter played the most dominant role in explaining the maximum variance in the genotypes. The genotypes IPSA-10 and VC 6379 (23-11) showed a better degree of tolerance to waterlogging concerning yield and associated morpho-physiological traits.

Amin *et al.* (2017) conducted a study on yield performance of 10 selected mungbean (*Vigna radiata* L. Wilczek) genotypes, *viz.* GK-7, GK-48, GK-65, VC-6173A, CO-3, IPSA-12, IPSA-13, IPSA-15, BARI Mug-5 and BUmug 2 was evaluated under waterlogged condition in the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during April to July 2011. Waterlogging depth was 3-5 cm, created by irrigation from tap water and imposed at 22 days after emergence of seedlings which was maintained for 2, 4 and 6 days in the three different treatments. Yield and yield contributing characters of the mungbean genotypes were significantly affected by waterlogging. The longer the waterlogging period, the more was the reduction in seed yield and yield contributing characters. Among the 10 genotypes, IPSA-13 performed the best in respect of grain yield production under waterlogging condition, which was followed by VC-6173A and BUmung 2.

Rana *et al.* (2019) carried out a field experiment was at the experimental field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, 1706 during kharif II season to evaluate 26 blackgram genotypes for understanding the flood tolerance in respect of yield and yield contributing characters. The experiment was laid out with a randomized complete block design with three replications. Water logging depth was 3-5 cm, created by irrigation from tap water and imposed at 29 days after emergence of seedlings which was maintained for 8 days. Multivariate analysis was performed involving eight qualitative plant characters. A wide range of variation was found for all the qualitative plant characters like plant height, plant dry weight, branches per plant, pods per plant, pod length, seeds per pod, 1000-seed weight and yield per plant. Flooding reduced all the growth parameters of blackgram but degree of reduction varied greatly over the blackgram genotypes. Considering yield performance, the genotypes BU Acc 25 showed the highest yield per plant (9.03 g) followed by the BU Acc 17 (6.47 g) and BU Acc 24 (6.17) under flooding . The yield reduction percent of the same genotypes were minimum (43.86, 60.82 and 65.96, respectively) compared to control which is very important for selection of those genotypes as a flooding tolerant.

Neashata *et al.* (2020) examined with some promising mungbean genotypes were employed to evaluate waterlogging tolerance and molecular characterization using SSR marker. Waterlogging treatment was applied to 25-d old plants maintaining 2-3 cm waterlogging depth for three days with extended seven days saturation period. It significantly reduced the growth and yield but the plants remarkably improved their depressed characters during the recovery period. The early response of waterlogging was the development of adventitious roots which is an important adaptive mechanism of plants under waterlogged situations. Based on waterlogging tolerance index calculated as the percent ratio of relative growth rate (RGR) in waterlogged plants and RGR in non-waterlogged plants of all plant components, the genotypes ACC12890054 and BUmug 4 appeared as the most tolerant to waterlogging. The genotypes ACC12890085 and ACC 12890054 that showed better tolerance to waterlogging gave the highest relative yield of 46% followed by BUmug 4 and VC 6173-A genotypes. Based on the correlation coefficient and relative values, the genotypes were grouped into four clusters using K-means cluster analysis. In SSR analysis, PIC values of the markers were above or almost equal to 0.5 indicating the used primers were effective to differentiate the genotypes at the molecular level. In analysis 16 pairs of mungbean genotypes showed 41.7% maximum dissimilarity. We grouped 12 genotypes into four clusters using unweighted pair group method with arithmetic mean (UPGMA). These four main clusters are distinctly dissimilar to each other on the base of genetic characters. Thus, the findings of this research could be used for envisaging promising mungbean genotypes and developing waterlogged-tolerant mungbean variety(s).

Kyu *et al.* (2021) carried out a study aimed to compare the waterlogging tolerance of mungbean and blackgram genotypes under the varying duration of waterlogging stress at germination and seedling stages. We evaluated the responses to different durations of transient waterlogging in a sandy clay loam under temperature-controlled glasshouse conditions. Waterlogging durations were 0, 1, 2, 3, 4, 5, 6, 7, and 8 days during germination and 0, 2, 4, 8, and 16 days during the seedling stage. We used two mungbean genotypes (green testa), Celera II-AU (small-seeded), and Jade-AU (large-seeded), contrasting in seed size and hypocotyl pigmentation, and a blackgram genotype (black testa), Onyx-AU. Waterlogging reduced soil redox potential delayed or even prevented germination, decreased seedling establishment, and affected shoot and root development. In the seedlings waterlogged (WL) at 15 days after sowing (DAS), adventitious root formation and crown nodulation varied between the genotypes, and 16 days of waterlogging substantially reduced growth but did not result in plant death. Plants in soil with waterlogging for 8-16 days followed by drainage and sampling at 39 DAS had reduced shoot and root dry mass by 60-65% in mungbean and 40% in blackgram compared with continuously drained controls, due at least in part to fewer lateral roots. Soil plant analysis development (SPAD) chlorophyll content was also reduced. Onyx-AU, a blackgram genotype, was more tolerant to transient waterlogging than Jade-AU and Celera II-AU in both growth stages. Of the two mungbean genotypes, Celera II-AU had a greater seedling establishment than Jade-AU post waterlogging imposed at sowing. In contrast, Jade-

AU had more plant biomass and greater recovery growth than Celera II-AU after waterlogging and recovery during the seedling stage. Both species were delayed in emergence in response to the shorter periods of transient waterlogging at germination, and with the longer waterlogging germination and emergence failed, whereas at the seedling stage both showed adaptation by the formation of adventitious roots.

Binh and Tai (2021) conducted a study to evaluate the germination, physiological responses, yield-related traits, and seed yield of three mungbean varieties, *viz.* DXVN7, DXVN5, and DX11, under waterlogging conditions in the 2019 summer. In experiment 1, the seeds of the three mungbean varieties were immersed in distilled water in Petri dishes for 12, 24, 36, 48, and 72 hours. Afterwards, water was removed and the percentage of germinated seeds was calculated at 84h after sowing. In experiment 2, plants were waterlogged at the seedling stage (25 days after germination) for 3, 6, and 9 days. Waterlogging depth was maintained at 3cm above the soil surface. Physiological traits were determined at the recovery period after termination of waterlogging (45 days after germination). The results showed that waterlogging significantly decreased germination percentages, plant height, root dry weight, leaf relative water content (RWC), SPAD value, Fv/Fm index, leaf photosynthesis, total dry weight, and seed yield of all varieties. Germination percentages at 12 and 24 hours of waterlogging were not significantly affected, whereas germination was significantly reduced at up to 36 hours of waterlogging. Seventy-two hours of waterlogging caused failure in germination. Nine days of waterlogging at the seedling stage adversely affected the physiological traits and seed yield of the mungbean varieties with 31% of yield reduction. Meanwhile, plants grew better at 3 days of waterlogging. Among the three varieties, DXVN7 showed the best adaptability under waterlogging conditions, attaining the highest seed germination and yield.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh during the Kharif season from March 2022 to June 2022 to study the response of mungbean to variety and different levels of waterlogging condition. This chapter presents a brief description about location, soil and climatic condition of the experimental area, crop or planting materials, treatments, experimental design and layout, crop growing procedure, intercultural operations, data collection and statistical analysis. The details of the materials and methods have been presented below:

3.1 Description of the experimental site

The experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka 1207. The location of the experimental area was situated at 23°77´N latitude and 90°33´ E longitude at an altitude of 8.5 meter above the sea level. The experimental field belongs to the Agro-ecological zone of "The Madhupur Tract", AEZ-28.

3.2 Climate and weather

The geographical location of the experimental site was under the subtropical climate, having 3 distinct seasons, winter season from November to February, the pre-monsoon period or hot season from March to April and monsoon period from May to October. The climate was characterized by heavy rainfall, high humidity, high temperature and relatively long day temperature and short day period during the Rabi season including the month of October to March.

3.3 Soil Characteristics

The soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soil was clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and had organic matter 1.33%. The experimental area was flat having available irrigation and drainage system and above flood level.

A. Morphological characteristics of the initial soil

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow Red Brown Terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical propertics of the initial soil

Characteristics	Value
%Sand	27
%Silt	43
%Clay	30
Textural class	Clay loam
pH	5.6
Organic carbon (%)	0.77
Organic matter (%)	1.33
Total N (%)	0.06
Available P (ppm)	18.50
Exchangeable K (meq 100 g^{-1} soil)	0.10
Available S (ppm)	22.0

3.4 Plant materials

Three mungbean varieties *viz.*, BARI Mungbean-6, BARI Mungbean-7 and BARI Mungbean-8 released by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The seeds of those varieties were used as the planting materials for this study.

3.5 Treatments and treatment combinations of experiment

The experiment comprised of two factors *viz.*, mungbean varieties and waterlogging condition.

Factor A: Varieties (3)

a) BARI mung-6 (V_1)

b) BARI mung-7 (V_2) and

c) BARI mung-8 (V_3)

Factor B: Waterlogging condition (3)

a) W_0= Control (no irrigation)

b) W_1= Well watered (under normal condition) and

c) W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

There were 9 treatment combinations. The treatment combinations are as follows: V_1W_0, V_1W_1, V_1W_2, V_2W_0, V_2W_1, V_2W_2, V_3W_0, V_3W_1 and V_3W_3.

3.6 Experimental design and lay out

The two-factorial experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The size of the individual plot was 1.5 m × 1.0 m and total numbers of plots were 27. There are 9 treatment combinations. Each block was divided into 9 unit plots and the treatments were assigned in the unit plots at random. Lay out of the experiment was done on 22nd February, 2022 with inter plot spacing of 0.50 m and inter block spacing 0.50 m.

3.7 Land preparation

The plot selected for the experiment was opened by power tiller driven rotovator on the 5th March 2022; afterwards the land was ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed and the large clods were broken into smaller pieces to obtain a desirable tilth of soil for sowing of seeds. Finally, the land was leveled and the experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in the following section.

3.8 Fertilizers application

The sources of N, P, K, S, Zn and B were urea, triple superphosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate and boric acid. Fertilizers were applied 24-32-48-3-1.5 kg NPKSZnB ha^{-1}, respectively. Half of urea and all other fertilizers were applied during the final land preparation. Rest of urea will be top dressed in two equal splits at 35 and 65 DAS.

3.9 Seed collection and sowing

Seeds of BARI mung-6, BARI mung-7 and BARI mung-8 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Seeds were sown in the main field on the 7th March, 2022 having line to line distance of 30 cm and plant to plant distance of 10 cm.

3.10 Cultural and management practices

Various intercultural operations such as plant thinning, weeding, and insecticide spraying were carried out as needed to keep the plants healthy and the field weed free. The plants were attacked by cutworm at a very early growth stage (after l5 days of seedling emergence), which was removed by applying Malathion. Special precautions were taken to protect the crop from birds, particularly during the sowing and germination stages. The field was irrigated twice, once after 15 days and again after 30 days.

3.11 Harvesting

The crop was harvested at maturity on 15th May 2022. The harvested crop of each plot was bundled separately. Seed and stover yields were recorded plot wise and the yields were expressed in t ha^{-1}.

3.12 Collection of experimental data

Five (5) plants from each plot were selected as random and were tagged for the data collection. Data were collected at 30, 45 and 60 DAS. The sample plants were cut down to ground level prior to harvest and dried properly in the sun. The seed yield and stover yield per plot were recorded after cleaning and drying those properly in the sun. Data were collected on the following parameters:

i. Plant height (cm)
ii. Number of leaves plant^{-1}
iii. Number of branches plant^{-1}
iv. Number of pod plant^{-1}
v. Pod length (cm)
vi. Seed per pod
vii. 1000-seed weight
viii. Seed yield (t ha^{-1})
ix. Stover yield (t ha^{-1})
x. Biological yield (t ha^{-1})
xi. Harvest index (t ha^{-1})
xii. Available phosphorus content (ppm) in post harvest soil sample and
xiii. Exchangeable potassium content (meq 100 g^{-1} soil) in post harvest soil sample

3.13 Recording of data

i) Plant height (cm)

The plant height was measured from the ground level to the top of the canopy of 5 randomly selected plants from each plot and averaged. It was done at the maturity stage of the crop.

ii) Number of leaves plant^{-1}

No. of leaves were counted from 5 randomly selected plants at 30, 45 and 60 different days after sowing (DAS) from each plot and averaged.

iii) Number of branches plant^{-1}

No. of branches plant^{-1} were counted from 10 randomly selected plants at 45 and 60 days after sowing (DAS) from each plot and averaged.

iv) Number of pods plant^{-1}

Pods of 5 randomly selected plants were counted at 60 days after sowing (DAS) from each plot and averaged.

v) Pod length (cm)

Pod length (cm) of 5 randomly selected plants were measured at 60 days after sowing (DAS) from each plot and averaged.

vi) Seeds pod^{-1}

Seeds in pods of 5 randomly selected plants were counted at maturity stage from each plot and averaged.

vii) 1000-seed weight (g)

1000-seed from each plot were collected after harvest and weighed.

