INFLUENCE OF NITROGEN, PHOSPHORUS AND SPACING ON THE GROWTH, YIELD AND SEED QUALITY OF MUNGBEAN

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CERTIFICATE

This is to certify that the thesis entitled "INFLUENCE OF NITROGEN, PHOSPHORUS AND SPACING ON THE GROWTH, YIELD AND SEED QUALITY OF MUNGBEAN" submitted to Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (MS) in Seed Technology, embodies the results of a piece of bona fide research work carried out by Rifat Ben-Islam Deep, Registration. No. 12-05045 under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

Date:

Dhaka, Bangladesh

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ABSTRACT

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during kharif-I season (March to July, 2017) to study the effect of fertilizer and spacing on the morphological characteristics, yield contributing characters, yield and seed quality of mungbean. The experiment consisted of Factor A: Fertilizer management (4 levels); F_0 = N + P_2O_5 (0 + 0) kg ha^{-1}(Control), F_1= N + P_2O_5 (15 + 30) kg ha^{-1}(25 % lower than recommended dose by BARI), F_2 = N + P_2O_5 (20 + 40) kg ha^{-1}(Recommended dose by BARI), F_3 = N + P_2O_5 (25 + 50) kg ha^{-1}(25 % higher than recommended dose by BARI), and factor B: Plant spacing (3 levels); S_1 = 30 cm ×10 cm, S_2 = 30 cm × 15 cm, S_3 = 30 cm × 20 cm. The variety, BARImung-6 was used in this experiment as the test crop. The experiment was laid out in a split-plot design with three replications where levels of fertilizer were assigned in the main plot and spacing in the sub-plots. The results indicated significant variations in plant height, number of leaves plant^{-1}, number of pods plant^{-1}, pod length, number of seeds plant^{-1}, weight of 1000 seeds, seed yield, stover yield, biological yield, harvest index, germination percentage, germination index, shoot length, root length, dry weight of seedling and EC test due to fertilizer and/or spacing. Results also revealed that, N + P_2O_5 (25 + 50) kg ha^{-1} (F_3) treatment significantly influenced the morphological characters, yield contributing characters, yield and seed quality of mungbean. The highest seed yield (1.49 t ha^{-1}) was obtained from this treatment. On the other hand, 30 cm × 20 cm (S_3) treatment significantly influenced the morphological characters, yield contributing characters but 30 cm × 10 cm (S_1) treatment influenced significantly on yield which gives highest seed yield (1.44 t ha^{-1}) due to its high plant density. Among the treatment combination, N + P_2O_5 (25 + 50) kg ha^{-1} fertilizer with 30 cm × 10 cm plant spacing (F_3S_1) seemed to be more promising for obtaining higher yield (1.97 t ha^{-1}) and for having better quality seed production in mungbean.

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LIST OF ACRONYMS

AEZ	= Agro-Ecological Zone
As follows	= viz.
BARI	= Bangladesh Agricultural Research Institute
BAU	= Bangladesh Agricultural University
BBS	= Bangladesh Bureau of Statistics
CV%	= Percentage of coefficient of variance
cv.	= Cultivar
DAE	= Department of Agricultural Extension
DAS	= Days after sowing
et al.	=And others
FAO	= Food and Agriculture Organization
g	= gram
ha^{-1}	= Per hectare
Journal	= *J.*
kg	= Kilogram
LSD	= Least Significant Difference
Max	= Maximum
Meter	= m
mg	= milligram
Min	= Minimum
N	= Nitrogen
No.	= Number
NPK	= Nitrogen, Phosphorus and Potassium
NS	= Not significant
P	= Phosphorus
SAU	= Sher-e-Bangla Agricultural University
SRDI	= Soil Resources and Development Institute
Ton per hector	= t ha^{-1}
TSP	= Triple Super Phosphate
That is	= *i.e.*
%	= Percentage
^{0}C	= Degree Celsius

CHAPTER I

INTRODUCTION

Pulse crops belong to grain legumes. Bangladeshi farmer cultivate different kinds of pulse crops. Among them lentil, cowpea, blackgram, mungbean, fieldpea and grasspea are significant. The main source of protein for the people of Bangladesh, particularly for the poor sections are pulses. These are also the finest source of protein for domestic animals. Besides, the crops also have the ability to improve soils through nitrogen fixation. Rice protein is deficient in lysine whereas pulse protein is rich in lysine. According to FAO (2013) recommendation, a minimum intake of pulse by an adult should be 80 g day^{-1}, whereas it is only 13.42 g in Bangladesh (BBS, 2017). This is mainly because of the fact that the national production of the pulses is not adequate to meet up our national demand. Both the acreage and production of the pulses are declining in Bangladesh day by day due to the dominancy of wheat and boro rice in our cropping system. In Bangladesh, total production of pulses is only 0.65 million ton compared to 2.7 million tons of the requirement. This implies that the deficiency is almost 80% of the total requirement (Rahman *et al.,* 2007), which is mostly due to the low yield of pulse crop. At present, the area under pulse crop is 0.406 million hectare with the production of 0.322 million tons (BBS, 2013).

Mungbean (*Vigna radiata* L. Wilczek) is otherwise known as the green gram, maash, or moong. In Sanskrit, mudga, is a plant species resembling to mung which belongs to the family of Fabaceae. Mungbean is mainly cultivated in East Asia, Southeast Asia and Indian subcontinent. It is one of the most significant pulse crops of Bangladesh, as it is an excellent source of easily-digestible protein of low flatulence, which complements the staple rice diet in the country. It contains the amino acid, lysine which is generally adequantly present in food grains (Elias *et al*., 1986). mungbean holds the 3rd in protein content and 4th in acreage production in summer (BBS, 2017). Total summer pulse production is 387000 ton which covers 372310.79 ha of land of which mungbean occupies only 41277.93 ha and production is 35000 ton (BBS, 2017). Mungbean is produced for both human consumption and as fodder. Seeds of mungbean contains 51% carbohydrate, 26% protein, 10% moisture, 4% mineral and 3% vitamin (Afzal *et al*., 2008). This legume is known to have high nutrient values with excellent source of vegetable protein (seeds and sprouts contain to 28% of proteins). Sprouts of mungbean is also rich in vitamins, minerals and amino acids (especially lysine). Mungbean is considered as a substitute to animal protein as it forms a balanced diet when used with cereals (Khan *et al.*, 2001; Anjum *et al.*, 2006).

Cultivation of mungbean can also help to improve the physical, chemical and biological properties of soil as well as enhance soil fertility status through nitrogen fixation. In total, mungbean could be considered as an inevitable component of sustainable agriculture. Mungbean has a special significance in intensive crop production system of the country for its short growing period (Ahmed *et al*., 1978). In Bangladesh it can be cultivated in both late winter and summer season. Growing of mungbean in the summer season could be an effective effort to increase pulse production in Bangladesh. It can be said 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 little more than 1 tha^{-1} against the potential yield of 2 to 3 t ha^{-1}. Low yields of grain legumes, as well as mungbean make the crop less competitive with cereals and high value crops. Therefore, to meet the situation it is compulsory to boost up the production through suitable management practices. Midst of the cultural practices spacing and optimum use of fertilizer plays a significant role in growth and yield of mungbean.

Imbalanced nutrition or no fertilizer application is one of the most important constrains. Farmers have a wrong understanding of the fact that mungbean does not need fertilizers. The management of fertilizer is the significant factor that greatly affects the growth attributes and yield of this crop. Nitrogen and phosphorus are both integral components of virtually all the biochemical compounds that make plant life possible. There is no conceivable substitute of these two elements in constructing the biochemical machinery of plants. It is unequivocally clear that both N and P are essential elements in their structural, biochemical and physiological roles contributing to crop growth (Sinclair *et al.,* 2002). Nitrogen is an essential nutrient that required for plant growth. Nitrogen is vital because it is a major component of chlorophyll, the compound by which plants use sunlight energy to produce sugars from water and carbon dioxide (i.e., photosynthesis). It is also a major component of amino acids, the building blocks of proteins. Without proteins, plants wither and die. Nitrogen deficiency reduces the number of branches per plant, plant height, stem diameter, pod length, number of nodes. Pulses have relatively more requirement of P among the field crops. Phosphorus plays a remarkable role in plant physiological processes. It is a crucial constituent of majority of enzymes which are of great significance in the transformation of energy in carbohydrate metabolism in different types of plants and is closely related in cell division and seed development. Phosphorus fertilization and adoption of high yielding varieties are the important agronomic practices that greatly effect yield and profit of many crops including mungbean (Arya *et al.,* 1988). Application of small amount of nitrogen as a starter dose has a beneficial effect on crop yield and quality (Sandhu *et al.*, 1978). Pulses even though fix atmospheric N_2 by symbiotic means but application of nitrogenous fertilizer as starter or initial dose becomes helpful in increasing the growth and yield of legume crops (Ardeshana *et al*., 1993). Cultivation of crop in tropical soils is often limited by low P availability and the recovery of P applied as fertilizers by crops is usually very low, because most P becomes unavailable due to adsorption, precipitation or conversion to organic forms (Araujo *et al*., 2005).

The optimum plant density is a pre-requisite for obtaining higher productivity (Rafiei, 2009). Plant density affects the plant growth (Jahan *et al.,* 2005) as well as grain yield in mungbean (Jahan *et al.,* 2004). Improper spacing reduced the yield of mungbean up to 20-40% due to competition for light, space, water and nutrition. The optimum spacing favors the plants to grow in their both aerial and underground parts through efficient utilization of solar radiation and nutrients and thus increase grain yield (Miah *et al*., 1990). Plant density may vary with genotype, time of sowing, growing conditions, etc. (Sekhon *et al.,* 1996, 2002). Plant population may not only be defined in terms of number of plants m^{-2} (plant density) but also in terms of arrangement of plants on the ground (spatial arrangement or plant geometry) (Kaul *et al.,* 2002). The optimum plant population can be maintained by using adequate seed rate. Economic plant density helps in estimating the most profitable seed rate (Regan *et al.,* 2003). For obtaining high yields, optimum seed rate should be used for planting in an appropriate planting geometry. Extensive studies showed that 20 x 10 cm spacing was superior to 30 x 10 cm in summer season while in kharif (rainy season) 30 x 10 cm spacing was optimum for obtaining higher grain yields of mungbean (Ahlawat *et al.*, 2002). In Bangladesh, planting density of 30 x10 cm gave higher yield of mungbean than 20 x 20 cm or 40 x 30 cm planting density (Sarkar *et al.*, 2004). High variation has been reported in mungbean with respect to growth, phenology, yield attributes and grain yield (Yimram *et al*., 2009). So, there is a wide scope to conduct research activities on this topic. Hence, the present piece of research was conducted with following objectives.