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

Seeds obtained from 1 m^2 area from the center of each individual plot was dried, weighed carefully and then converted into t ha^{-1} as yield.

ix) Stover yield (t ha^{-1})

Stover obtained from 1 m^2 area from the center of each individual plot was dried, weighed carefully and expressed in t ha^{-1}.

x) Biological yield (t ha^{-1})

Biological yield is the summation of grain yield and straw yield. Biological yield was determined using the following formula:

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

xi) Harvest index (%)

Harvest index denotes the ratio of grain yield to biological yield and was calculated with the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Seed yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

xii) Available phosphorous content (ppm) in post harvest soil sample

Available phosphorous was extracted from the soil by Bray-1 method (Bray and Kurtz, 1945). Phosphorous in the extract was determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a spectrophotometer.

xiii) Available Potassium content (meq 100 g^{-1} soil) in post harvest soil sample

Available potassium was extracted from soil by 1N ammonium acetate. The exchangeable potassium content in plant samples were determined by flame photometer (Black, 1965).

3.14 Statistical analysis

The collected data were compiled and tabulated. Statistical analysis was done on various characters to find out the significance of variance resulting from the experimental treatments. Data were analyzed using analysis of variance (ANOVA) technique with the help of computer package program MSTAT-C (software) and the mean differences were adjudged by least significant difference test (LSD) as laid out by Gomez and Gomez (1984).

CHAPTER IV

RESULTS AND DISCUSSION

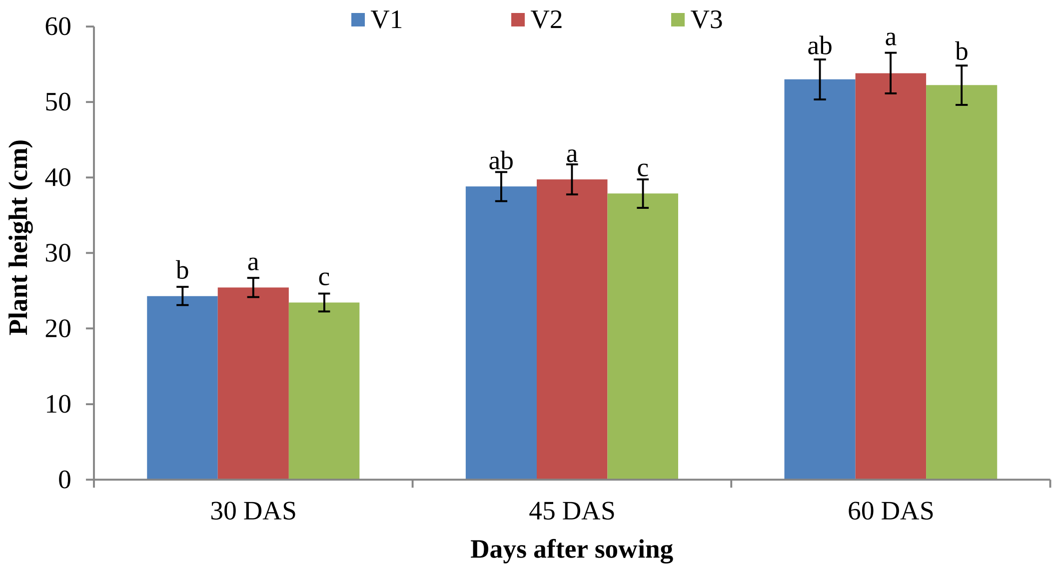
CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to evaluate the growth and yield performance of mungbean varieties under waterlogging condition at vegetative stage. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Plant height (cm)

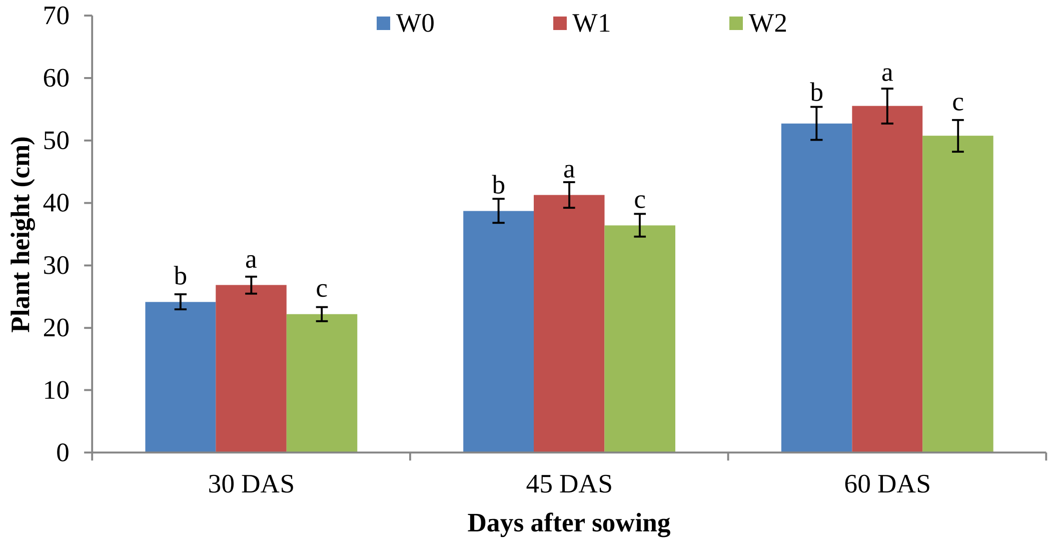
Significant influenced was observed on plant height by different varieties of mungbean at different growth stages (Figure 1). Results found that the tallest plant (25.43, 39.75 and 53.81 cm at 30, 45 and 60 DAS, respectively) was achieved from the variety, V_2 (BARI mung-7) which was statistically similar with V_1 at 45 and 60 DAS, respectively. On the other hand, the shortest plant (23.45, 37.87 and 52.22 cm at 30, 45 and 60 DAS, respectively) was observed from the variety, V_3 (BARI mung-8). This might be due to varietal execution. Similar results on plant height were also obtained by Hossain *et al.* (2016), Uddin *et al.* (2009) who revealed that plant height of mungbean significantly influenced by varietal execution.



V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8

Figure 1. Effect of variety on plant height at different days after sowing of mungbean

Plant height at different growth stages was significantly influenced by different levels of waterlogging condition in the study (Figure 2). It was observed that the tallest plant (26.84, 41.29 and 55.52 cm at 30, 45 and 60 DAS, respectively) was obtained from the treatment, W_1 (Well watered under normal condition) where the shortest plant (22.19, 36.41 and 50.76 cm at 30, 45 and 60 DAS, respectively) was found from the treatment, W_2 (Waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS). Binh and Tai (2021) reported that growth parameters of mungbean significantly influenced by waterlogging condition. Rana *et al.* (2019) also observed the similar trends.



W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

Figure 2. Effect of waterlogging condition on plant height at different days after sowing of mungbean

Significant difference on plant height of mungbean at different growth stages was observed in the study. Combined effect of variety and different levels of waterlogging condition showed significant differences (Table 1 and Appendix IV). Results observed that the tallest plant (28.67, 42.33 and 56.75 cm at 30, 45 and 60 DAS, respectively) was found from the treatment combination of V_2W_1 (BARI mung-7 growing at well watered condition) which was statistically similar with V_1W_1 treatment combination at 45 and 60 DAS, respectively. The shortest plant (21.35, 35.27 and 50.00 cm at 30, 45 and 60 DAS, respectively) was obtained from the treatment combination of V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) which was statistically similar with V_1W_2 treatment combination at 30, 45 and 60 DAS, respectively; with V_2W_2 treatment combination at 60 DAS.

Table 1. Combined effect of variety and waterlogging condition on plant height at different days after sowing of mungbean

Treatment combinations	Plant height at		
	30 DAS	45 DAS	60 DAS
V_1W_0	24.15 cde	38.72 cde	52.81 de
V_1W_1	26.55 b	41.18 ab	55.28 ab
V_1W_2	22.24 fg	36.51 fg	50.87 fg
V_2W_0	24.62 cd	39.47 bcd	53.25 cd
V_2W_1	28.67 a	42.33 a	56.75 a
V_2W_2	23.00 ef	37.45 ef	51.42 efg
V_3W_0	23.71 de	38.00 def	52.13 def
V_3W_1	25.29 c	40.35 bc	54.53 bc
V_3W_2	21.35 g	35.27 g	50.00 g
$LSD_{0.05}$	**1.18**	**1.96**	**1.68**
CV%	**2.80**	**2.92**	**1.83**

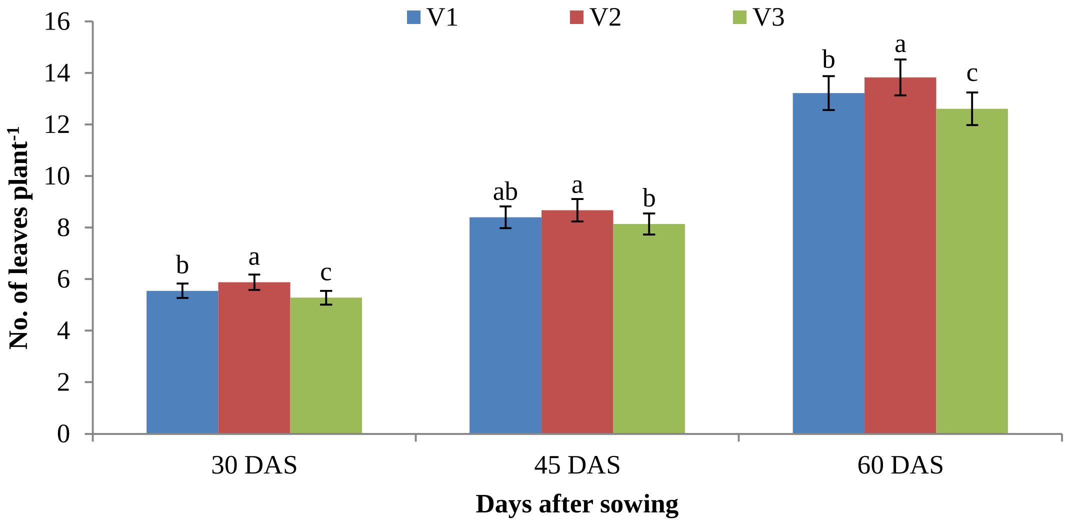
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Here, V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8;

W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

4.2 Number of leaves plant^{-1}

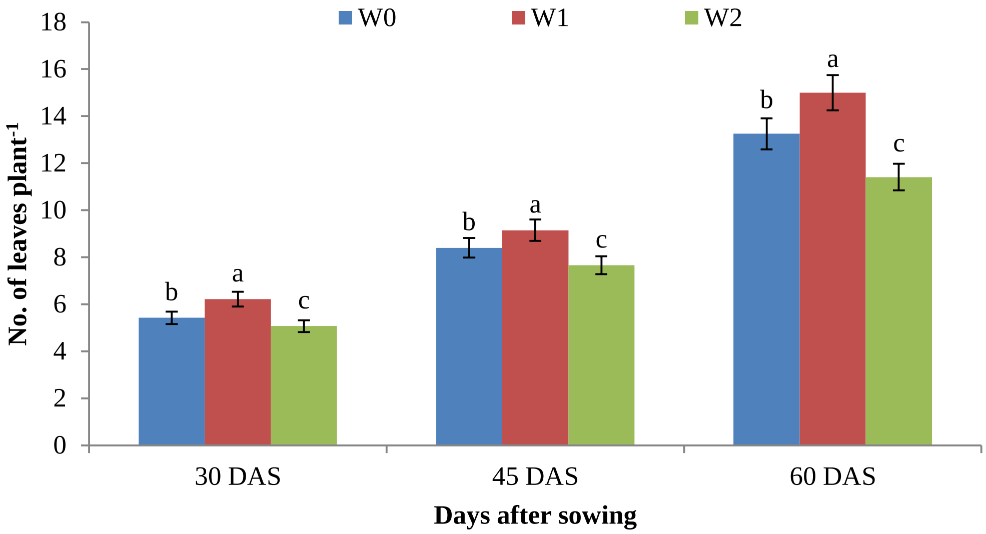
Significantly influence on number of leaves plant^{-1} was revealed under the study due to different varieties of mungbean at different growth stages (Figure 3). Result noted that the maximum number of leaves plant^{-1} (5.88, 8.67 and 13.83 at 30, 45 and 60 DAS, respectively) was observed from the variety, V_2 (BARI mung-7) which was statistically similar with V_1 at 45 DAS and the minimum number of leaves plant^{-1} (5.28, 8.14 and 12.61 at 30, 45 and 60 DAS, respectively) was achieved from the variety, V_3 (BARI mung-8). Similar trend of results was also obtained by Hossain *et al.* (2016) and Jahan *et al.* (2020). Jahan *et al.* (2020) reported that the interaction of phosphorus levels and varieties had a considerable effect on the growth, yield, and yield attributes of mungbean.