OBJECTIVE

- To determine the optimum level of nitrogen and phosphorus for maximizing the growth, yield and seed quality of mungbean,
- To assess the effect of spacing on growth, yield and seed quality of mungbean, and
- To identify the combined effect of fertilizer and spacing on the growth, yield and seed quality of mungbean**.**

CHAPTER II

REVIEW OF LITERATURE

The growth, yield and seed quality of mungbean are influenced by fertilizer and plant spacing. Following review of literature includes reports as studied by several investigators who were engaged in understanding the problems that may help to explain and interpret the results of the present investigation. In this chapter, an attempt has been made to review the available information at home and abroad regarding the effect of fertilizer and plant spacing on the growth, yield and seed quality of mungbean.

2.1. Effect of fertilizer

Omran *et al.* (2018) conducted a field experiment at National Agricultural Sciences and Technology University (ANASTU) Kandahar, Afghanistan during summer 2015, to study the effect of nitrogen (N) and phosphorus (P) application rates on growth and yield of mungbean. The treatments consisted of three N-levels (25, 40 and 55 kg N ha^{-1}), three P-levels (40, 60 and 80 kg P_2O_5 ha^{-1}) and one absolute control (N_0P_0). The experiment was conducted using a factorial RCBD replicated thrice. Application of 55 kg N ha^{-1} showed significant improvement in growth attributes viz., plant height, number of branches $plant^{-1}$, total dry matter and straw yield (5.1 t ha^{-1}) over control and 25 kg N ha^{-1} level. Application of 40 kg N ha^{-1} showed highest number of pods $plant^{-1}$, seeds pod^{-1}, 1000-seed weight, grain yield (2.1 t ha^{-1}). P application at 80 kg P_2O_5 ha^{-1} showed greater plant height, higher number of branches $plant^{-1}$, total dry matter and straw yield (5 t ha^{-1}). However, 60 kg P_2O_5 ha^{-1} resulted in highest number of pods $plant^{-1}$, seeds pod^{-1}, 1000-seed weight and grain yield (2.1 t ha^{-1}). The interaction effect of N and P revealed that yield attributes and yield were highest with the application of 40 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1}. Overall, this study indicates that the mungbean should be fertilized with 40 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1} in semi-arid region of Afghanistan.

Razzaque *et al.* (2017) conducted a pot experiment at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during kharif- II season of 2011 to investigate the growth, dry matter production and yield of mungbean genotypes under nutrient stress soil. Ten mungbean genotypes viz., IPSA-12, GK-27, IPSA-3, IPSA-5, ACC12890053, GK-63, ACC12890055, BARI Mung-6, BUmug- 4 and Bina moog- 5 and six nitrogen fertilizer levels viz., 0, 20, 40, 60, 80 and 100 kg N ha^{-1} were included as experimental treatments. Results revealed that increasing nitrogen level in nutrient stress soil increased growth and dry matter production up to 60 kg N ha^{-1} irrespective of genotype and thereafter decreased. Among the mungbean genotype IPSA 12 showed maximum leaf area, dry matter production and seed yield (14.22 g $plant^{-1}$) in nutrient stress soil. The lowest seed yield (7.33 g $plant^{-1}$) was recorded in ACC12890053 under control condition.

Jalali *et al.*, (2017) conducted a study at the Experimental Farm of (ANASTU), Kandahar during 2015 to study the effect of varying nitrogen levels on growth and yield of mungbean (*Vigna radiata* L. Wilczek) in semi-arid region of Kandahar, Afghanistan. Experimental treatments comprised of seven N levels (0, 10, 20, 30, 40, 50, 60 kg N ha^{-1}). The experiment was laid-out in a RCB design with three replications. The results indicated that nitrogen levels with a few expectations significantly influenced the growth parameters and yield characteristics of mungbean. The maximum plant height and net assimilation rate was recorded when nitrogen was applied @ 60 kg N ha^{-1} while the lowest were found in control treatment. The highest leaf area surface, leaf area index, total dry matter $plant^{-1}$, number of primary branches $plant^{-1}$, root dry weight, root length, root nodule count at maximum flowering, crop growth rate and relative growth rate were recorded from the plots supplied with N @ 40 kg ha^{-1}. Total number of pods $plant^{-1}$, pod length, number of grains pod^{-1}, number of grains $plant^{-1}$, grains weight $plant^{-1}$ were significantly highest with treatment 30 kg N ha^{-1}, but 1000-grains weight had non-significant influence due to N levels. Grain, straw and biological yield were found significantly higher (1.96, 5.29, 7.25 t ha^{-1}) in treatment 30 kg N ha^{-1}. Significantly lowest grain, straw and biological yields were recorded in control treatment. Harvest index was non-significant with maximum harvest index (27.7%) in treatment 20 kg N ha^{-1} and the lowest (24.3%) in control.

Imran *et al.* (2016) conducted a field experiment with two mungbean cultivars, Swat-1 and NM-98, four levels of phosphorous (0, 20, 40, and 60 kg ha^{-1}) in the form of TSP, and four tillage systems, zero tillage (no tillage), minimum tillage (2-time), conventional tillage (4-time), and maximum tillage (6-time) were used. Results divulge that plant height, number of pods $plant^{-1}$, number of seeds pod^{-1}, biological yield, seed yield, 1000 seed weight, harvest index and protein content were significantly affected by mungbean cultivars, various phosphorous levels, and tillage systems. Cultivar swat-1 stands first in term of growth and yield. Highest thousand seed weight, seed yield, biological yield, and harvest index (%) were produced by P at the rate of 60 kg ha^{-1}, while maximum plant height, number of pods plant^{-1}, number of seeds pod^{-1}, and protein content were given by P at the rate of 40 kg ha^{-1} at par with P at the rate of 60 kg ha^{-1}. Among different tillage systems, maximum number of pods plant^{-1}, 1,000 seed weight, biological yield, seed yield, and protein content were observed in maximum tillage system. In case of interaction between P × T, maximum pods plant^{-1}, 1,000 seed weight, biological yield, seed yield, and protein content were produced by 60 kg P ha^{-1} + maximum tillage system.

Hossen *et al.* (2015) conducted an experiment at the research field of the Horticulture Research Center at Labukhali, Patuakhali during the period from January to March 2014 to find out the most suitable BARI mungbean variety and optimum rates of N concerning higher seed yield under the regional condition of Patuakhali (AEZ–13). Two BARI mungbean varieties namely BARImung-5 (V_1) and BARImung-6 (V_2) and five levels of N fertilizer including control viz. 0 kg N ha^{-1} (N_0), 30 kg N ha^{-1} (N_{30}), 45 kg N ha^{-1} (N_{45}), 60 kg N ha^{-1} (N_{60}), and 75 kg N ha^{-1} (N_{75}) were used for the present study as level factor A and B, respectively. In case of variety, BARImung-6 produced significantly longest pod (7.56 cm), maximum pods (9.14) plant^{-1}, maximum seeds (9.14) pod^{-1}, higher weight of 100–seed (4.48 g), highest seed weight (4.33 g plant^{-1}) and highest seed yield (1.56 t ha^{-1}) than BARImung-5 at harvest. In case of N fertilizer, longest pod (7.96 cm), maximum pods plant^{-1} (10.45), maximum seeds pod^{-1} (9.70), higher weight of 100 seed (4.52 g), higher weight of seed (5.73 g plant^{-1}) and greater seed yield (1.85 t ha^{-1}) were also obtained in 45 kg N ha^{-1} compare other N levels. The BARImung-6 × 45 kg N ha^{-1} for seed yield was found under the regional condition of Patuakhali (AEZ-13).

Amruta *et al.* (2015) conducted a field experiment at Department of Seed Science and Technology, GKVK, UAS, Bangalore during kharif 2012 to assess the response of nutrient levels and spacing on growth and yield attributes of Black gram cv. LBG-625 (Rashmi). Experimental results revealed that fertilizer application of 50:100:100 NPK kg ha^{-1} + Black gram rhizobia (250 g ha^{-1}) + PSB- *Bacillus megaterium* (250 g ha^{-1}) with the spacing of 60 x 10 cm recorded significantly higher number of branches plant^{-1} (5.60), number of leaves plant^{-1} (29.87), plant spread plant^{-1} (756.00), number of cluster plant^{-1} (14.07), number of pods cluster^{-1} (22.60), number of pods plant^{-1} (54.40), pod weight plant^{-1} (g) (22.60), seed recovery per cent (98.45) and processed seed yield (q ha^{-1}) (15.83) as compared to rest of the treatments. Hence, it can be concluded that the application of 50:100:100 NPK kg ha^{-1} + Black gram rhizobia (250 g ha^{-1}) + PSB- *Bacillus megaterium* (250 g ha^{-1}) with the spacing of 60 x 10 cm would be useful to enhance the productivity of black gram. The conjunctive use of inorganic fertilizers and bio-fertilizer may be suggested for higher productivity along with overall betterment.

Mainul *et al.* (2014) conducted an experiment at the experimental field of Sher-e-Bangla Agricultural University, Bangladesh during the period from February to April of 2012 to evaluate the effect of different levels of nitrogen on growth and yield performance as well as nutrient content of mungbean (BARImung-6). Four levels of nitrogen viz. N_0 (Control), N_1 (10 kg ha^{-1}), N_2 (20 kg ha^{-1}) and N_3 (25 kg ha^{-1}) were used as treatment on experiment followed by Randomized Complete Block Design with three replications. Maximum plant height (40.52 cm), number of leaves (19.14), number of branches (10.09), average dry weight plant^{-1} (7.35 g), number of pods plant^{-1} (15.90), number of seeds pod^{-1} (4.49), 1000 seed weight (42.56 g), seed yield (1.06 t ha^{-1}), stover yield (2.08 t ha^{-1}), N content in seed (3.60 %), P content in seed (0.48 %) and K content in seed (1.26 %) were found in N_3 which was statistically similar with N_2 whereas minimum from N_0.

Achakzai *et al.* (2012) conducted a field experiment to estimate the growth response of mungbean (*Vigna radiata* (L.) Wilczek) cultivars subjected to different levels of applied N fertilizer. To accomplish the aim, an experiment conducted in the experimental field of Agricultural Research Institute (ARI), Quetta. The soil of the study area was basic in reaction, salt free, medium textured having low organic matter and total N contents. Four different cultivars of mungbean viz., NM-92, NM-98, M-1, and NCM-209 grown in kharif season for two consecutive years i.e., 2007 and 2008. Six different levels of N fertilizer applied at the rate zero, 20, 40, 60, 80 and 100 kg ha^{-1}. While, a constant dose of P_2O_5 and K_2O also applied to each N level (except control, zero). Urea fertilizer used as a source of N, while TSP and SOP as sources of P and K, respectively. The plot size kept as 2.40 m^2 (4 x 0.15), and arranged in a randomized complete block design (RCBD). Results showed that different fertilizer levels did significantly ($p<0.05$) influenced most of the growth attributes of the mungbean. Maximum days to flowering (48.25) and number of branches plant^{-1} (3.83) recorded for plants subjected to highest dose of applied N fertilizer viz., 100 kg ha^{-1}. Similar responses toward added N fertilizer also noted for various cultivars of mungbean. Maximum days to flowering (47.72) and number of leaves plant^{-1} (5.86) recorded for NCM-209. Whereas, the maximum plant height (38.52 cm) number of branches plant^{-1} (3.72) obtained for mungbean cultivar M-1. The correlation coefficient (r) studies exhibited that plant height (0.593), number of leaves plant^{-1} (0.325), number of branches plant^{-1} (0.187) and leaf area (0.342) significantly ($p<0.05$) and positively correlated with their grain yield (kg ha^{-1}). On the other hand, days to 50% flowering (r=-0.265) are also significantly but negatively associated with their grain yield (kg ha^{-1}). Thus based on correlation studies it could revealed that cultivars under cultivation displayed a wide range of variation for most of the mentioned growth traits and could be exploited in breeding programme to enrich the mungbean genetic treasure.

Chowdhury *et al.* (2011) conducted a field experiment at Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, during the period from February to April, 2008 to assess the effect of N and S fertilizers with or without bio-fertilizer (Bradyrhizobium) on yield contributing characters of Binamoog-6. The experiment was laid out in Randomized Complete Block Design (RCBD) with nine treatments and three replications. The treatments were T_1-N_0S_0, T_2-N_0S5, T_3-N_0S_{10}, T_4-$N_{15}S_0$, T_5-$N_{15}S_5$, T_6-$N_{15}S_{10}$, T_7-$N_{30}S_0$, T_8-$N_{30}S_5$ and T_9-$N_{30}S_{10}$ with or without bio-fertilizer (Bradyrhizobium).Data were recorded at 35 days after sowing (DAS), 49 DAS and at harvest. There were significant variations among the different treatments combination in terms of nodulation, growth, yield and quality. Result showed that Bradyrhizobium inoculation significantly increased the number of pod plant^{-1}, number of seed pod ha^{-1}, 1000-seed weight, stover yield, grain yield. The highest number of pod plant^{-1} (18.78), number of seed pod^{-1} (11.89), 1000seed weight (43.40 gm), stover yield (3.80 t ha^{-1}) and grain yield (1.92 t ha^{-1}) were recorded in N0S10 treatment. The result revealed that the inoculation of bio-fertilizer (Bradyrhizobium) significantly increased the yield by positively influencing the yield contributing characters of Binamoog-6.

Uddin *et al.* (2010) conducted a field experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during September to December 2009 to evaluated the effect of date of planting and level of phosphorus on the shoot dry matter and yield of different varieties of mungbean. The experiment consisted of three mungbean varieties viz. BARIMung-5, BARIMung-6 and BINAMung-6, three planting dates viz. 15 September, 30 September and 15 October and three levels of phosphorus viz. 0, 40, and 80 kg P_2O_5 ha^{-1}. The experiment was laid out in 3 factor randomized complete block design with three replications. Among the varieties BARIMung-6 produced the highest seed yield (1.10 t ha^{-1}), which was similar to BARIMung-5. The lowest seed yield (0.99 t ha^{-1}) was obtained in BINAMung-6. Among the dates of planting, the highest seed yield (1.17 t ha^{-1}) was obtained on 15 September and the lowest one was obtained on 15 October. The highest seed yield (1.13 t ha^{-1}) was obtained in 80 kg P_2O_5 ha-1 followed by 40 kg P_2O_5 ha^{-1} and the lowest seed yield (0.98 t ha^{-1}) was obtained in control (no phosphorus application) treatment. In case of interaction, the variety BARIMung-6 planted on 15 September with 80 kg P_2O_5 ha^{-1} was superior in relation to shoot dry matter and seed yield compared to other varieties, which resulted in the highest seed yield. Seed yield of mungbean was found to have a significant positive correlation (r= 0.813) with shoot dry matter. In contrast, the lowest shoot dry matter and seed yield were found in variety BINAMung-6 planted on 15 October with control (no phosphorus application) treatment.

Ali *et al.* (2008) conducted a field experiment to assess the performance of green gram (*Vigna radiata* L.) in wheat-green gram cropping system. Wheat crop received three treatments (T_1) 60-45-0-0, (T_2) 120:90:60:5, and (T_3) 60:90:60:5 kg N: P_2O_5: K_2O: Zn ha^{-1}. The third treatment received 20 t ha^{-1} FYM one month before sowing of wheat. Wheat crop was followed by green gram which received (T_1) 0:45:0:0, (T_2) 0:90:60:5 and (T_3) 0:90:60:5 kg N: P_2O_5: K_2O: Zn ha^{-1} in the respective treatments. The experimental data showed that T_3 gave the highest green gram yield of 516 kg ha^{-1} and significantly different from other treatments with an increase of about 61 % over T_1 and 15 % over T_2.

Sadeghipour *et al*. (2010) conducted a field experiment on green gram at Tehran (Iran) with five levels of nitrogen (0, 30, 60 and 90 kg N ha^{-1}) and six levels of phosphorus (0, 30, 60, 90, 120 and 150 kg P_2O_5 ha^{-1}). The experimental results showed that application of N and P fertilizers significantly increased the seed yield of mungbean. The maximum seed yield (224.2 g m^{-2}) was obtained when 90 kg N ha^{-1} and 120 kg P_2O_5 ha^{-1} was applied. This escalation in seed yield was mainly due to more number of pods per plant, number of seeds per pod and 1000 seed weight.

Khatun *et al.* (2008) conducted a field experiment to evaluate the effect of irrigation and phosphorus fertilization on growth and yield of summer mungbean (cv. BINAmoog-5). Experimental treatments comprised four levels of irrigation viz. no irrigation, one irrigation at 20 DAS, two irrigations at 20 & 40 DAS and three irrigations at 20, 40 & 60 DAS and four levels of phosphorus viz. 0, 20, 30 & 40 kg P_2O_5 ha^{-1}. The highest number of branches $plant^{-1}$, number of pods $plant^{-1}$, pod length, number of seeds pod^{-1}, seed yield and harvest index were achieved from two irrigations. Application of 30 kg P_2O_5 ha^{-1} produced the highest number of seeds pod^{-1}, seed yield and harvest index. The highest seed yield was attained from the interaction of two irrigations × 40 kg P_2O_5 ha^{-1}.

Sultana *et al.* (2008) carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from February to May 2006 to appraise the effect of nitrogen and phosphorus on growth and yield of summer mungbean. CV. BINA moog-5. Experimental treatments comprised four levels of nitrogen viz. 0, 20, 30 and 40 kg N ha^{-1} and four levels of phosphorus viz. 0, 20, 30 and 40 kg P_2O_5 ha^{-1}. The experiment was laid out in a randomized complete block design with three replications. The highest grain yield was obtained in 30 kg N ha^{-1} due to improvement of yield components. The lowest grain yield was obtained in the no nitrogen i.e. control treatment. In case of phosphorus, 30 kg P_2O_5 ha^{-1} produced the highest grain yield while 0 kg P_2O_5 produced the lowest yield. Interaction of 30 kg N ha^{-1} 30 kg P_2O_5 ha^{-1} produced the highest grain yield.

Jain *et al.* (2007) carried out a field experiment to assess the response of mung bean to phosphorus and micronutrients viz. Zn, Mo and B with Rhizobium inoculation on the cultivars Pusa-105 and Pusa Vishal of mung bean (*Vigna radiata*) with different combinations. The *Rhizobium* inoculation with phosphorus 40 Kg ha^{-1}, Zn 4 Kg ha^{-1}, Mo 0.6 Kg ha^{-1} and B 0.1 Kg ha^{-1} gave the highest N and P uptake and total sugar in the seeds of green gram.

Raman *et al.* (2006) conducted a field experiment during February to May 2002 in Annamalainagar. Tamil Nadu. India to evaluate the effect of foliar nutrition on crop nutrient uptake and yield of greengram *(V. radiata).* There were 10 foliar spray treatments, consisting of water spray. 2% diammonium phosphate (DAP) at 30 and 45 days after sowing, 0.01% Penshibao, 0.125% Zn chelate, 30 ppm NAA, DAP + NAA, DAP + Penshibao, DAP + Zn chelate, DAP + Penshibao + NAA, and DAP + NAA + Zn chelate. Crop nutrient uptake, yield and its attributes (number of pods/plant and number of seeds/pod) of greengram augmented significantly due to foliar nutrition. The foliar application of DAP + NAA + Penshibao was significantly superior to other treatments in increasing the values of N. P and K uptakes, yield attributes and yield. The highest grain yield of 1529 kg ha^{-1} was recorded with this treatment.

Naeem *et al.* (2006) studied the effect of organic manures and inorganic fertilizers on growth and yield of green gram (*Vigna radiata* L.) and reported that grain yield was recorded highest (1104 kg ha^{-1}) with the application of the inorganic fertilizers @ 25:50:50 kg NPK ha^{-1}. Among organic sources, poultry manure @ 3.5 t ha^{-1} was found the best followed by FYM @ 5 t ha^{-1}. The economic analysis revealed maximum net benefit from the treatment, where poultry manure was applied.

Vikrant *et al.* (2005) carried out a field experiment on a sandy loam soil in Hisar, Haryana India during khatif 2000-01 and 2001-02 to investigate the effects of P (0. 20. 40 and 60 kg P_2O_5ha^{-1}) applications to green gram cv. Asha. Application of 60 kg P, being at par with 40 kg P, was significantly superior to 0 and 20 kg P ha^{-1} in respect of grain, stover and protein yields of green gram.