V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8

Figure 3. Effect of variety on number of leaves plant^{-1} at different days after sowing of mungbean

Significant variation was found on number of leaves plant^{-1} at different growth stages influenced by different levels of waterlogging condition (Figure 4). Results showed that the maximum number of leaves plant^{-1} (6.22, 9.15 and 15.00 at 30, 45 and 60 DAS, respectively) was obtained from the treatment, W_1 (Well watered under normal condition). The minimum number of leaves plant^{-1} (5.07, 7.66 and 11.41 at 30, 45 and 60 DAS, respectively) was found from the treatment, W_2 (Waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS). Ullah (2006) reported that water logging over 48 hours reduced the germination, plant height, leaves number significantly and that over 60 hours reduced germination and growth parameters drastically.



W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

Figure 4. Effect of waterlogging on number of leaves plant^{-1} at different days after sowing of mungbean

Significant influenced on number of leaves plant^{-1} of mungbean at different growth stages was found by combined effect of variety and different levels of waterlogging condition (Table 2 and Appendix V). Results showed that the maximum number of leaves plant^{-1} (6.45, 9.50 and 15.67 at 30, 45 and 60 DAS, respectively) was obtained from the treatment combination of V_2W_1 (BARI mung-7 growing at well watered condition) which was statistically similar with V_1W_1 treatment combination at 45 DAS. The lowest number of leaves plant^{-1} (4.72, 7.43 and 10.75 at 30, 45 and 60 DAS, respectively) was achieved by the treatment combination of V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) which was statistically similar with V_1W_2 treatment combination at 45 DAS, respectively.

Table 2. Combined effect of variety and waterlogging condition on number of leaves plant^{-1} at different days after sowing of mungbean

Treatment combinations	Number of leaves per plant at		
	30 DAS	**45 DAS**	**60 DAS**
V_1W_0	5.45 d	8.33 cd	13.27 d
V_1W_1	6.21 b	9.15 ab	14.92 b
V_1W_2	5.00 e	7.72 ef	11.48 g
V_2W_0	5.67 c	8.67 bcd	13.81 c
V_2W_1	6.45 a	9.50 a	15.67 a
V_2W_2	5.51 cd	7.83 ef	12.00 f
V_3W_0	5.13 e	8.19 de	12.67 e
V_3W_1	6.00 b	8.81 bc	14.43 b
V_3W_2	4.72 f	7.43 f	10.75 h
$LSD_{0.05}$	**0.21**	**0.48**	**0.49**
CV%	**2.21**	**3.34**	**2.16**

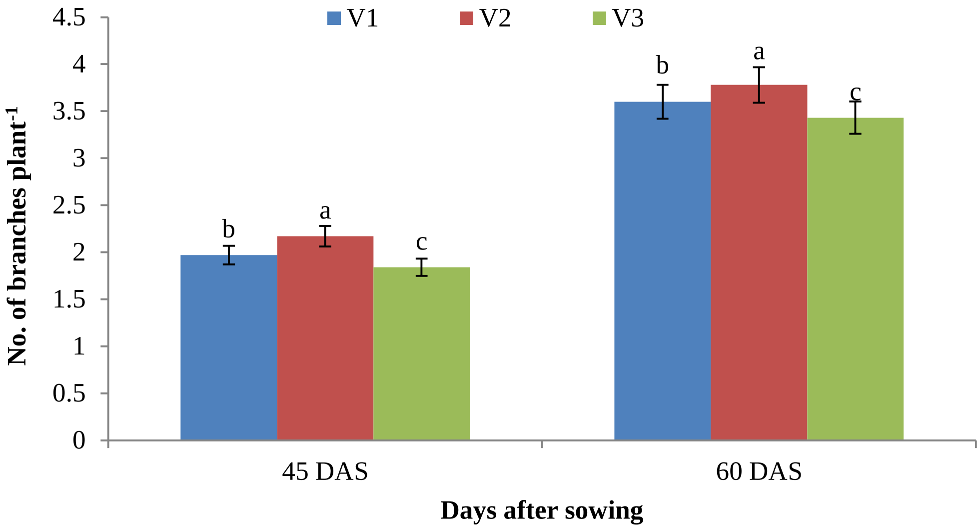
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Here, V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8;

W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

4.3 Number of branches plant^{-1}

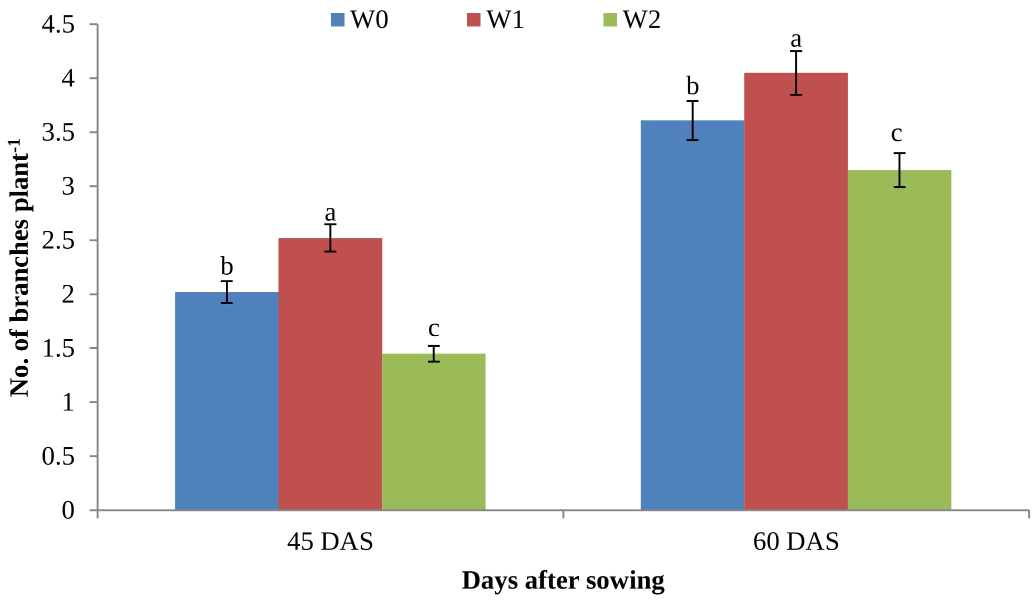
Significant variation was found on number of branches plant^{-1} at different growth stages due to cause of different variety of mungbean (Figure 5). Result revealed that the highest number of branches plant^{-1} (2.17 and 3.78 at 45 and 60 DAS, respectively) was obtained from the variety, V_2 (BARI mung-7) where the lowest number of branches plant^{-1} (1.84 and 3.43 at 45 and 60 DAS, respectively) was observed from the variety, V_3 (BARI mung-8). The result achieved from the present study was similar with the findings of Parvez *et al.* (2013) reported that the longest plant, highest number of branches plant^{-1}, number of total pods plant^{-1}, seeds plant^{-1} and seed weight plant^{-1} were obtained from varietal execution. Buriro *et al.* (2015) also found the similar trends.



V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8

Figure 5. Effect of variety on number of branches plant^{-1} at different days after sowing of mungbean

Number of branches plant^{-1} at different growth stages of mungbean was significantly affected by different levels of waterlogging condition (Figure 6). Results showed that the highest number of branches plant^{-1} (2.52 and 4.05 at 45 and 60 DAS, respectively) was achieved from the treatment, W_1 (Well watered under normal condition). The minimum number of branches plant^{-1} (1.45 and 3.15 at 45 and 60 DAS, respectively) was found from the treatment, W_2 (Waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS). Ullah (2006) reported that significant influence of almost all the physiological parameters were found with successive increase in duration of water logging over 12 hours but increasing the duration drastically reduced the growth parameters.



W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

Figure 6. Effect of waterlogging on number of branches plant^{-1} at different days after sowing of mungbean

Significant difference was remarked for number of branches plant^{-1} at different growth stages of mungbean due to combined effect of variety and different levels of waterlogging condition (Table 3 and Appendix VI). Results showed that the highest number of branches plant^{-1} (2.63 and 4.27 at 45 and 60 DAS, respectively) was achieved from the treatment combination of V_2W_1 (BARI mung-7 growing at well watered condition) which was statistically similar with V_1W_1 treatment combination at 45 DAS. The lowest number of branches plant^{-1} (1.26 and 3.00 at 45 and 60 DAS, respectively) was revealed from the treatment combination of V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) which was statistically similar with V_1W_2 treatment combination at 60 DAS, respectively.

Table 3. Combined effect of variety and waterlogging condition on number of branches plant^{-1} at different days after sowing of mungbean

Treatment combinations	Number of branches plant^{-1} at	
	45 DAS	60 DAS
V_1W_0	2.00 d	3.67 c
V_1W_1	2.50 ab	4.00 b
V_1W_2	1.43 f	3.14 ef
V_2W_0	2.20 c	3.75 c
V_2W_1	2.63 a	4.27 a
V_2W_2	1.67 e	3.33 de
V_3W_0	1.86 d	3.42 d
V_3W_1	2.42 b	3.87 bc
V_3W_2	1.26 g	3.00 f
$LSD_{0.05}$	**0.14**	**0.21**
CV%	**4.20**	**3.37**

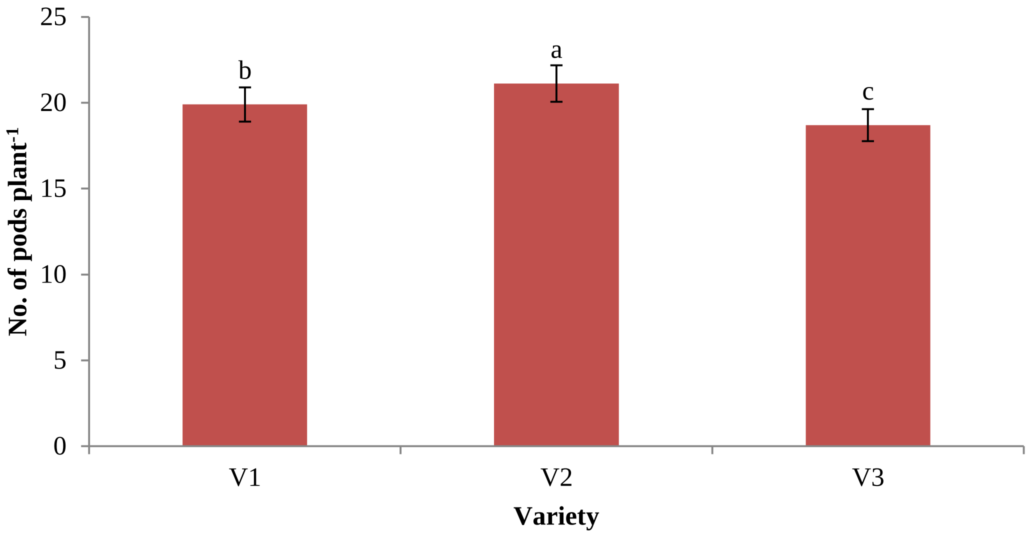
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Here, V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8;

W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

4.4 Number of pods plant^{-1}

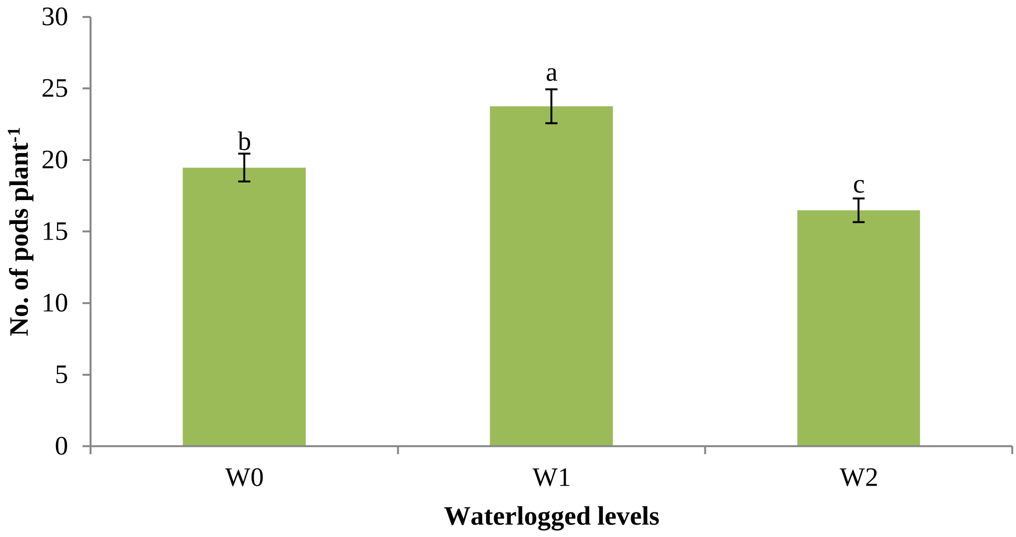
Significant difference was observed on number of pods plant^{-1} due to different varieties of mungbean (Figure 7). Results revealed that the maximum number of pods plant^{-1} (21.12) was obtained from the variety, V_2 (BARI mung-7) where the lowest number of pods plant^{-1} (18.69) was observed from the variety, V_3 (BARI mung-8). The result achieved from the present study was similar with the findings of Uddin *et al.* (2009) who reported that pods plant^{-1}, seed plant^{-1}, seed pod^{-1}, weight of 1000-seeds, seed yield and stover yield were significantly influence by the bio-fertilizer (*Bradyrhyzobium* inoculums) treatment with the varietal differences. Parvez *et al.* (2013) reported that the highest number of branches plant^{-1}, number of total pods plant^{-1}, seeds plant^{-1} and seed weight plant^{-1} were obtained when variety treated with 60 kg P_2O_5 applied.



V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8

Figure 7. Effect of variety on number of pods plant^{-1} of mungbean

Number of pods plant^{-1} of mungbean was significantly affected by different levels of waterlogging condition (Figure 8). Results exposed that the maximum number of pods plant^{-1} (23.75) was observed from the treatment, W_1 (Well watered under normal condition). On the other hand, the minimum number of pods plant^{-1} (16.49) was obtained from the treatment, W_2 (Waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS). Rana *et al.* (2019) reported that pods per plant, pod length, seeds per pod, 1000-seed weight and yield per plant significantly influenced by the water logging stress. Flooding reduced all the growth parameters of mungbean but degree of reduction varied greatly over the mungbean varieties. Islam *et al.* (2014) also reported that wet puddling situation performed the worst, showing depressed plant growth throughout the growing period and thus seed production was affected the most.



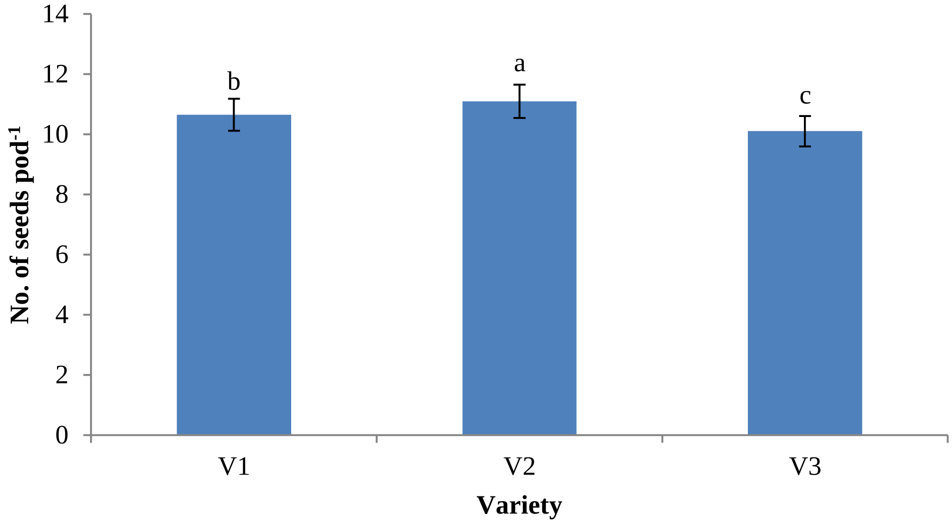
W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

Figure 8. Effect of waterlogging condition on number of pods plant^{-1} of mungbean

Significant variation was observed for number of pods plant^{-1} of mungbean influenced by combined effect of variety and different waterlogging condition (Table 6 and Appendix VII). It was remarked that the maximum number of pods plant^{-1} (25.25) was obtained from the treatment combination of V_2W_1 (BARI mung-7 growing at well watered condition). The lowest number of pods plant^{-1} (15.75) was revealed from the treatment combination of V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) which was statistically similar with V_1W_2 treatment combination.

4.5 Number of seeds pod^{-1}

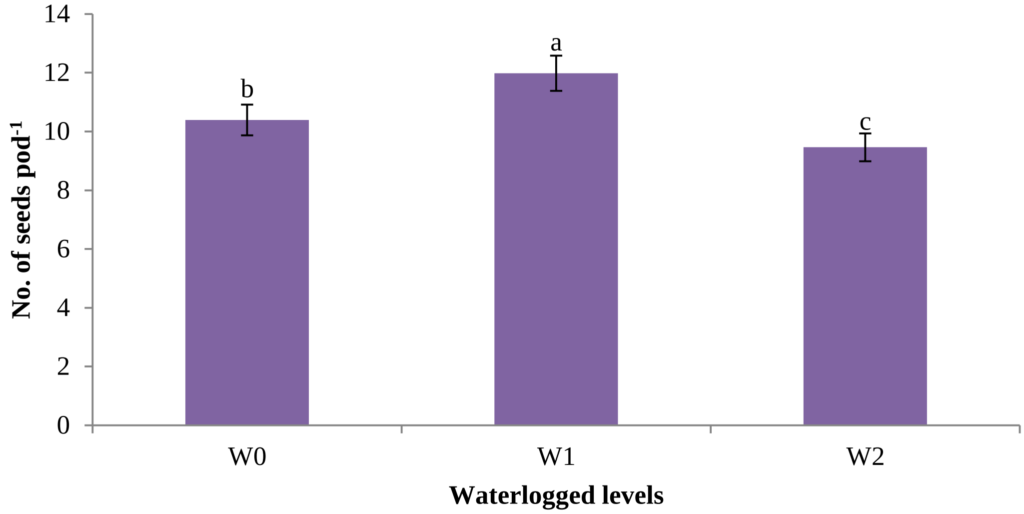
Number of seeds pod^{-1} was significantly influenced by different variety of mungbean (Figure 9). The highest number of seeds pod^{-1} (11.09) was obtained from the variety, V_2 (BARI mung-7) where the lowest number of seeds pod^{-1} (10.10) was observed from the variety, V_3 (BARI mung-8). The present finding was similar with the findings of Rahman *et al.* (2016). They reported that mungbean varieties significantly influenced on pods plant^{-1}, pod length, seeds pod^{-1}, seed yield and stover yield. Jahan *et al.* (2020) also reported that the highest number of leaves, number of pods and seeds pod^{-1} were obtained from V_1 (BARI mung-5) when 127.5 kg P ha^{-1} (T_4) was applied,



V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8

Figure 9. Effect of variety on number of seeds pod^{-1} of mungbean

Significant influence was found in terms of number of seeds pod^{-1} of mungbean influenced by different levels of waterlogging condition (Figure 10). The highest number of seeds pod^{-1} (11.98) was obtained from the treatment, W_1 (Well watered condition) where the lowest number of seeds pod^{-1} (9.46) was obtained from the treatment, W_2 (Waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS). Rana *et al.* (2019) reported that pods per plant, seeds per pod and yield per plant influenced greatly by the waterlogged stress.



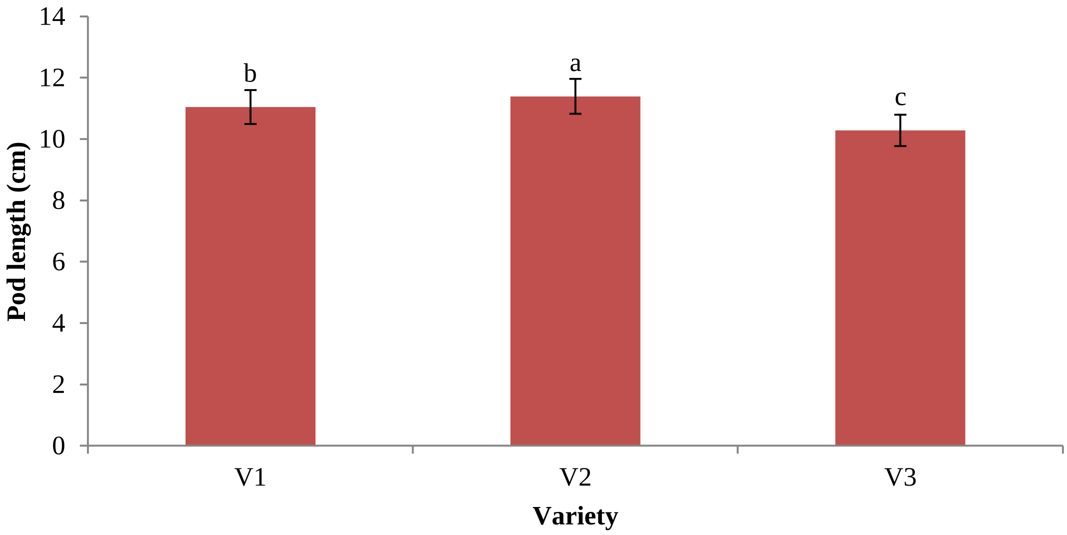
W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

Figure 10. Effect of waterlogging condition on number of seeds pod^{-1} of mungbean

Combined effect of variety and different waterlogging condition showed significant variation on number of seeds pod^{-1} of mungbean (Table 4 and Appendix VII). It was found that the highest number of seeds pod^{-1} (12.80) was observed from the treatment combination of V_2W_1 (BARI mung-7 growing at well watered condition). The lowest number of seeds pod^{-1} of mungbean (9.15) was revealed from the treatment combination of V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) which was statistically similar with V_1W_2 treatment combination.

4.6 Pod length (cm)

Significant variation on pod length was obtained due to different variety of mungbean (Figure 11). It was revealed that the highest pod length (11.39 cm) was observed from the variety, V_2 (BARI mung-7) where the lowest pod length (10.28 cm) was achieved from the variety, V_3 (BARI mung-8). Miah *et al.* (2009) found the similar trends. Parvez *et al.* (2013) revealed that performance of mungbean affected by variety and level of phosphorus.

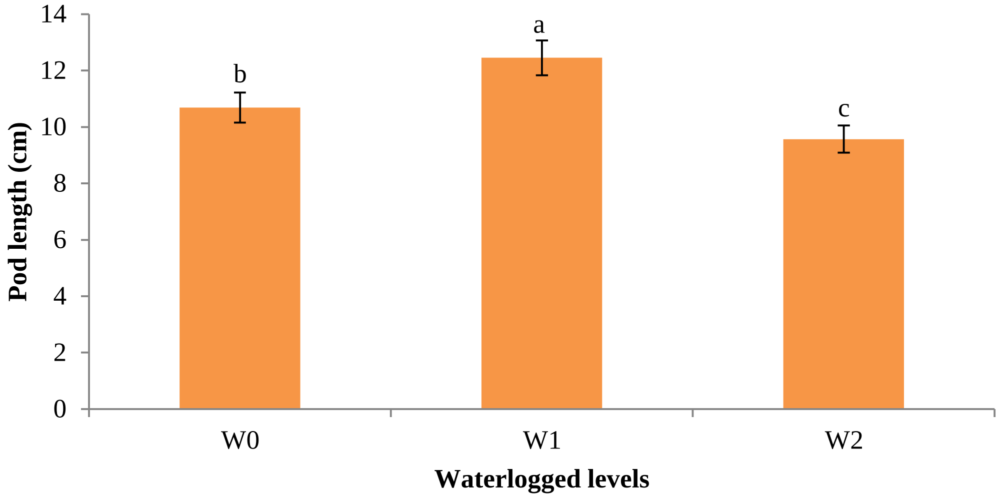


V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8

Figure 11. Effect of variety on pod length of mungbean

Significant variation was observed in terms of pod length influenced by different levels of waterlogging condition (Figure 12). It was achieved that the highest pod length (12.45 cm) was obtained from the treatment, W_1 (Well watered condition) where the lowest pod length (9.57 cm) was obtained from the treatment, W_2

(Waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS). Binh and Tai (2021) Waterlogging at the seedling stage adversely affected the physiological traits and seed yield of the mungbean varieties with 31% of yield reduction. Kyu *et al.* (2021) revealed that waterlogging reduced soil redox potential delayed or even prevented germination, decreased seedling establishment, and affected shoot and root development as well as the yield traits.