Oad *et al.* (2005) conducted a field experiment to assess the effect of different NPK levels (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg/ha) on the growth and yield of mungbean cv. AEM 96 in Tandojam, Pakistan, during the spring season of 2004. The different NPK levels significantly influenced the crop parameters. The 10-30-30 kg NPK ha^{-1} was the best treatment, recording plant height of 56.3, germination of 90.5%, satisfactory plant population of 162.0 prolonged days taken to maturity of 55.5, longest pods of 5.02 cm, seed weight of 10.5 g, seed index of 3.5 g and the highest seed yield of 1205.2 kg ha^{-1}. There was no significant change in the crop parameters beyond this level.

Khan *et al.* (2004) carried out an experiment to assess the effect of different levels of phosphorus on the yield components of mungbean cv. NM-98 in D.I. Khan. Pakistan in 2000. Treatments comprised: 0, 20, 40, 60, 80, and 100 kg P ha^{-1}. The increase in phosphorus levels decreased the days to flowering and increased the branches $plant^{-1}$, number of pods $plant^{-1}$, 1000-grain weight and grain yield. The highest yield of 1022 kg ha^{-1} was obtained at the phosphorus level of 100 kg ha^{-1} compared to a 774 kg ha^{-1} yield in the control. However, the most economical phosphorus level was 40 kg ha^{-1}, because it produced a grain yield statistically comparable to 100 kg P ha^{-1}.

Manpreet *et al.* (2004) conducted a study in Ludhiana. Punjab. India during summer 2000 to examine the response of mungbean genotypes (SML-134. SML-357 and SML-668) to P application (0. 20. 40 and 60 kg P_2O_5 ha^{-1}) under irrigated conditions. Yield attributes such as number of branches $plant^{-1}$ and pods $plant^{-1}$ were significantly higher in SML-357 and SML-134. Whereas pod length and 100-seed weight were higher in SML-668. Which, accounted for higher grain yield in this cultivar compared to SML-134 but was at par with SML-357. The straw yield displayed the reverse trend with significantly higher value for SML-134, thus lowering the harvest index significantly compared to SML-668 and SML- 357. Phosphorus application exhibited a non-significant effect on number of branches $plant^{-1}$, number of seeds pod^{-1}, pod length and 100 seed weight. However, the increase in P level presented significant increase in the number of pods per plant, which accounted for significantly higher grain and straw yields at higher levels (40 and 60 kg ha^{-1}) compared to lower levels (0 and 20 kg ha^{-1}). Harvest index remained unaffected with P application. The economic optimum P level for all the 3 summer mungbean genotypes was found to be 40 and 60 kg P_2O_5 ha^{-1}.

Malik *et al.* (2003) conducted an experiment to assess the effect of varying levels of nitrogen (0, 25 and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean (*Vigna radiata* L.) cultivar NM-98 during the year 2001. Even though plant population was not affected significantly but various growth and yield components were significantly affected by varying levels of nitrogen and phosphorus. A fertilizer combination of 25-75 kg NP ha^{-1} resulted in maximum seed yield (1112.96 kg ha^{-1}). Maximum protein content (25.6%) were obtained from plots fertilized @ 50-75 kg NP ha^{-1} followed by protein content of 25.1% obtained from plots fertilized @ 25-75 kg NP ha^{-1}. Highest net income (Rs. 21374.9) was also obtained by applying Nand P @ 25 and 75 kg NP ha^{-1}, respectively.

Asif *et al.* (2003) carried out a field trial to evaluate impact of phosphorus fertilizer on growth and yield of mungbean in India. They found that various levels of phosphorus significantly affected the number of leaves plant^{-1}, pods plant^{-1}, plant height, seeds pod^{-1} and 1000 grain weight. Phosphorus level of 35 kg ha^{-1} produced the maximum grain yield.

Satish *et al.* (2003) carried out afield trial in Haryana, India in 1999 and 2000 to evaluated the response of mungbean cultivars Asha, MH 97-2, MH 85-111 and K 851 to different P levels (0, 20, 40 and 60 kg P_2O_5 ha^{-1}). From the result it was discovered that the highest dry matter content in the leaves, stems and pods was obtained in Asha and MH 97-2. The total above-ground dry matter as well as the dry matter accumulation in leaves, stems and pods increased with increasing P level up to 60 kg P ha^{-1}. MH 97-2 and Asha produced significantly more number of pods and branches/plant compared to MH 85-111 and K 851. Phosphorus at 40 and 60 kg ha^{-1} increased the number of pods plant^{-1} grain yield and grains per pod over the control and P at 20 kg ha^{-1}. The number of branches per plant increased with increasing P rates.

Srinivas *et al.* (2002) carried out a field trial to assess the effects of N (0, 20, 40 and 60 Kg ha^{-1}) and P_2O_5, (50 and 75 Kg ha^{-1}) along with seed inoculation with Rhizobium culture on the growth, yield and yield components of mungbean. They observed from the result that number of pods per plant, pod length and seeds per pod were increased with increasing rates of P and with increasing rates of N up to 40 kg ha^{-1} and also found that 1000 seed weight in greengram.

Mahboob *et al.* (2002) carried out a field trial to investigate the effect of seed inoculation at different nitrogen levels on mungbean at the Agronomic Research Station, Farooqabad in Pakistan. They discovered that various yield components like 1000-grain weight was affected significantly with 50-50-0 N kg ha^{-1}, P kg ha^{-1}, K kg ha^{-1} application. Again they revealed that seed inoculation with 50-50-0 N kg ha^{-1}, kg ha^{-1}, K kg ha^{-1} exhibited superior performance in respect of seed yield (955 kg ha^{-1}).

Rajender *et al.* (2002) conducted a trial to assess the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-

111 and T44. Grain yield increased with increasing N rates up to 20 kg ha^{-1}. Further rise in N level did not influence the yield. The number of branches, number of pods per plant, numbers of seeds per pod. 1000-seed weight and straw yield increased with increasing rates P. whereas grain yield increased with increasing rates up to 40 kg P ha^{-1} only.

Rudreshhappa *et al.* (2002) conducted a trial to investigate the influence of N levels (0, 12.5 and 25 kg) on growth, yield and nutrient uptake of green gram in paddy fallows. Application of 12.5 kg N ha^{-1} was recorded to produce significantly higher seed yield. Further escalation in N doses (25 kg ha^{-1}) did not significantly increase the yield.

Pathak *et al*. (2001) conducted an experiment to assess the influence of N levels (0, 10, 20 and 30 kg ha^{-1}) on growth and yield of mungbean under rainfed condition during the summer of 1999 and found that application of 20 kg N ha^{-1} yielded poorer than 30 kg N ha^{-1}.

Umar *et al.* (2001) reported after conducting an experiment that plant height and numbers of branches plant^{-1} were significantly increased by phosphorus application. Number of pods plant^{-1}, seeds pod^{-1}, 1000-seed weight and grain yields were also increased significantly by application of phosphorus along with nitrogen.

Teotia *et al.* (2001) conducted a greenhouse experiment to study the influence of P and S interaction on yield and nutrient composition of mungbean cv. *Pant Moong-2* and discovered that P and S applied individually or in combination increased the N and K content of the grain and straw and the yield of the plant.

El-Metwally *et al.* (2001) conducted two field experiments to assess the effects of P levels (0, 15. 30 and 45 kg ha^{-1}) on the growth, yield and yield components as well as chemical composition of mungbean cv. Kawmy-1. Growth, yield and yield components of mungbean were markedly improved with the addition of 45 kg P ha^{-1}. Addition of 45 kg P ha^{-1} distinctly increased total carbohydrates and protein percentages compared with other treatments. Application of 45 kg P ha^{-1} markedly increased the number of pods per plant. Adding of 30 kg P ha^{-1} was the recommended treatments to obtain the best results for growth, yield and yield components as well as chemical composition of mungbean.

Tariq *et al*. (2001) carried out a field experiment to evaluate the influence of P and K application on growth and yield of green gram on a sandy clay loam soil under irrigated condition of Faisalabad (Pakistan). They indicated that plant height, number of branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, 1000-seeds weight and seed yields were increased significantly by application of P and K along with nitrogen. Application of P_2O_5 and K_2O each @ 70 kg ha^{-1} along with nitrogen application @ 30 kg ha^{-1} produced highest grain yield of 876.32 kg ha^{-1}.

Khan *et al.* (1999) conducted a trial to investigate the optimum phosphorus levels essential for obtaining high yield of mungbean under conditions prevailing in D. I. Khan. The influence of various phosphorus levels on two mungbean cultivars NM-92 and NM-54 revealed that all the yield and yield contributing factors were significantly influenced by the application P_20_5. However, no statistical difference between the cultivars was detected. Similarly, the interaction of phosphorus levels with the cultivars was also non-significant. The application of P_20_5 from 60-90 kg ha$^{–1}$ is recommended for realizing better yield of mungbean.

2.2. Effect of spacing

Gebremariam *et al.* (2018) carried out a field experiment during 2015 at Humera Agricultural Research Center, Humera, Ethiopia, to evaluate the growing performance of mung bean under varying inter-row and intra-row spacing. The experiment was organized in a split plot design with three replications. The treatments comprised four inter row spacing (20 cm, 25 cm, 30 cm 35 cm and 40 cm) were randomized in the main plots and four intra-row spacing (5 cm, 10 cm, 15 cm, and 20 cm) randomized in the sub-plots. Data on traits such as plant height at maturity, number of branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, 1000-seeds weight and seed yield were recorded. Results indicated significant interaction effect of inter row and intra row spacing on days to 50% maturity number of pods plant^{-1}, plant height and seed yield. On the other hand number of branches plant^{-1}, number of seeds pod^{-1} and 1000-seeds weight were not significantly affected by the interaction effect of inter and intra row spacing. Maximum seed yield was obtaining in inter row and intra row spacing of 30 cm and 5 cm respectively while maximum plant height was recorded in inter row spacing of 40cm and intra row spacing of 5 cm. As a result of main effect, the highest number of branches and seeds plant^{-1} were recorded at 40 cm inter row spacing. The main effect of intra row spacing was also significant on number of seeds pod^{-1} and 1000-seeds weight with the maximum values recorded at 20 cm spacing. To conclude, 30 cm inter row spacing and 5 cm intra row spacing would be the best spacing for maximum yield achievement.