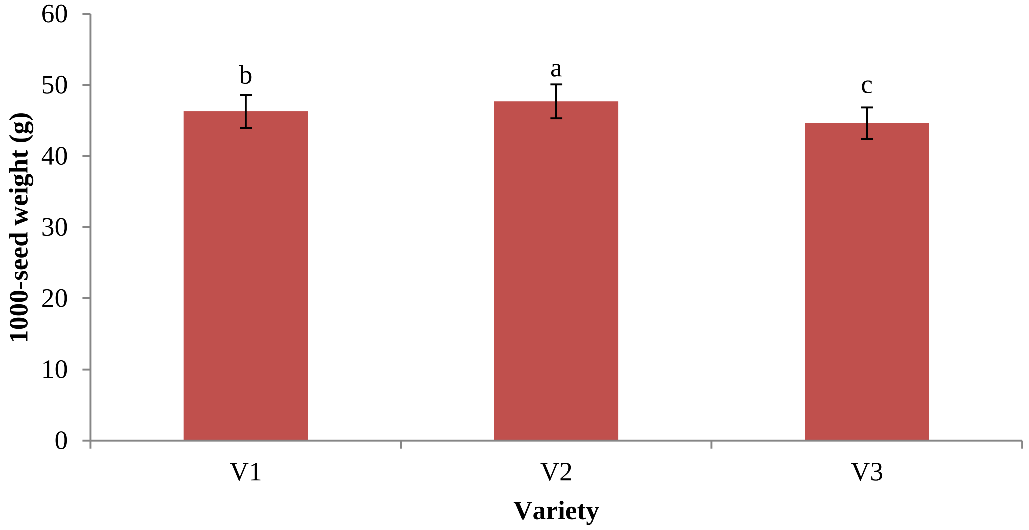
W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

Figure 12. Effect of waterlogging condition on pod length of mungbean

Pod length was significantly influenced by combined effect of variety and different waterlogging condition (Table 4 and Appendix VII). Results showed that the highest pod length of mungbean (13.21 cm) was obtained from the treatment combination of V_2W_1 (BARI mung-7 growing at well watered condition). The lowest pod length of mungbean (9.13 cm) was revealed from the treatment combination of V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) which was statistically similar with V_1W_2 treatment combination.

4.7 Weight of 1000-seed (g)

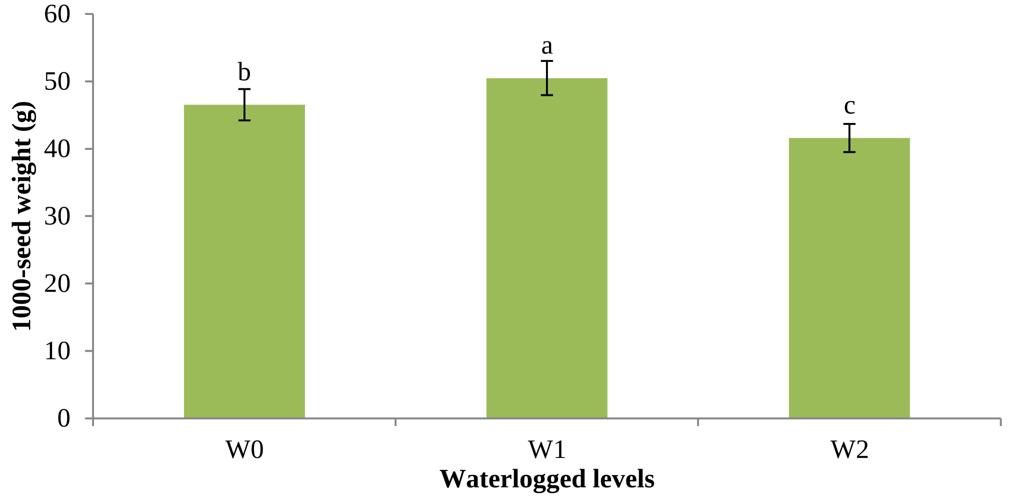
Weight of 1000-seed was significantly influenced by different varieties of mungbean under the study (Figure 13). It was remarked that the highest 1000-seed weight of mungbean (47.68 g) was obtained from the variety, V_2 (BARI mung-7) where the lowest 1000-seed weight of mungbean (44.62 g) was achieved from the variety, V_3 (BARI mung-8). Similar trend of result was also observed by Hossain *et al.* (2016), Uddin *et al.* (2009) and Parvez *et al.* (2013). They reported that varietal execution significantly influenced on 1000-seed weight of mungbean.



V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8

Figure 13. Effect of variety on 1000-seed weight of mungbean

Significant difference was found in terms of 1000-seed weight of mungbean affected by different levels of waterlogging condition (Figure 14). It was noted that the maximum 1000-seed weight of mungbean (50.49 g) was achieved from the W_1 (Well watered condition) treatment. On the other hand, the lowest 1000 grain weight (41.59 g) was observed from the W_2 (Waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) treatment. Binh and Tai (2021) revealed that waterlogging at the seedling stage adversely affected the physiological traits and seed yield of the mungbean varieties with 31% of yield reduction.



W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

Figure 14. Effect of waterlogging condition on 1000-seed weight of mungbean

Significant variation on 1000-seed weight was influenced by combined effect of variety and different levels of waterlogging condition (Table 4 and Appendix VII). Among the different treatment combinations, the highest 1000-seed weight (51.85 g) was obtained from the treatment combination of V_2W_1 (BARI mung-7 growing at well watered condition) which was statistically similar with V_1W_1 treatment combination. The lowest 1000-seed weight of mungbean (40.23 g) was revealed from the treatment combination of V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) which was statistically similar with V_1W_2 treatment combination.

Table 4. Combined effect of variety and waterlogging condition on number of pods plant^{-1}, number of seeds pod^{-1}, pod length and 1000-seed weight of mungbean

Treatment combinations	Number of pods plant^{-1}	Number of seeds pod^{-1}	Pod length (cm)	1000-seed weight (g)
V_1W_0	19.55 c	10.42 de	10.83 d	46.67 d
V_1W_1	23.67 b	12.00 b	12.67 b	50.48 ab
V_1W_2	16.48 ef	9.50 gh	9.62 fg	41.75 fg
V_2W_0	20.87 c	10.75 cd	11.00 cd	48.37 c
V_2W_1	25.25 a	12.80 a	13.21 a	51.85 a
V_2W_2	17.25 de	9.73 fg	9.95 ef	42.81 f
V_3W_0	18.00 d	10.00 ef	10.25 e	44.52 e
V_3W_1	22.33 b	11.15 c	11.48 c	49.13 bc
V_3W_2	15.75 f	9.15 h	9.13 g	40.23 g
$LSD_{0.05}$	**1.44**	**0.45**	**0.51**	**1.68**
CV%	**4.18**	**2.46**	**2.71**	**2.10**

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.

Here, V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8;

W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

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

Seed yield was significantly affected by different varieties of mungbean under the study (Table 5 and Appendix VIII). It was observed that the highest seed yield (1.64 t ha^{-1}) was obtained from the variety, V_2 (BARI mung-7) where the lowest seed yield (1.52 t ha^{-1}) was found from the variety, V_3 (BARI mung-8). Varietal execution on seed yield might be a genetical attribute which influenced the seed yield of mungbean. The result on seed yield agreement with the findings of Uddin *et al*. (2009) who reported that interaction effect of variety and bio-fertilizer (*Bradyrhyzobium*) inoculation was significant of all the parameters. Parvez *et al.* (2013) reported that mungbean variety can be grown with higher dose of phosphorus (60 kg P_2O_5 ha^{-1}) for higher seed yield.

Significant difference was found in terms of seed yield affected by different levels of waterlogging condition (Table 5 and Appendix VIII). Results showed that the highest seed yield (1.75 t ha^{-1}) was obtained from the treatment, W_1 (Well watered condition) where the lowest seed yield (1.41 t ha^{-1}) was found from the W_2 (Waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) treatment. Binh and Tai (2021) revealed that waterlogging at the seedling stage adversely affected the physiological traits and seed yield of the mungbean varieties with 31% of yield reduction. Amin *et al.* (2017) reported that the longer the waterlogging period, the more was the reduction in seed yield and yield contributing characters.

Significant variation on seed yield of mungbean was observed by combined effect of variety and different levels of waterlogging condition (Table 6 and Appendix VIII). It was noted that the highest seed yield (1.82 t ha^{-1}) was obtained from the treatment combination of V_2W_1 (BARI mung-7 growing at well watered condition). The lowest seed yield of mungbean (1.34 t ha^{-1}) was revealed from the treatment combination of V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS).

4.9 Stover yield (t ha^{-1})

Stover yield was significantly affected by different varieties of mungbean under the study (Table 5 and Appendix VIII). It was observed that the maximum stover yield (3.04 t ha^{-1}) was obtained from the variety, V_2 (BARI mung-7) where the lowest stover yield (2.92 t ha^{-1}) was found from the variety, V_3 (BARI mung-8) which was statistically similar with V_1 treatment. Varietal execution on stover yield might be a genetical attribute which influenced the stover yield of mungbean. The results on stover yield agreement with the findings of Uddin *et al*. (2009) reported that interaction effect of variety and bio-fertilizer (*Bradyrhyzobium*) inoculation was significant of all the parameters. Mungbean variety with *Bradyrhyzobium* inoculums produced the highest number of nodule and pod plant. It also showed the highest seed yield, stover yield and 1000-seed weight.

Significant difference was found in terms of stover yield affected by different levels of waterlogging condition (Table 5 and Appendix VIII). Results showed that the maximum stover yield (3.16 t ha^{-1}) was obtained from the W_1 (Well watered condition) treatment. On the other hand, the lowest stover yield (2.79 t ha^{-1}) was noted from the W_2 (Waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) treatment. Kumar *et al.* (2013) and Amin *et al.* (2017) reported that yield and yield contributing characters of the mungbean varieties were significantly affected by waterlogging. The longer the waterlogging period, the more was the reduction in seed yield and yield contributing characters.

Significant variation on stover yield of mungbean was observed by combined effect of variety and different levels of waterlogging condition (Table 6 and Appendix VIII). It was recorded that the maximum stover yield (3.21 t ha^{-1}) was obtained from the treatment combination of V_2W_1 (BARI mung-7 growing at well watered condition) which was statistically similar with V_1W_1 treatment combination. The minimum stover yield of mungbean (2.72 t ha^{-1}) was obtained from the treatment combination of V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) which was statistically similar with V_1W_2 treatment combinations.

4.10 Biological yield (t ha^{-1})

Biological yield was significantly affected by different varieties of mungbean under the study (Table 5 and Appendix VIII). It was observed that the maximum biological yield of mungbean (4.69 t ha^{-1}) was obtained from the variety, V_2 (BARI mung-7) where the lowest biological yield (4.44 t ha^{-1}) was found from the variety, V_3 (BARI mung-8) which was statistically similar with V_1 treatment. Buriro *et al.* (2015) reported that in addition to the recommended rates of nitrogen and phosphorus, the K applied @ 125 kg ha^{-1} significantly increased seed germination, plant height, number of branches per plant, number of pods, seed index and biological yield of mungbean varieties (kg ha^{-1}) as well. Tehulie *et al.* (2021) also revealed that interaction effect of the variety, inter and intra row spacing was highly significant on seed yield and yield traits.

Significant difference was found in terms of biological yield of mungbean affected by different levels of waterlogging condition (Table 5 and Appendix VIII). Results showed that the highest biological yield (4.91 t ha^{-1}) was obtained from the treatment, W_1 (Well watered condition) where the lowest biological yield (4.20 t ha^{-1}) was found from the W_2 (Waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) treatment. Kumar *et al.* (2013) observed the similar trends. Amin *et al.* (2017) revealed that yield and yield contributing characters of the mungbean varieties were significantly affected by waterlogging. The longer the waterlogging period, the more was the reduction in seed yield and yield contributing characters.

Significant variation on biological yield of mungbean was observed by combined effect of variety and different levels of waterlogging condition (Table 6 and Appendix VIII). It was noted that the maximum biological yield (5.03 t ha^{-1}) was obtained from the treatment combination of V_2W_1 (BARI mung-7 growing at well watered condition) which was statistically similar with V_1W_1 treatment combination. The lowest biological yield of mungbean (4.06 t ha^{-1}) was revealed from the treatment combination of V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) which was statistically similar with V_1W_2 treatment combination.

4.11 Harvest index (%)

Harvest index was significantly affected by different varieties of mungbean under the study (Table 5 and Appendix VIII). It was expressed that the highest harvest index (34.98%) was obtained from the variety, V_2 (BARI mung-7) which was statistically similar with V_1 treatment where the lowest harvest index (34.14%) was achieved from the variety, V_3 (BARI mung-8). Parvez *et al.* (2013) reported that harvest index was significantly increased with the varietal differences as well as the application of 60 kg P_2O_5. Kaysha *et al.* (2020) reported that the two-way interaction effect of variety with fertilizer rate significantly ($P < 0.05$) influenced yield and yield attributing traits. Accordingly, the maximum number of pod per plant (14.7), grain yield ha^{-1} (1294.7 kg ha^{-1}) and harvest index were recorded for N-26 variety at 150 kg NPS ha^{-1}.

Significant difference was found in terms of harvest index of mungbean influenced by different levels of waterlogging condition under the study (Table 5 and Appendix VIII). Results showed that the highest harvest index (35.67%) was achieved from the treatment, W_1 (Well watered condition) where the lowest harvest index (33.54%) was obtained from the treatment, W_2 (Waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS). Neashata *et al.* (2020) reported that waterlogging treatment significantly reduced the growth and yield but the plants remarkably improved their depressed characters during the recovery period. Binh and Tai (2021) revealed that waterlogging at the seedling stage adversely affected the physiological traits and seed yield of the mungbean varieties with 31% of yield reduction.

Combined effect of variety and different levels of waterlogging condition showed significant influence on harvest index of mungbean (Table 6 and Appendix VIII). It was indicated that the highest harvest index (36.15%) was obtained from the treatment combination of V_2W_1 (BARI mung-7 growing at well watered condition) which was statistically similar with V_1W_1, V_3W_1 and V_2W_0 treatment combination. The lowest harvest index of mungbean (33.00%) was revealed from the treatment combination of V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) which was statistically similar with V_1W_2, V_2W_2 and V_3W_0 treatment combination.

Table 5. Effect of variety and waterlogging condition on seed yield, stover yield, biological yield and harvest index of mungbean

Treatments	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Effect of variety				
V_1	1.58 b	2.97 b	4.55 b	34.63 ab
V_2	1.64 a	3.04 a	4.69 a	34.98 a
V_3	1.52 c	2.92 b	4.44 b	34.14 b
$LSD_{0.05}$	**0.03**	**0.06**	**0.12**	**0.80**
CV%	**1.97**	**2.19**	**2.81**	**2.33**
Effect of waterlogging condition				
W_0	1.58 b	2.99 b	4.57 b	34.55 b
W_1	1.75 a	3.16 a	4.91 a	35.67 a
W_2	1.41 c	2.79 c	4.20 c	33.54 c
$LSD_{0.05}$	**0.03**	**0.06**	**0.12**	**0.80**
CV%	**1.97**	**2.19**	**2.81**	**2.33**

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

Here, V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8; W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

Table 6. Combined effect of variety and waterlogging condition on seed yield, stover yield, biological yield and harvest index of mungbean

Treatment combinations	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1W_0	1.57 d	2.97 de	4.54 de	34.52 bcd
V_1W_1	1.76 b	3.17 ab	4.93 ab	35.67 ab
V_1W_2	1.41 f	2.77 fg	4.18 fg	33.70 de
V_2W_0	1.63 c	3.04 cd	4.67 cd	34.87 abcd
V_2W_1	1.82 a	3.21 a	5.03 a	36.15 a
V_2W_2	1.48 e	2.88 ef	4.36 ef	33.92 cde
V_3W_0	1.54 d	2.95 de	4.49 de	34.25 cde
V_3W_1	1.68 c	3.09 bc	4.77 bc	35.18 abc
V_3W_2	1.34 g	2.72 g	4.06 g	33.00 e
$LSD_{0.05}$	**0.05**	**0.11**	**0.22**	**1.39**
CV%	**1.97**	**2.19**	**2.81**	**2.33**

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.

Here, V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8;

W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

4.12 Available phosphorus content (ppm) in post harvest soil

Available phosphorus content in post harvest soil was significantly affected by different varieties of mungbean under the study (Table 7 and Appendix IX). It was expressed that the maximum available phosphorus content (20.89 ppm) in post harvest soil was obtained from the variety, V_2 (BARI mung-7) treatment which was statistically similar with the post harvest soil of V_1 variety. On the other hand, the minimum available phosphorus content (19.78 ppm) in post harvest soil was achieved from the post harvest soil of variety, V_3 (BARI mung-8).

Significant variation was found in case of available phosphorus content in post harvest soil of mungbean cultivation influenced by different levels of waterlogging condition under the study (Table 7 and Appendix IX). Results indicated that the maximum available phosphorus content (22.13 ppm) was achieved from the in post harvest soil of the treatment, W_1 (Well watered condition) where the minimum available phosphorus content (18.39 ppm) was obtained from the post harvest soil of the treatment, W_2 (Waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS).

Combined effect of variety and different levels of waterlogging condition showed significant influence on available phosphorus content in post harvest soil of mungbean cultivation (Table 8 and Appendix IX). It was recorded that the maximum available phosphorus content (22.75 ppm) was obtained from the post harvest soil of the treatment combination of V_2W_1 (BARI mung-7 growing at well watered condition) which was statistically similar with V_1W_1 treatment combination. The minimum available phosphorus content (17.82 ppm) was revealed from the post harvest soil of the treatment combination of V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) which was statistically similar with V_1W_2 treatment combination.

4.14 Exchangeable potassium content (meq 100 g^{-1} soil) in post harvest soil

Exchangeable potassium content in post harvest soil was significantly influenced by different varieties of mungbean under the study (Table 7 and Appendix IX). It was expressed that the maximum exchangeable potassium content (16.59 meq 100 g^{-1} soil) was obtained in post harvest soil from the variety, V_2 (BARI mung-7) treatment. On the other hand, the minimum exchangeable potassium content (15.28 meq 100 g^{-1} soil) in post harvest soil was achieved from the post harvest soil of variety, V_3 (BARI mung-8).

Significant variation was found in terms of exchangeable potassium content in post harvest soil of mungbean cultivation influenced by different levels of waterlogging condition under the study (Table 7 and Appendix IX). Results indicated that the maximum exchangeable potassium content (17.72 meq 100 g^{-1} soil) was achieved from the in post harvest soil of the treatment, W_1 (Well watered condition) where the minimum exchangeable potassium content (13.98 meq 100 g^{-1} soil) was obtained from the post harvest soil of the treatment, W_2 (Waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS).

Combined effect of variety and different levels of waterlogging condition showed significant influence on exchangeable potassium content in post harvest soil of mungbean cultivation (Table 8 and Appendix IX). From the result of the experiment showed that the maximum exchangeable potassium content (18.33 meq 100 g^{-1} soil) was obtained from the post harvest soil of the treatment combination of V_2W_1 (BARI mung-7 growing at well watered condition) which was statistically similar with V_1W_1 treatment combination. The minimum exchangeable potassium content (13.33 meq 100 g^{-1} soil) was revealed from the post harvest soil of the treatment combination of V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) which was statistically similar with V_1W_2 treatment combination.

Table 7. Effect of variety and waterlogging condition on available phosphorus content and exchangeable potassium content in post harvest soil of mungbean cultivation

Treatments	Available P content (ppm)	Exchangeable K content (meq 100 g^{-1} soil)
Effect of variety		
V_1	20.27 ab	15.89 b
V_2	20.89 a	16.59 a
V_3	19.78 b	15.28 c
$LSD_{0.05}$	**0.63**	**0.58**
CV%	**3.12**	**3.66**
Effect of waterlogging condition		
W_0	20.41 b	16.05 b
W_1	22.13 a	17.72 a
W_2	18.39 c	13.98 c
$LSD_{0.05}$	**0.63**	**0.58**
CV%	**3.12**	**3.66**

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

Here, V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8; W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

Table 8. Combined effect of variety and waterlogging condition on available phosphorus content and exchangeable potassium content in post harvest soil of mungbean cultivation

Treatment combinations	**Available P content (ppm)**	**Exchangeable K content (meq 100 g^{-1} soil)**
V_1W_0	20.43 c	16.00 cd
V_1W_1	22.00 ab	17.67 ab
V_1W_2	18.37 ef	14.00 fg
V_2W_0	20.92 bc	16.81 bc
V_2W_1	22.75 a	18.33 a
V_2W_2	19.00 de	14.62 ef
V_3W_0	19.88 cd	15.35 de
V_3W_1	21.63 b	17.15 b
V_3W_2	17.82 f	13.33 g
$LSD_{0.05}$	**1.09**	**1.00**
CV%	**3.12**	**3.66**

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.

Here, V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8;

W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

CHAPTER V

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

The present piece of work was done at the research field of Sher-e-Bangla Agricultural University, Dhaka during the period from March to June 2022 to find out the growth and yield performance of mungbean varieties under waterlogging condition.

The experiment was laid out in a randomized complete block design with three replications. The experiment comprised of two factors *viz.* Factor A: V_1= BARI mung-6, V_2= BARI mung-7 and V_3= BARI mung-8; and Factor B: W_0= Control (no irrigation), W_1= Well watered (under normal condition) and W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS). The size of the individual plot was 1.5 m × 1.0 m and total numbers of plots were 27. There were 9 treatment combinations. Half of urea and all other fertilizers were applied during the final land preparation. Rest of urea will be top dressed in two equal splits at 35 and 65 DAS.

Mungbean seeds were sown on 7th March 2022 and the crop was harvested on 15th May 2022. The agronomic data were collected at 30, 45 and 60 days after sowing (DAS). The data were collected plot wise for plant height (cm), number of leaves plant^{-1}, number of branches plant^{-1}, number of pods plant^{-1}, pod length (cm), number of seeds pod^{-1}, weight of 1000-seed (g), seed yield (t ha^{-1}) , stover yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%). The data of post harvest soil chemical analysis viz., total nitrogen content (%), available phosphorus content (ppm) and exchangeable potassium (meq/100 g soil) were recorded. Variety and waterlogging condition both had significant influence on the growth and yield of mungbean.

In case of variety, results found that the tallest plant (53.81 cm at 60 DAS), maximum number of leaves plant^{-1} (13.83 at 60 DAS), number of branches plant^{-1} (3.78 at 60 DAS), number of pods plant^{-1} (21.12), number of seeds pod^{-1} (11.09), pod length (11.39 cm), 1000-seed weight of mungbean (47.68 g), seed yield (1.64 t ha^{-1}), stover yield (3.04 t ha^{-1}), biological yield (4.69 t ha^{-1}) and harvest index (34.98%) was obtained from the variety, V_2 (BARI mung-7). On the other hand, the shortest plant (52.22 cm at 60 DAS), minimum number of leaves plant^{-1} (12.61 at 60 DAS), number of branches plant^{-1} (3.43 at 60 DAS), number of pods plant^{-1} (18.69), number of seeds pod^{-1} (10.10), pod length (10.28 cm), 1000-seed weight of mungbean (44.62 g), seed yield (1.52 t ha^{-1}), stover yield (2.92 t ha^{-1}), biological yield (4.44 t ha^{-1}) and harvest index (34.14%) was achieved from the variety, V_3 (BARI mung-8). In case of post harvest soil chemical analysis, the maximum total nitrogen content (0.070%), available phosphorus content (20.89 ppm) and exchangeable potassium content (16.59 meq/100 g soil) in post harvest soil was obtained from the variety, V_2 (BARI mung-7) treatment where the minimum total nitrogen content (0.063%), available phosphorus content (19.78 ppm) and exchangeable potassium content (15.28 meq/100 g soil) in post harvest soil was achieved from the variety, V_3 (BARI mung-8).

Considering different waterlogging condition, results observed that the tallest plant (55.52 cm at 60 DAS), maximum number of leaves plant^{-1} (15.00 at 60 DAS), number of branches plant^{-1} (4.05 at 60 DAS), number of pods plant^{-1} (23.75), number of seeds pod^{-1} (11.98), pod length (12.45 cm), 1000-seed weight of mungbean (50.49 g), seed yield (1.75 t ha^{-1}), stover yield (3.16 t ha^{-1}), biological yield (4.91 t ha^{-1}) and harvest index (35.67%) was obtained from the W_1 (Well watered under normal condition) treatment. On the other hand, the shortest plant (50.76 cm at 60 DAS), minimum number of leaves plant^{-1} (11.41 at 60 DAS), number of branches plant^{-1} (3.15 at 60 DAS), number of pods plant^{-1} (16.49), number of seeds pod^{-1} (9.46), pod length (9.57 cm), 1000-seed weight of mungbean (41.59 g), seed yield (1.41 t ha^{-1}), stover yield (2.79 t ha^{-1}), biological yield (4.20 t ha^{-1}) and harvest index (33.54%) was recorded from W_2 (Waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) treatment. the maximum total nitrogen content (0.075%), available phosphorus content (22.13 ppm) and exchangeable potassium content (17.72 meq/100 g soil) in post harvest soil was achieved from the treatment, W_1 (Well watered condition) treatment where the minimum total nitrogen content (0.058%), available phosphorus content (18.39 ppm) and exchangeable potassium content (13.98 meq/100 g soil) was obtained from the treatment, W_2 (Waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) treatment.

In case of combined effect of variety and different waterlogging condition, significant variation was observed on the growth and yield of mungbean. Results indicated that the tallest plant (56.75 cm at 60 DAS), maximum number of leaves plant^{-1} (15.67 at 60 DAS), number of branches plant^{-1} (4.27 at 60 DAS), number of pods plant^{-1} (25.25), number of seeds pod^{-1} (12.80), pod length (13.21 cm), 1000-seed weight of mungbean (51.85 g), seed yield (1.82 t ha^{-1}), stover yield (3.21 t ha^{-1}), biological yield (5.03 t ha^{-1}) and harvest index (36.15%) was obtained from the treatment combination of V_2W_1 (BARI mung-7 growing at well watered condition). On the other hand, the shortest plant (50.00 cm at 60 DAS), minimum number of leaves $plant^{-1}$ (10.75 at 60 DAS), number of branches $plant^{-1}$ (3.00 at 60 DAS), number of pods $plant^{-1}$ (15.75), number of seeds pod^{-1} (9.15), pod length (9.13 cm), 1000-seed weight (40.23 g), seed yield (1.34 t ha^{-1}), stover yield (2.72 t ha^{-1}), biological yield (4.06 t ha^{-1}) and harvest index (33.00%) was revealed from V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS) treatment combination. The maximum total nitrogen content in post harvest soil (0.080%), available phosphorus content (22.75 ppm) and exchangeable potassium content (18.33 meq/100 g soil) was obtained from the treatment combination of V_2W_1 (BARI mung-7 growing at well watered condition). The minimum total nitrogen content in post harvest soil (0.056%), available phosphorus content (17.82 ppm) and exchangeable potassium content (13.33 meq/100 g soil) was revealed from the treatment combination of V_3W_2 (BARI mung-8 growing at waterlogged condition at pre-flowering stage 24 hours at 20-30 DAS).