Yeasmin *et al.* (2016) an investigation carried out an investigation at the experimental field of the Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during September to November 2014 to evaluate the productivity of three mungbean genotypes, viz., GK-24 (G_1), GK-63 (G_2) and BU mug 4 (G_3) under four plant spacing (densities) such as i) 15 cm x 10 cm= 66 plants m^{-2} (D_1), ii) 20 cm x 10 cm= 50 plants m^{-2} (D_2), iii) 25 cm x 10 cm= 40 plants m^{-2} (D_3) and iv) 30 cm x 10 cm=33 plants m^{-2} (D_4). The experiment was conducted in a factorial randomized complete block design with three replications. A wide variation among the genotypes was observed in relation to light transmission, yield, and yield contributing characters. At 30 cm x 10 cm spacing (D_4) the highest light transmission ratio (LTR) was observed in G_1 genotype (57.92) and the lowest LTR value in G_2 genotype (46.92). Among the three genotypes, G_1 produced the highest seed yield (1094 kg ha^{-1}). But highest seed number pod^{-1} was found in D_2 (11.61) while maximum pods plant^{-1} (11.08) was in D_4 treatment followed by D_3 (10.59). Among the four plant densities, treatment D_3 showed the highest 1000-seed weight (50.30 g). The highest seed yield (1114 kg ha^{-1}) was recorded in the treatment D_4. Among the interaction, the highest number of seeds pod^{-1} (12.20) was found in the treatment D_1G_3, though the highest number of pods plant^{-1}(12.03) was in treatment D_4G_1 but the1000-seed weight was the highest (51.92 g) in D_3G_1. The highest seed yield (1230 kg ha^{-1}) was recorded from treatment D_4G_1. The result revealed that GK- 24 genotype performed the best in all respects of yield and yield attributes at 30 cm x 10 cm spacing compared to other treatments.

Kumar *et al.* (2016) conducted a field experiment during spring/summer season of 2007 and 2008 at Crop Research Centre of Institute of Agricultural Sciences, Bundelkhand University, Jhansi (U.P.), to investigate the influence of planting date, seed rate and rows pacing on yield and yield attributes of bold seeded mungbean. Four planting dates (February 25, March 11, March 26 and April 10), three seed rates (30, 40 and 50 kg/ha) and two row spacing (20 cm and 30 cm) were tested. Grain yield increased with delay in planting up to March 11, thereafter it declined significantly and drastic reduction was observed beyond March 26. Seed rate of 40 kg ha^{-1} and row spacing of 20 cm was found to be optimum for higher yield of bold seeded spring mungbean. Nodulation studies were affected significantly due to different planting dates but row spacing and seed rate does not influenced significantly.

Kabir *et al.* (2016) reported that plant growth regulator plays an important role of crops yield especially in mungbean. Row spacing also play vital role in mungbean yield. Therefore, a field experiment was carried out to assess the influence of plant growth regulator (NAA) and row spacing on growth and yield of mungbean. The experiment comprises of four levels of NAA viz., 0, 20, 40 and 60 ppm and three different spacing viz., 20 cm × 10 cm, 30 cm × 10 cm and 40 cm × 10 cm. The results indicated significant variations in number of pods plant, pod length, number of seeds pod^{-1}, 1000 seeds weight, seed yield, stover yield, biological yield and harvest index due to plant growth 1 regulator (NAA) and/or row spacing. The maximum 1000 seeds weights, seed yield and harvest index were found when mungbean was sown with row spacing in 30cm × 10cm in combination with 40 ppm NAA. Therefore, yield of mungbean can be improved by applying NAA and row spacing.

Yadav *et al.* (2014) conducted an experiment comprised of three dates of sowing (July 15, August 1 and August 16), three spacing (20 cm x 10 cm, 30 cm x 10 cm and 40 cm x 10 cm) and six fertilizer and seed treatments (Control-without fertilizer and seed treatment with microbial inoculants),recommended dose of fertilizer (RDF) as basal dose (12.5 kg ha^{-1} N and 40 kg ha^{-1} P_2O_5), seed treated with Rhizobium and Phosphate Solubilizing Bacteria (PSB), alone and or in combination, seed treated with Rhizobium and PSB + RDF , seed treated with Rhizobium and PSB + RDF as basal dose + Borax spray (100 ppm) at flower initiation in split-plot design with three replications in order to explore the possibility of enhancement of quality seed production in mungbean cv. NDM 1 during wet (kharif) 2013. The seed yield and harvest index and their contributing traits namely, number of pods plant^{-1}, pod length, number of seeds pod^{-1} and 1000 seed weight were decreased significantly as delayed the sowing. Spacing 30 x 10 cm was appeared superior as compared to either 20 x 10 cm or 40 x 10 cm. Use of Rhizobium, PSB and Borax had also revealed significant advantage over control and or no-inoculation. The treatment consist of seed treated with *Rhizobium* and Phosphate Solubilizing Bacteria + Fertilizer (12.5 kg ha^{-1} N and

40 kg ha^{-1} P_2O_5), as basal dose + Borax spray (100 ppm) at flower initiation being applied at 30 cm x 10 cm spacing apart and sown on 15th July may be exploited to realize higher seed yield and harvest index and also to improve seed vigour in the terms of germination, seedling length, vigour index and field emergence of mungbean.

Rasul *et al.* (2012); conducted a field trial to establish the proper inter-row spacing and suitable variety evaluation in Faisalabad, Pakistan. Three mungbean varieties V_1, V_2, V_3 (NM-92, NM-98, and M-1) were grown at three inter-row spacing (S_1-30 cm, S_2-60 cm and S_3-90 cm) respectively. Experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement randomizing varieties in the main and inter-row spacing in the sub-plots. The data recorded were analysed statistically using Fisher's analysis of variance technique and Least Significant Difference (LSD) test at 5% probability level. Highest seed yield was achieved for variety V_2 at 30 cm spacing. Among varieties V_2 exhibited the highest yield 727.02 kgha^{-1} while the lowest seed yield 484.79 kg ha^{-1} was obtained with V_3. The spacing 30 cm showed highest seed yield 675.84 kg ha^{-1} as compared to other spacing treatments. Low potential varieties and improper agronomic practices may be a serious cause of low productivity in pulses. The interaction of V_2S_1 exhibited significantly higher yield than other treatments. The lowest seed yield was obtained at V_3S_1 (462.8 kg ha^{-1}). The higher yield in V_2S_1 was characterized by more number of plants in narrow spacing of 30 cm (37 plants m^{-2}), plant height of 51.4 cm, higher number of fruit bearing branches (7 $plant^{-1}$), the highest number of pods per plant (18.86), number of seeds per pod (10.06), 1000 grain weight (4.8 g), the highest biological yield (4894.2 kg ha^{-1}) with a harvest index of (17.75) and the highest number of nodules per plant (15) were the components of high yield formation for mung bean variety V_2 under the inter-row spacing of 30cm. So, it can be concluded that mung bean variety Nm-98 should be grown at inter row spacing of 30 cm under the agro-climatic conditions of Faisalabad.

Begum *et al.* (2009) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from March to June, 2007 to investigate the influence of cultivar and seed rate on morphological characters, yield attributes and yield of summer mungbean. The experiment comprised four varieties viz., BINA moog2, BINA moog5, BINA moog6 and BINA moog7 and four seed rates viz. 30, 40, 50 and 60 kg ha^{-1}. The experiment was laid out in a randomized complete block design with four replications. Results revealed that variety and seed rate had significant effect on the studied crop characters and yield. The variety BINA moog7 showed superiority in relation to plant height, number of branches and effective pods per plant, number of seeds pod^{-1} compared to other varieties, which resulted in the highest seed yield both per plant and per hectare. The plant height, stover yield and number of non-effective pods per plant increased with the increase in seed rate, while branch number, number of effective pods per plant, seeds per pod, 100-seed weight, as well as seed weight per plant decreased with increasing seed rate. The higher number of branches and effective pods per plant, number of seeds pod, 100seed weight and seed yield per plant were recorded at the rate of 30 and 40 kg seeds ha^{-1} and the lowest values for the above parameters were observed at the rate of 60 kg seeds ha^{-1}. But per unit area basis, the highest seed yield was recorded in 40 kg seeds ha^{-1} followed by 50 kg seeds ha^{-1} due to accommodation of higher number of plants. BINA moog7 interacted favorably with the seed rate of 30 kg ha^{-1} to produce the highest seed yield.

Kabir *et al.* (2008) conducted a field experiment to assess the influence 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. BARIMung-2, BARIMung-3, BARIMung-4, BARIMung-5 and BINAMung-2 and three spacing of planting viz. 30 cm × 10 cm, 20 cm × 20 cm and 40 cm × 30 cm. The experiment was laid out in a randomized complete block design with three replications. It was observed from the experiment that the highest seed yield was obtained from BARIMung-2 whereas BINAMung-2 attained 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. BARIMung-2 planted at a spacing of 30 cm × 10 cm gave the maximum seed yield.

Birhanu *et al.* (2008) carried out an experiment to investigate the main cropping season at two locations in North Gondar Zone, Ethiopia, to determine the optimum inter- and intra-row spacing of mung bean for maximum yield and yield components. The experiment was laid in a randomized complete block design with three replications in a factorial arrangement of four inter-row (20, 30, 40 and 50 cm) and three intra-row (5, 10 and 15 cm) spacing using mung bean variety Rasa (N-26). Significant interaction effect of inter- and intra-row spacing was observed for days to maturity, number of branches per plant, number of pods per plant, grain yield, harvest index, days to flowering, plant height and aboveground dry biomass yield. The highest grain yield (1882.67 kg ha^{-1}) was obtained at interaction of 40 × 10 cm spacing, while the lowest (1367.8 kg ha^{-1}) was obtained from 20 × 5 cm spacing. However, the result of economic analysis showed that the maximum net benefit was obtained at spacing of 40 × 15 cm.

Tickoo *et al.* (2006) conducted a field trial with Mungbean cultivars Pusa 105 and Pusa Vishal which were sown at 22.5 and 30 cm spacing and supplied with 36-46 and 58-46 kg N-P ha^{-1} during the kharif season of 2000. The location of the experiment site in Delhi, India. Cultivar Pusa Vishal achieved higher biological and grain yield (3.66 and 1.63 t ha^{-1} respectively) compared to cv. Pusa 105. Row spacing at 22.5 cm resulted in higher grain yields in both crops.

Bhatti *et al.* (2005) conducted a field experiment on a sandy-clay loam soil in Faisalabad, Pakistan for two consecutive years (2001 and 2002) to investigate the insfluence of intercrops and planting patterns on the agronomic traits of sesame. The planting patterns encompassed 40 cm spaced single rows, 60 cm spaced 2-row strips and 100 cm spaced 4-row strips, while the cropping systems were sesame + mungbean, sesame + mashbean *(Vigna aconitifolia)*, sesame + soybean, sesame + cowpea and sesame alone. In the midst of the intercropping patters, sesame intercropped with mungbean, mashbean, soybean and cowpea in pattern of 100 cm spaced 4-row strips (mungbean 25 cm apart) proved to be feasible, easily workable and more productive than sesame mono-cropping.