Considering all the parameters studied the following conclusion may be drawn:-

The growth and yield of mungbean responded significantly by the combined application of V_2W_1 (BARI mung-7 growing at well watered condition). So, BARI mung-7 variety can be grown at well watered condition for obtaining higher yield of mungbean.

RECOMMENDATIONS:-

Based on the findings of the experiment, it could be said that, BARI mung-7 variety can be grown at well watered condition for obtaining higher yield of mungbean. It might be the best combination for higher yield of mungbean and also to maintain soil fertility and productivity in Tejgaon series under AEZ No. 28.

However, to reach a specific conclusion and recommendation more research work on mungbean should be done in different Agro-ecological zones of Bangladesh because the experiment was conducted for only one cropping season in a specific location only.

REFERENCES

REFERENCES

Ahmed, S., Nawata, E. and Sakuratani, T. (2002). Effects of waterlogging at vegetative and reproductive growth stages on photosynthesis, leaf water potential and yield in mungbean. *Plant Prod. Sci.*, **5**(2): 117-123.

Amin, M. R., Karim, M. A., Khaliq, Q. A., Islam, M. R. and Aktar, S. (2017). The influence of waterlogging period on yield and yield components of mungbean (*Vigna radiata* L. Wilczek). *The Agriculturists*, **15**(2): 88-100.

Anee, T. I., Nahar, K., Rahman, A., Mahmud, J. A., Bhuiyan, T. F., Alam, M. U. and Hasanuzzaman, M. (2019). Oxidative damage and antioxidant defense in Sesamum indicum after different waterlogging durations. *Plants,* **8**(7): 196.

Armstrong, W., Beckett, P. M., Colmer, T. D., Setter, T. L. and Greenway, H. (2019). Tolerance of roots to low oxygen: 'Anoxic'cores, the phytoglobin-nitric oxide cycle, and energy or oxygen sensing. *J. Plant Physiol.*, **239**: 92-108.

Barickman, T. C., Simpson, C. R. and Sams, C. E. (2019). Waterlogging causes early modification in the physiological performance, carotenoids, chlorophylls, proline, and soluble sugars of cucumber plants. *Plants*, **8**(6): 160.

BBS (Bangladesh Bureau of Statistics). (2017). Yearbook of Statistics of Bangladesh.Statistics Division.Ministry of Planning, Government of the Peoples' Republic of Bangladesh, Dhaka. Pp. 68.

Belay, F., Meresa, H., Syum, S. and Gebresilasie, A. (2019). Evaluation of improved mung bean (*Vigna radiata* L.) varieties for yield in the moisture stress conditions of Abergelle Areas, Northern Ethiopia. *J. Agric. Sci. Practice*, **4**(4): 139-143.

Binh, V. T. and Tai, S. S. (2021). Effect of waterlogging duration on germination, physiological characteristics, and yield of mungbean (*Vigna radiata* L.). *Vietnam J. Agric. Sci.*, **4**(1): 936-945.

Black, C. A. (1965). Methods of Soil Analysis. Part-l and 2. *American Soc. Agron*. Inc. Publisher, Madison, Wisconsin, U.S.A.

Borrego-Benjumea, A., Carter, A., Zhu, M., Tucker, J. R., Zhou, M. and Badea, A. (2021). Genome-wide association study of waterlogging tolerance in barley (*Hordeum vulgare* L.) under controlled field conditions. *Frontiers Plant Sci.*, **12**: 711654.

Bray, R. H. and Kurtz, L. T. (1945). Determination of total, organic, and available forms of phosphorus in soils. *Soil Sci.*, **59**(1): 39-46.

Buriro, M., Hussain, F., Talpur, G. H., Gandahi, A. W. and Buriro, B. (2015). Growth and yield response of mungbean varieties to various potassium levels. *Pakistan J. Agric. Agril. Eng. Vet. Sci.*, **31**(2): 203-210.

Fernandez, G. C. J. and Shanmugasundaram, S. (1988). The AVRDC mungbean improvement program. The past, present and future. In: Fernandez, J. and Shanmugsundaram, S. (eds) Mungbean. Asian Vegetable Research and Development Centre, Shanhua, P. 58-70.

Food and Agriculture Organization of the United Nations (FAO). (2017). The impact of disasters and crises on agriculture and food security.

Frauque, A., Haraguchi, T., Hirota, O. and Rahman, M. A. (2000). Growth analysis, yield, and canopy structure in maize, mungbean intercropping. *Bu. Inst. of Tropical Agric*. Kyushu University Fukuoka, Japan, **23**: 61-69.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedures for Agricultural research; John Wiley and Sons: New York, NY, USA.

Hossain, M. M., Mahbub, M. M. and Shirazy, B. J. (2016). Growth and yield performance of mungbean varieties in summer cultivation. *Scientia Agriculturae*, **16**(3): 79-82.

Intergovernmental Panel on Climate Change (IPCC). (2021). Climate Change Widespread, Rapid, and Intensifying.

Islam, M. R., Akter, N., Parvej, S. S. and Haque, K. S. (2014). Growth and yield response of mungbean (*Vigna radiata* L. Wilczek) genotypes to wet puddling, flooding and saturated soil culture. *J. Plant Sci.*, **2**(6): 311-316.

Islam, M. R., Hamid, A., Khaliq, Q. A., Ahmed, J. U., Haque, M. M. and Karim, M. A. (2007). Genetic variability in flooding tolerance of mungbean (*Vigna radiata* L. Wilczek) genotypes. *Euphytica*, **156**: 247-255.

Jackson, M. L. (1973). Soil chemical analysis, pentice hall of India Pvt. *Ltd., New Delhi, India*, **498**: 151-154.

Jahan, M. N., Barua, S., Ali, H., Ali, M. N., Chowdhury, M. S. H., Hasan, M. M. and Hossen, K. (2020). Effects of phosphorus fertilization on hybrid varieties of mungbean [*Vigna radiata* (L.) Wilczek] in a salinity prone area of the subtropics. *Acta Agrobotanica*, **73**(3): 1-10

Kabir, M. H. and Sarkar, M. A. R. (2008). Seed yield of mungbean as affected by variety and plant spacing in Kharif-I season. *Journal of the Bangladesh Agricultural University*, *6*(452-2016-35516).

Kaul, A. K. (1982). Pulses are Bangladesh. BARC, Farm gate, Dhaka. p. 27.

Kaysha, K., Shanka, D. and Bibiso, M. (2020). Performance of mung bean (*Vigna radiata* L.) varieties at different NPS rates and row spacing at Kindo Koysha district, Southern Ethiopia. *Cogent Food Agric.*, **6**(1): 1771112.

Khan, M. R. I. (1981). Nurtitional quality characters in in pulses. In: Proc. National Workshop on Pulses. pp. 199-206.

Kumar, P., Pal, M., Joshi, R. and Sairam, R. K. (2013). Yield, growth and physiological responses of mung bean [*Vigna radiata* (L.) Wilczek] genotypes to waterlogging at vegetative stage. *Physiol. Mol. Biol. Plants*, **19**: 209-220.

Kyu, K. L., Malik, A. I., Colmer, T. D., Siddique, K. H. and Erskine, W. (2021). Response of mungbean (cvs. Celera II-AU and Jade-AU) and blackgram (cv. Onyx-AU) to transient waterlogging. *Frontiers in Plant Sci.*, **12**: 709102.

Lambers, H., Oliveira, R. S., Lambers, H. and Oliveira, R. S. (2019). Photosynthesis, respiration, and long-distance transport: photosynthesis. *Plant Physiol. Ecol.*, p. 11-114.

Miah, M. A. K., Anwar, M. P., Begum, M. A. H. F. U. Z. A., Juraimi, A. S. and Islam, M. A. (2009). Influence of sowing date on growth and yield of summer mungbean varieties. *J. Agric. Soc. Sci*. **5**(3): 73-76.

Murphy, J, and Riley, J. P. (1962). A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Acta.* **27**: 31-36.

Musgrave, M. E. and Ding, N. (1998). Evaluating wheat cultivars for waterlogging tolerance. *Crop Sci.*, **38**(1): 90-97.

Nahar, S. N., Rafiqul, I. M., Hasan, M., Nasimul, B. M. and Uddin, A. J. (2020). Evaluation of yield and yield-related traits for waterlogging tolerance in mungbean genotypes using multivariate techniques. *J. Agric. Sci. (Belgrade)*, **65**(2): 99-120.

Neashata, N. J., Islama, M. R., Mehfuz Hasanb, M. and Islama, M. (2020). Assessment of waterlogging tolerance in mungbean genotypes utilizing morphological traits and SSR markers. *Annals Agric. Sci.*, **18**: 258-268.

Olorunwa, O. J., Adhikari, B., Shi, A. and Barickman, T. C. (2022). Screening of cowpea (*Vigna unguiculata* (L.) Walp.) genotypes for waterlogging tolerance using morpho-physiological traits at early growth stage. *Plant Sci.*, **315**: 111136.

Parvez, M. T., Paul, S. K. and Sarkar, M. A. R. (2013). Yield and yield contributing characters of mungbean as affected by variety and level of phosphorus. *J. Agrofor. Environ.*, **7**(1): 115-118.

PloSchuk, R. A., Miralles, D. J., Colmer, T. D., Ploschuk, E. L. and Striker, G. G. (2018). Waterlogging of winter crops at early and late stages: impacts on leaf physiology, growth and yield. *Frontiers in Plant Sci.*, **9**: 1863.

Qi, X., Li, Q., Ma, X., Qian, C., Wang, H., Ren, N. and Chen, X. (2019). Waterlogging-induced adventitious root formation in cucumber is regulated by ethylene and auxin through reactive oxygen species signalling. *Plant, Cell Environ.*, **42**(5): 1458-1470.

Rabbani, M. G., Chowdhury, A. K. M. S. H., Bari, M. A. and Salam, M. A. (2013). Effect of variety and sowing date on the growth and yield of summer mungbean (*Vigna radiata* L. Wilczek). *J. Agron. Environ.*, **7**(1): 27-30.

Rahman, M. M., Zahan, T., Ali, M. S., Begum, M., & Bell, R. W. (2016). Effect of variety and seed rate on yield performance of mungbean under strip tillage system. *Bangladesh Agron. J.*, **19**(1): 81-86.

Ramakrishna, S., Huang, Z. M. and Bibo, G. A. (2000). The potential of knitting for engineering composites-a review. *Composites Part A: App. Sci. Manufac.*, **31**(3): 197-220.

Rana, M. S., Hossain, M. A., Urmi, T. A., Ahmed, S., Haque, M. M. and Islam, M. M. (2019). Evaluation of Blackgram (*Vigna mungo* L.) genotypes for their tolerance to flooding. *The Agriculturists*, **17**(1-2): 89-101.

Sharma, A. and Dhanda, S. (2014). Abiotic stress response in *Vigna radiata* L. (Mungbean). *Intl. J. Life Sci. Biotechnol. Pharma Res.*, **3**(4): 14.

Singh, D. P. and Singh, B. B. (2011). Breeding for tolerance to abiotic stresses in mungbean. *J. Food Legumes*, **24**(2): 83-90.

Smethurst, C. F. and Shabala, S. (2003). Screening methods for waterlogging tolerance in lucerne: comparative analysis of waterlogging effects on chlorophyll fluorescence, photosynthesis, biomass and chlorophyll content. *Functional Plant Biol.*, **30**(3): 335-343.

Tehulie, N. S., Fikadu, T. and Purba, J. H. (2021). Response of Mungbean [*Vigna radiata* (L.) Wilczek] Varieties to Plant Spacing under Irrigation at Gewane, Northeastern Ethiopia. *Agro Bali: Agric. J.*, **4**(1): 1-14.

Uddin, M. S., Amin, A. K. M. R., Ullah, M. J. and Asaduzzman, M. (2009). Interaction effect of variety and different fertilizers on the growth and yield of summer mungbean. *American-Eurasian J. Agron.*, **2**(3): 180-184.

Ullah, M. (2006). Effect of Water Logging on Germination, Emergence and Subsequent Development of Mungbean (Vigna radiata) cv. Kanti. *Karnataka J. Agric. Sci.*, **19**(3): 513-516.

Valentini, R., Epron, D., De Angelis, P., Matteucci, G. and Dreyer, E. (1995). In situ estimation of net CO_2 assimilation, photosynthetic electron flow and photorespiration in Turkey oak (*Q. cerris* L.) leaves: diurnal cycles under different levels of water supply. *Plant Cell Environ.* **18**(6): 631-640.

Voesenek, L. A. C. J. and Sasidharan, R. (2013). Ethylene and oxygen signaling-drive plant survival during flooding. *Plant Biol.*, **15**(3): 426-435.

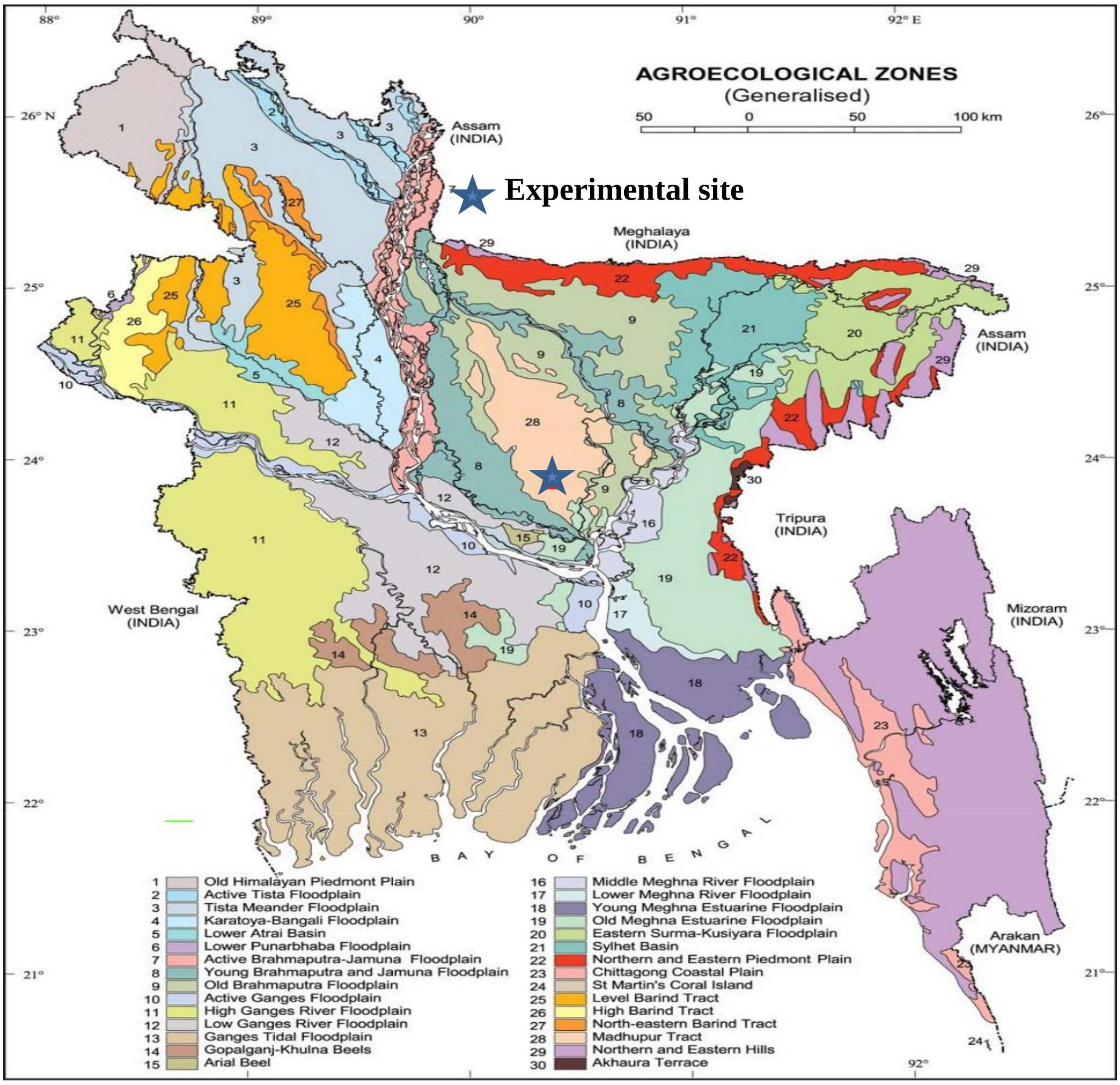
Wagner, P. A. and Dreyer, E. (1997). Interactive effects of waterlogging and irradiance on the photosynthetic performance of seedlings from three oak species displaying different sensitivities (Quercus robur, Q petraea and Q rubra). In *Annales des sciences forestières* (Vol. 54, No. 5, pp. 409-429). EDP Sciences.

Wu, X., Tang, Y., Li, C., McHugh, A. D., Li, Z. and Wu, C. (2018). Individual and combined effects of soil waterlogging and compaction on physiological characteristics of wheat in southwestern China. *Field Crops Res.*, **215**: 163-172.

APPENDICES

APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

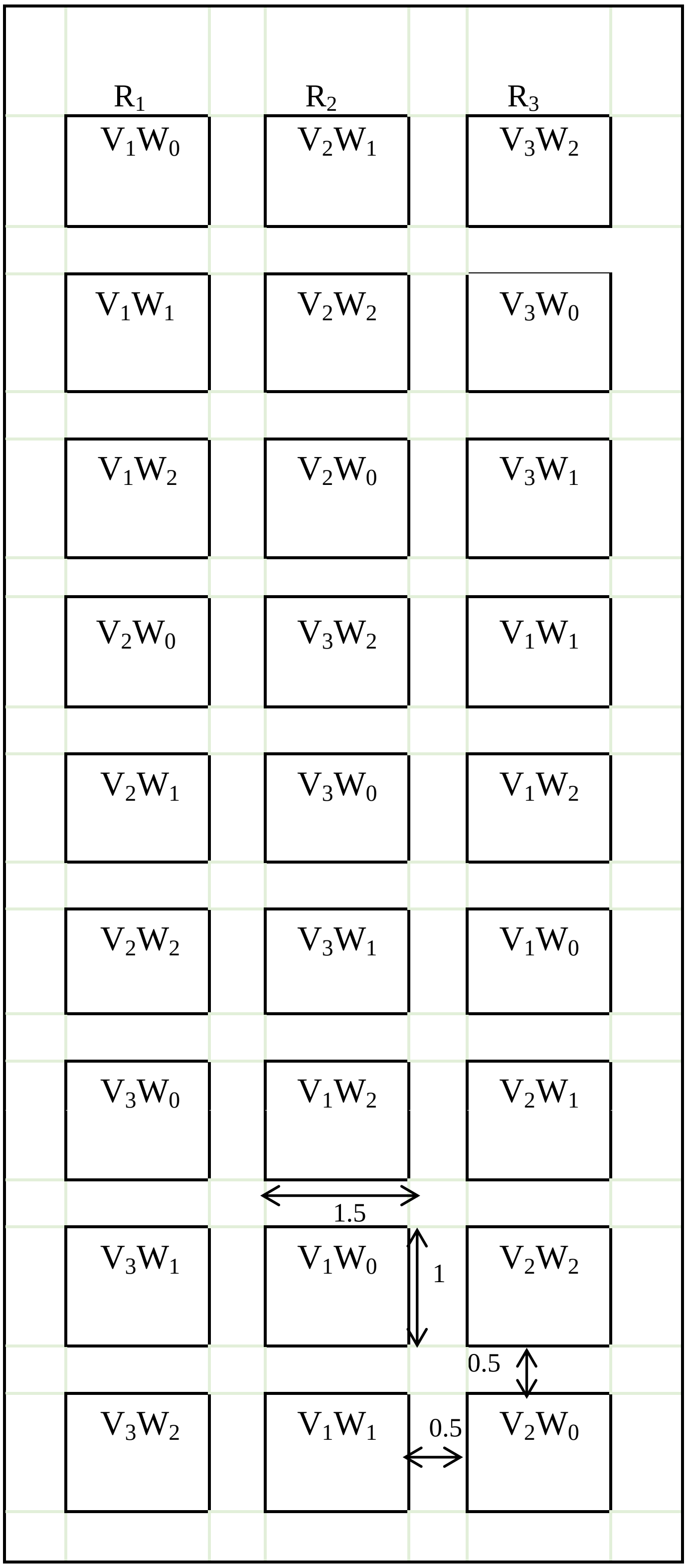


Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from March 2022 to June 2022

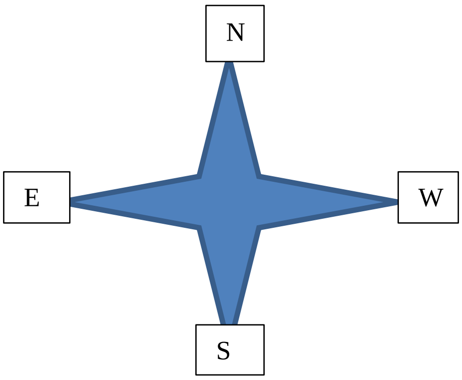
Month and year	RH (%)	Air temperature (C)			Rainfall (mm)
		Max.	*Min.*	*Mean*	
March, 2022	35.75	21.55	15.25	18.40	20.7
April, 2022	67.30	34.70	24.60	29.65	165.0
May, 2022	69.50	32.65	23.85	28.25	182.5
June, 2022	73.00	31.50	22.50	27.00	88.6

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

Appendix III: Layout of the experimental field



Legends



Factor A: Varieties (3)

a) BARI mung-6 (V_1)

b) BARI mung-7 (V_2) and

c) BARI mung-8 (V_3)

Factor B: Waterlogging stress (3)

a) W_0= Control (no irrigation)

b) W_1= Well watered (under normal condition) and

c) W_2= Waterlogged condition (at pre-flowering stage 24 hours at 20-30 DAS)

Length of plot: 1.5 m, **Width of plot:** 1 m

Replication to replication distance: 0.5 m

Plot to plot distance: 0.5 m,

Unit plot size: 1.5 m × 1 m (1.5 m^2)

Appendix IV. Mean square values of plant height at different days after sowing of mungbean

Sources of variation	Degrees of freedom	Mean square of plant height at		
		30 DAS	45 DAS	60 DAS
Replication	2	7.2720	10.4544	26.6944
Factor A	2	8.8690**	7.9244**	5.6665**
Factor B	2	48.8232**	53.5512**	51.4166**
A×B	4	1.2758*	0.1246*	0.3262*
Error	16	0.4673	1.2844	0.9444

* significant at 5% level of significance
** significant at 1% level of significance

Appendix V. Mean square values of number of leaves plant^{-1} at different days after sowing of mungbean

Sources of variation	Degrees of freedom	Mean square of number of leaves plant^{-1} at		
		30 DAS	45 DAS	60 DAS
Replication	2	0.5776	0.6136	2.2201
Factor A	2	0.7942**	0.6163**	3.2942**
Factor B	2	3.1022**	5.0179**	29.1112**
A×B	4	0.0302*	0.0258*	0.0172*
Error	16	0.0152	0.0786	0.0816

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VI. Mean square values of number of branches plant^{-1} at different days after sowing of mungbean

Sources of variation	Degrees of freedom	Mean square of number of branches plant^{-1} at	
		45 DAS	60 DAS
Replication	2	0.0940	0.3364
Factor A	2	0.2331**	0.2809**
Factor B	2	2.5477**	1.7826**
A×B	4	0.0077*	0.0076*
Error	16	0.0070	0.0147

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VII. Mean square values of yield components of mungbean growing during experimentation

Sources of variation	Degrees of freedom	Mean square of			
		Number of pods plant^{-1}	Number of seeds pod^{-1}	Pod length	1000-seed weight
Replication	2	8.7030	1.0000	1.4480	28.4440
Factor A	2	13.2860**	2.2257**	2.8465**	20.9970**
Factor B	2	119.7440**	14.6562**	19.0497**	178.5090**
A×B	4	0.5010*	0.2483*	0.2392*	0.3820*
Error	16	0.6930	0.0681	0.0876	0.9440

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VIII. Mean square values of yield of mungbean growing under the experiment

Sources of variation	Degrees of freedom	Mean square of grading of tuber			
		Seed yield	Stover yield	Biological yield	Harvest index
Replication	2	0.0300	0.0584	0.2952	17.1672
Factor A	2	0.0342**	0.0353**	0.1374**	1.5890**
Factor B	2	0.2652**	0.3031**	1.1374**	10.1857**
A×B	4	0.0007*	0.0016*	0.0042*	0.0495*
Error	16	0.0009	0.0043	0.0165	0.6472*

* significant at 5% level of significance
** significant at 1% level of significance

Appendix IX. Mean square values of post harvest soil chemical analysis of mungbean growing under the experiment

Sources of variation	Degrees of freedom	Mean square of	
		Available phosphorus content	Exchangeable potassium content
Replication	2	34.0278	4.8841
Factor A	2	2.8022**	3.8664**
Factor B	2	31.3700**	31.4840**
A×B	4	0.0163*	0.0183*
Error	16	0.4028	0.3387

* significant at 5% level of significance
** significant at 1% level of significance