Ihsanullah *et al.* (2002) revealed that highest plant height (47.50 cm) was observed in 43 cm row spacing where plants were spaced 7 cm within rows. Maximum pods $plant^{-1}$ (28.25), number of seeds pod^{-1} (10.25), biological yield per plant (39.75 g), grain yield per plant (6.87 g), 100-seed weight (4.27 g) biological yield (3854 kg ha^{-1}), grain yield (921 kg ha^{-1}) were recorded for row spacing of 20 cm where plants were spaced 15 cm within rows. Grounded on these results, 20 cm row-to-row spacing with 15cm plant-to-plant can be recommended for irrigated condition to get higher yield.

Khan *et al.* (2001) carried out a field experiment with mungbean during the summer season of 2000, in Peshawar, Pakistan. The row spacing treatments were 25 and 50 cm, while plant spacing were 5, 7.5 and 10 cm. Emergence of seedlings m^{-2}, days to flowering, days to maturity, number of grains pod^{-1}, number of branches $plant^{-1}$, plant height (cm), 1000 grain weight (g), percent hard grain (%), biological yield (kg) and grain yield (kg ha^{-1}) were significantly influenced by row and plant spacing, pods number $plant^{-1}$ and harvest index were not significantly affected at 5% level of significance with row and plant spacing. The results revealed that a spacing of 50 cm between rows and 10 cm within rows produced the maximum number of pods $plant^{-1}$, seeds pod^{-1}, 1000 grain weight, low percent hard grain and high biological yield, harvest index and grain yield (kg ha^{-1}).

CHAPTER III

MATERIALS AND METHODS

A field experiment was conducted at the Sher-e-Bangla agricultural University farm to study the effect of nitrogen, phosphorus and spacing on the growth, yield and seed quality of mungbean. The details of the experimental materials and methods used in this experiment have been described below:

3.1. Site description

3.1.1. Geographical location

The experimental area was situated at 23°77´N and 90^{0}35´E longitude at an elevation of 8.6 meter above the sea label.

3.1.2. Agro-Ecological Zone

The location of experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments repressed the dissected edges of the Modhupur tract leaving small hillocks of red soils as "islands" surrounded by floodplain. The location of experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.3. Soil

The soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace soils under Tejgaon series. Soil contain 1.08% organic matter with a pH of 7.1. The experimental zone was flat having accessible irrigation and drainage system and above flood level. Soil samples from 0-15 cm depth were collected from experimental fields. Analysis of the collected soil sample were done by Soil Resource and Development Institute (SRDI, Dhaka. The chemical properties of the soil are presented in Appendix II).

3.1.4. Climate

The geographical location of the experimental site belongs to the subtropical climate, categorized by 3 distinct seasons, the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. Metrological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected in details from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix III.

3.2. Test crop and its characteristics

The test crop used for the experiment was BARI Mung-6. After multilocation trials, Bangladesh Agricultural Research Institute (BARI) released this variety for general cultivation with a popular name BARI Mung-6 in the year 2003. The plant achieves a height of 40-45 cm, the color of the leaves is light green and its life duration is 55-58 days. Seeds are light brown yellow in color and size of the seed is larger than local varieties. It contains 20-25 % protein. Weight of thousand seed is 51-52 g. Under appropriate management practices it may produce up to 2.0 t ha^{-1} of seed.

3.3. Experimental details

3.3.1. Treatments

The experiment comprised two factors.

Factor A: **Doses of fertilizer (Nitrogen + Phosphorus)-4**

i. $F_0 = N + P_2O_5$ (0 + 0) kg ha^{-1} (Control)
ii. $F_1 = N + P_2O_5$ (15 + 30) kg ha^{-1} (25 % lower than recommended dose by BARI)
iii. $F_2 = N + P_2O_5$ (20 + 40) kg ha^{-1} (Recommended dose by BARI)
iv. $F_3 = N + P_2O_5$ (25 + 50) kg ha^{-1} (25 % higher than recommended dose by BARI)

Factor B: **Spacing-3**

i. S_1 = 30 cm × 10 cm
ii. S_2 = 30 cm × 15 cm
iii. S_3 = 30 cm × 20 cm

There were 12 (4 × 3) treatment combinations viz., F_0S_1, F_0S_2, F_0S_3, F_1S_1, F_1S_2, F_1S_3, F_2S_1, F_2S_2, F_2S_3, F_3S_1, F_3S_2 and F_3S_3.

3.3.2. Experimental design and layout

The experiment was laid out in a split-plot with three replications. The layout of the experiment was prepared for distributing the combination of doses of fertilizer (main plot) and spacing (sub-plot) which is shown in Appendix VI. The 12 treatment combinations of the experiment were assigned at 36 plots. The size of each unit plot

2.4 m × 1.6 m. The spacing between blocks and plots were 1.0 m and 0.5 m, respectively.

3.4. Growing of crops

3.4.1. Raising seedlings

3.4.1.1. Seed collection

The test crop (BARI Mung-6) seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur**.**

3.4.1.2. Land preparation

The land was first ploughed by a tractor drawn disc plough and successively cross ploughed four times with power tiller and ladder. Each corners of the land were spaded. After that the plot was harrowed to bring the soil in a good tilth condition. The land was then comprehensively leveled by using a ladder. Stubbles and weeds were removed from the field. All the clods from the plot were broken into small pieces. Finally, the unit plots were also prepared by using spade before sowing of seed.

3.4.1.3. Fertilizer application

The fertilizers were applied as basal dose at final land preparation where K_2O was applied @ 20 kg ha^{-1} in all plots as per BARI recommendation while, nitrogen and phosphorus fertilizer was applied as per treatment variables. All fertilizers were applied by broadcasting and mixed thoroughly with soil.

3.4.1.4. Sowing of seeds

The seed of mungbean were sown in the research field on 16th March, 2017. Seed were sown in rows by hand plough. The distances between row to row and seed to seed were as per treatment variables. Mature two seeds were placed in each point at 2–3 cm depth from the soil surface.

3.4.2. Intercultural operations

3.4.2.1. Thinning

The thinning was done 15 days after sowing on 31th March, 2017 maintaining plant to plant distance as per treatment variables.

3.4.2.2. Weed control

The crop was infested with some weeds during the early stage of crop establishment. Two hand weddings were done; first weeding was done at 15 days after sowing followed by second weeding at 15 days after first weeding.

3.4.2.3. Application of irrigation water

Irrigation water was added to each plot, first irrigation was done as pre-sowing and other two were given 2-3 days after weeding.

3.4.2.4. Plant protection

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

3.4.3. Harvesting and sampling

Harvesting was started on 3^{rd} June, 2017. It was done by three hand picking from 3^{rd} June 15^{th} June according to maturity status. Five sample plants were collected from different places of each plot leaving undisturbed very small in the center at first harvest. This five sample plants were used for taking morphological and yield attributes data. As for the second harvest, the matured crops were harvested from a pre-demarcated area of four linear 1m area at the center of each plot. Those sample plants were used for taking yield data. At third harvest rest of the crop from each plot were harvested separately. The harvested crops were tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The pods were separated, cleaned and dried in the sun for 3 to 5 consecutive days for achieving safe moisture of seed.

3.4.4. Threshing

The crop was sun dried for four days by placing them on the open threshing floor. Seeds were separated from the pods by beating the bundles with bamboo sticks.

3.4.5. Drying, cleaning and weighing

The seeds thus collected were dried in the sun for reducing the moisture in the seeds to a constant level. The dried seeds and straw were cleaned and weighed.

3.5. Seed quality

Seeds obtained from the field experiment were taken separately. These seeds were used for taking quality determination experiments in the laboratory. For this purpose standard germination test was conducted and other different quality attributes data were taken.

3.6. Recording of data

The data were recorded on the following parameters

A. Morphological characters

- a) Plant height (cm)
- b) Number of leaves per plant
- c) No. of plant m^{-2}

B. Yield contributing characters

- a) Pods $plant^{-1}$ (no.)
- b) Pod length (cm)
- c) Seeds pod^{-1} (no.)
- d) 1000 seed weight

C. Yield parameter

- a) Seed yield (t ha^{-1})
- b) Stover yield (t ha^{-1})
- c) Biological yield (t ha^{-1})
- d) Harvest index (%)

D. Seed quality parameter

- a) Total germination (TG %)
- b) Germination index (GI)
- c) Shoot length (cm)

d) Root length (cm)
e) Dry weight of seedlings
f) Electric conductivity (EC) test

3.7. Procedure of recording data

i. Plant height (cm)

The height of the 5 selected plant was measured from the ground level to the tip of the plant at harvest.

ii. Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted at time of final harvest. Leaves number plant^{-1} were recorded by counting all leaves from 5 plant of each plot and mean was calculated.

iii. Number of plants m^{-2}

Number of plants m^{-2} was counted and recorded of each plot 3 times and mean were calculated.

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

Pods plant^{-1} was counted from the 5 selected plant sample and then the average pod number was calculated.

vi. Pod length (cm)

Length of pod was measured by meter scale from 20 pods of plants and then the average seed number was calculated.

vi. Seeds pod^{-1} (no.)

Seeds pod^{-1} was counted from 20 selected pods of plants and then the average seed number was calculated.

vii. Weight of 1000 seeds (g)

1000 seeds were counted, which were taken from the seeds sample of each plot separately, then weighed in an electrical balance and data were recorded.

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

Seed yield was recorded on the basis of seeds plot^{-1} which was harvested from four linear 1m area at the center of each plot and was expressed in terms of yield (t ha^{-1}). Seed yield was adjusted to 12% moisture content.

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

After separation of seeds from area of four linear 1m area at the center of each plot area plants, the straw and shell harvested area was sun dried and the weight was recorded and then converted into t ha^{-1}.

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

The summation of seed yield and above ground stover yield was the biological yield.

Biological yield =Grain yield + Stover yield.

xi. Harvest index (%)

Harvest index was calculated on dry basis with the help of following formula.

Harvest index (HI %) = $\frac{Seed\ yield}{Biological\ yield} \times 100$

Here, Biological yield = Grain yield + stover yield

xii. Total germination (TG %)

Total germination (TG) was calculated as the number of seeds which was germinated within 15 days as a proportion of number of seeds set for germination test in each treatment.

TG (%) = $\frac{Number\ of\ germinated\ seeds}{Total\ number\ of\ seeds\ set\ for\ germination}$ x 100.

xiii. Germination index (GI)

Germination index (GI) was calculated as following formula

Germination index = $(\frac{No.of\ germinating\ seeds}{Days\ of\ first\ count}) + \ldots\ldots\ldots + (\frac{No.of\ germinating\ seeds}{Days\ of\ final\ count})$

xiv. Shoot length (cm)

Randomly selected 10 seedlings from each treatment were collected and cotyledons were removed from them and shoot was measured with a ruler.

xv. Root length (cm)

Randomly selected 10 seedlings from each treatment were collected and cotyledons were removed from them and root was measured with a ruler.

xvi. Seedling dry weight (mg)

The dried radicles and shoots were weighted to the nearest milligram (mg) and the mean radicle and shoot dry weight and consequently mean seedling dry weight were determined with an electric balance.

xvii. Electrical conductivity test

Assessment of seed vigor has long been an important tool of seed quality control programs and electrical conductivity test is one of the methods for assessment of seed vigor. Electrical conductivity **(**EC) test was done using EC meter and for this 50 gm seed were soaked in water for 24h before collecting the data.

3.8 Statistical analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatments by using the Statistix-10 computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Different Test (LSD) at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

Present study was undertaken to determine the effect of fertilizer and spacing on the growth, yield and seed quality of mungbean. Data on different morphological, yield contributing characters, yield and seed quality were recorded to find out the optimum management of fertilizer and spacing on mungbean. The results of the experiment have been presented and discussed in this chapter.

4.1. Effect on morphological characters

4.1.1. Length of plant (cm)

4.1.1.1. Effect of fertilizer

The analysis of variance revealed that plant height was significantly affected by different levels of fertilizer management at harvest (Appendix V and Table 1). Among the fertilizer levels, F_3 showed the tallest plant (45.75 cm) which was statistically similar to F_2 (42.07 cm). On the other hand, the shortest plant (35.94 cm) was observed in the F_0 treatment where no fertilizer was applied followed by F_1 (38.20 cm). It was observed that plant height increased gradually with the increase of fertilizer doses. This might be due to higher availability of N and P_2O_5 and their uptake that progressively enhanced the vegetative growth of the plant. This result corroborates with the findings of Agbenin *et al.* (1991), who found that application of N significantly increased plant height. Suhartatik (1991) also reported that NPK fertilizers significantly increased the plant height of mungbean.

4.1.1.2. Effect of spacing

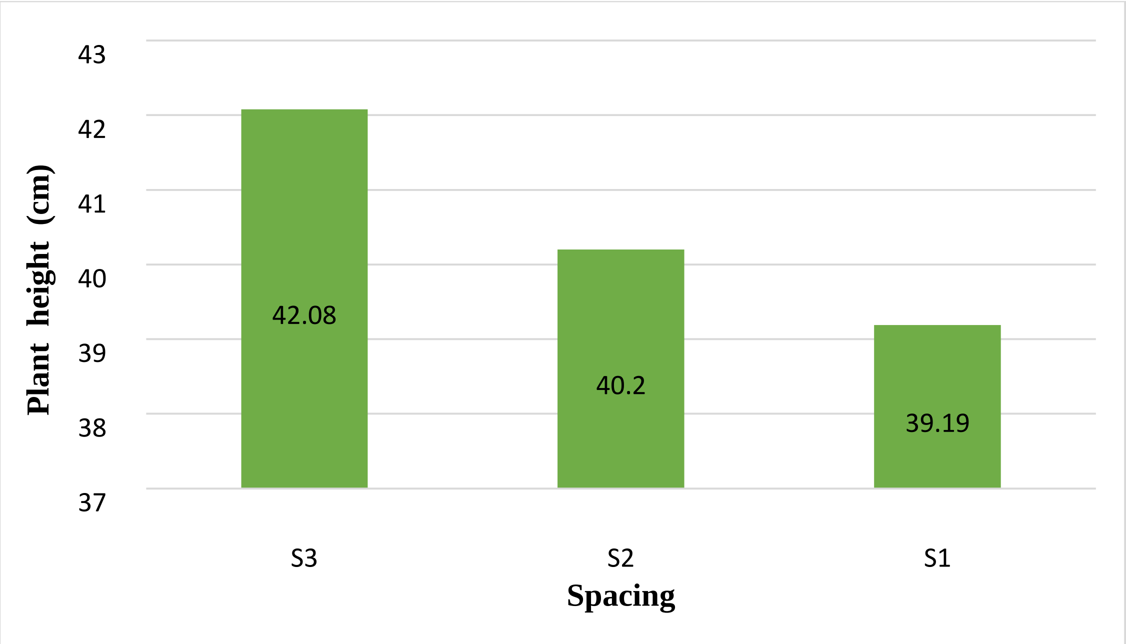
The effect of spacing on plant height of mungbean was also significant (Appendix V and Fig. 1). The tallest plant (42.08 cm) was produced from 30 cm × 10 cm spacing (S_1) which was statistically similar to S_2 (40.20 cm). On the other hand, the shortest plant (39.19 cm) was observed in S_3. It was observed that plant height increased gradually with the decrease of spacing.

Table 1. Effect of fertilizer management on plant height, number of leaves plant^{-1} and plant m^{-2} at final harvest

Fertilizer	Plant height (cm)	Leaves plant^{-1} (no.)	Plants m^{-2} (no.)
F_0	35.94 c	3.70 d	19.69 c
F_1	38.20 bc	4.34 c	20.53 bc
F_2	42.07 ab	5.65 b	21.85 ab
F_3	45.75 a	6.66 a	22.72 a
$LSD_{(0.05)}$	**4.03**	**0.62**	**2.02**
CV (%)	**8.65**	**10.67**	**8.29**

Means in a column followed by the same letter(s) are not significantly different at 5% level

F_0: N + P_2O_5 (0 + 0) kg ha^{-1}
F_1: N + P_2O_5 (15 + 30) kg ha^{-1}
F_2: N + P_2O_5 (20 + 40) kg ha^{-1}
F_3: N + P_2O_5 (25 + 50) kg ha^{-1}



S_1: 30 × 10 cm
S_2: 30 × 15 cm
S_3: 30 × 20 cm

Figure 1. Effect of spacing management on plant height of mungbean ($LSD_{(0.05)}$ = 2.78)

Table 2. Combined effect of fertilizer and spacing management on plant height, number of leaves plant^{-1} and plant m^{-2} at final harvest

Interaction (Fertilizer x Spacing)	Plant height (cm)	Leaves plant^{-1} (no.)	Plants m^{-2} (no.)
F_0S_1	36.41 d	3.53 d	27.73 b
F_0S_2	35.73 d	3.70 d	17.88 de
F_0S_3	35.68 d	3.86 d	13.45 f
F_1S_1	40.25 b-d	4.20 cd	28.84 b
F_1S_2	37.74 cd	4.40 cd	18.38 c-e
F_1S_3	36.62 d	4.43 cd	14.36 f
F_2S_1	42.91 a-c	4.96 c	30.48 ab
F_2S_2	41.72 b-d	5.93 b	20.09 cd
F_2S_3	41.57 b-d	6.06 b	15.00 f
F_3S_1	48.75 a	6.36 ab	31.83 a
F_3S_2	45.61 ab	6.53 ab	20.73 c
F_3S_3	42.89 bc	7.06 a	15.61 ef
$LSD_{(0.05)}$	**5.56**	**0.90**	**2.80**
CV (%)	**7.94**	**9.04**	**6.48**

Means in a column followed by the same letter(s) are not significantly different at 5% level

F_0: N + P_2O_5 (0 + 0) kg ha^{-1}
F_1: N + P_2O_5 (15 + 30) kg ha^{-1}
F_2: N + P_2O_5 (20 + 40) kg ha^{-1}
F_3: N + P_2O_5 (25 + 50) kg ha^{-1}

S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

4.1.1.3. Combined effect of fertilizer and spacing

Combined effect of different of fertilizer and spacing had significant effect on the plant height of mungbean (Appendix V and Table. 2). It was observed from the table that plant height increased gradually with the increase of fertilizer and decrease spacing. The tallest plant (48.75 cm) was observed in the treatment combination of F_3S_1 which was statistically similar to F_3S_2 (45.61 cm) and F_2S_1 (42.91 cm). On the other hand, the shortest plant (35.68 cm) was recorded with F_0S_3 treatment which was statistically identical to F_0S_2 (35.73 cm), F_0S_1 (36.41 cm) and F_1S_3 (36.62 cm)

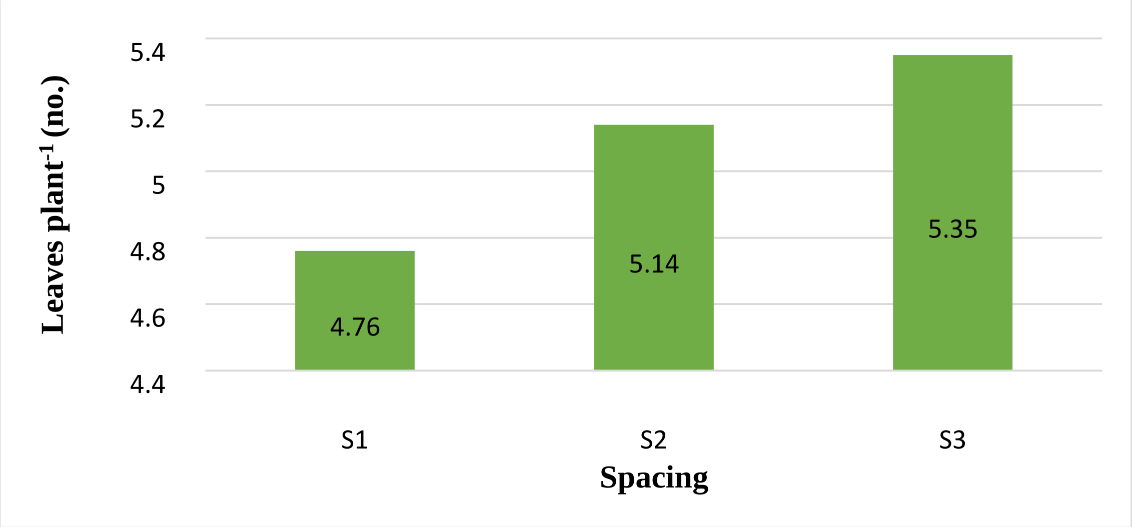
4.1.2. Number of leaves plant^{-1}

4.1.2.1. Effect of fertilizer

The effect of fertilizer on number of leaves per plant of mungbean was significant (Appendix V and Table 1). The highest number of leaves (6.65) was produced from the plant maintaining F_3 .On the other hand, the lowest number of leaves (3.70) was observed in F_0. It was observed that number of leaves per plant increased gradually with the increase of fertilizer doses. This might be due to higher availability of N & P_2O_5 and their uptake that progressively enhanced the vegetative growth of the plant. Malik *et al.* (2003) also observed that leaves plant^{-1} was significantly affected by varying level of fertilizer.

4.1.2.2. Effect of spacing

Significant variation was observed on number of leaves plant^{-1} mungbean of due to the spacing (Appendix V and Fig. 2). The figure shows that number of leaves plant^{-1} increased gradually with the increase of spacing. Among the different spacing, S_3 showed the maximum leaves plant^{-1} (5.35) which was statistically similar with S_2 (5.14). On the other hand, the minimum leaves plant^{-1} (4.76) was observed in the S_1.



S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

Figure 2. Effect of spacing on number of leaves plant^{-1} of mungbean (LSD $_{(0.05)}$ = 0.39)

4.1.2.3. Combined effect of fertilizer and spacing

Combined application of different management of nitrogen and spacing had significant effect on the number of leaves of mungbean (Appendix V and Table 2). The maximum leaves plant^{-1} (7.06) was observed in the treatment combination of F_3S_3, which was statistically similar to F_3S_2 (6.53) and F_3S_1 (6.36). On the other hand, the lowest number of leaves (3.53) was recorded with F_0S_1 which is with which was statistically identical to F_0S_2 (3.70) and F_0S_3 (3.86).

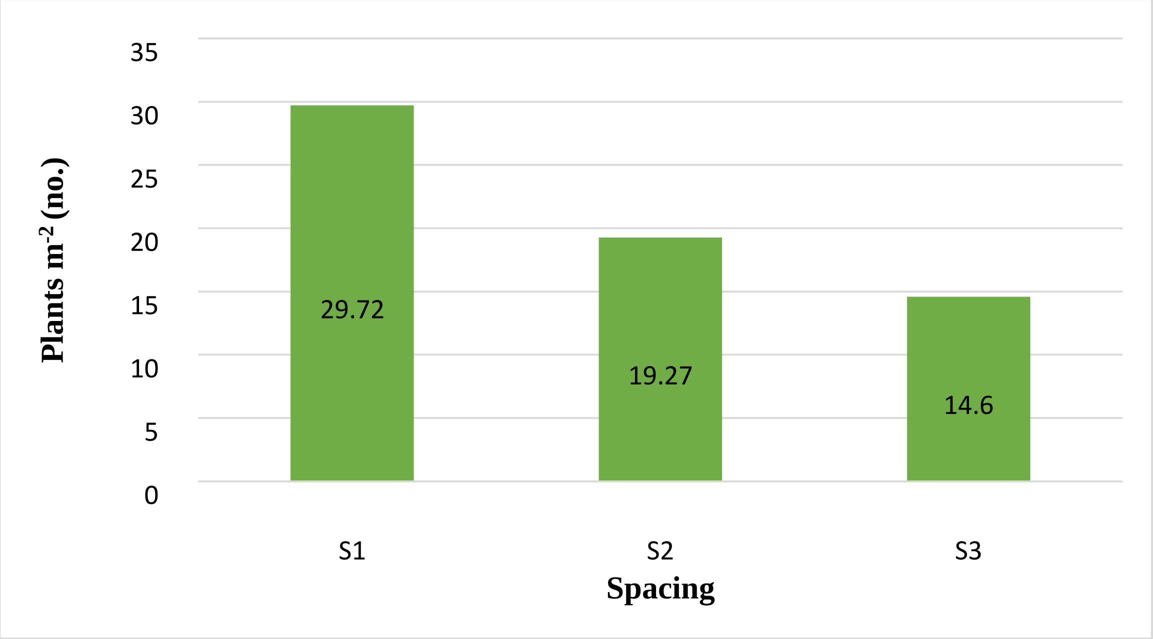
4.1.3. Number of plants m^{-2}

4.1.3.1 Effect of fertilizer

Significant variation was observed in the number of plants m^{-2} of mungbean when different combination of N + P_2O_5 fertilizers were applied (Appendix V and Table 1). The maximum number of plants m^{-2} (22.72) was recorded in F_3 treatment which was statistically similar to F_2 (21.85). On the other hand, the minimum number of plants m^{-2} (19.69) was recorded with F_0 treatment.

4.1.3.2. Effect of spacing

The effect of spacing on plants m^{-2} of mungbean was also significant (Appendix V and Fig. 3). The maximum number of plants m^{-2} (29.72) was recorded in S_3 treatment. On the other hand, the minimum number of plants m^{-2} (14.60) was recorded with S_1 treatment.



S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

Figure 3. Effect of spacing on number of plants m^{-2} of mungbean (LSD $_{(0.05)}$ = 1.18)

4.1.3.3. Combined effect of fertilizer and spacing

Combined application of different management of fertilizer and spacing had significant effect on the number of plants m^{-2} (Appendix V and Table 2). The maximum number of plants m^{-2} (31.83) was observed in the treatment combination of F_3S_3 which was statistically similar to F_2S_1 (30.48) .On the other hand, the minimum number of plants m^{-2} (13.45) was recorded with F_0S_3, which was statistically identical to F_1S_3 (14.36) and F_2S_3 (15.00) and similar to F_3S_3 (15.61).

4.2. Effect on yield contributing characters

4.2.1. Number of pods plant^{-1}

4.2.1.1. Effect of fertilizer

Statistically significant differences were found for number of pod plant^{-1} of mungbean due to different level of fertilizer (Appendix VI and Table 3). The highest number of pod plant^{-1} (18.97) was recorded from F_3 treatment, whereas, the lowest (13.93) was observed from F_0 treatment. It was observed that number of pod plant^{-1} increased gradually with the increase of fertilizer doses. This might be due to higher availability of N & P_2O_5 and their uptake that progressively increase photosynthesis and other physiological function of plant resulting in higher pod plant^{-1}.Tank *et al*. (1992) also observed that mungbean fertilized with N along with P_2O_5 significantly increased the number of pods plant $^{-1}$.

Table 3. Effect of fertilizer management on number of pod plant^{-1}, length of pod, number of seed pod^{-1} and 1000 seed weight

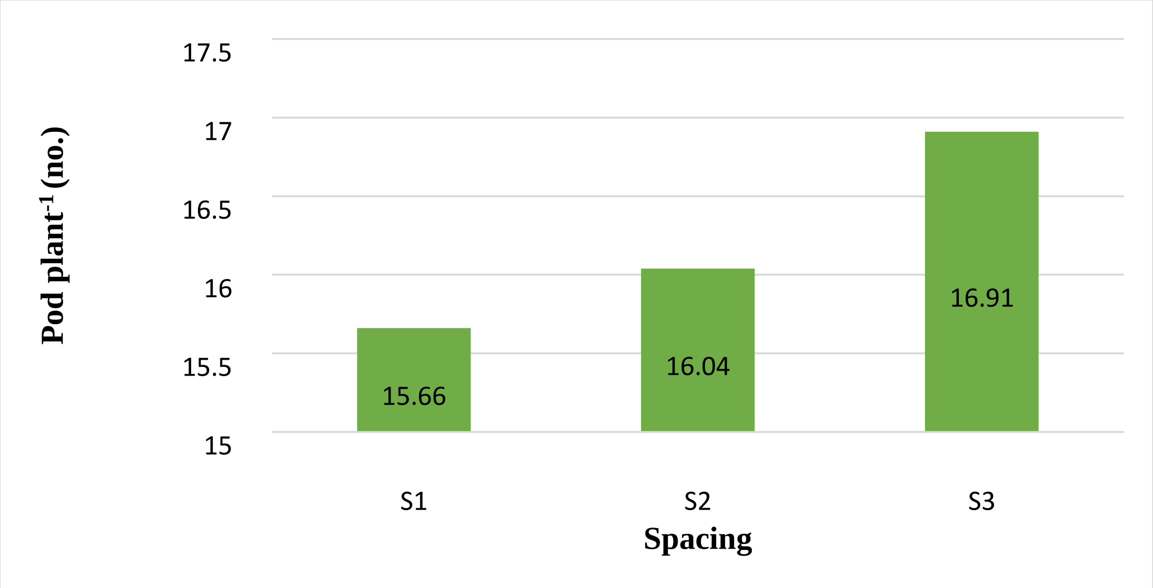
Fertilizer	Pods plant^{-1} (no.)	Length of pod (cm)	Seeds pod^{-1} (no.)	1000 seed weight (g)
F_0	13.93 c	7.08 d	8.80 c	49.17 c
F_1	15.43 bc	7.88 c	9.94b	51.05 bc
F_2	16.50 b	8.69 b	10.35b	51.97 ab
F_3	18.97 a	9.65 a	11.51a	53.33 a
$LSD_{(0.05)}$	**1.79**	**0.76**	**0.51**	**1.95**
CV (%)	**9.61**	**8.01**	**4.42**	**3.30**

Means in a column followed by the same letter(s) are not significantly different at 5% level

F_0: N + P_2O_5 (0 + 0) kg ha^{-1}
F_1: N + P_2O_5 (15 + 30) kg ha^{-1}
F_2: N + P_2O_5 (20 + 40) kg ha^{-1}
F_3: N + P_2O_5 (25 + 50) kg ha^{-1}

4.2.1.2. Effect of spacing

Number of pods plant^{-1} of mungbean differed significantly due to plant spacing (Appendix VI and Fig. 4). The figure indicates that highest number of pod plant^{-1} (16.91) was recorded from S_3 treatment which was statistically similar to that of S_2 (16.04). The lowest (15.66) was found from treatment S_1. It was observed from the figure that number of pod plant^{-1} increased gradually with the increase of spacing. Idris *et al*. (2008) indicated that increasing plant spacing increased number of pods per plant and consequently gave the highest seed yield.



S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

Figure 4. Effect of spacing on number of pod plant^{-1} of mungbean (LSD $_{(0.05)}$ = 0.57)

4.2.1.3. Combined effect of fertilizer and spacing

Interaction effect of fertilizer and spacing showed significant variation in number of pods plant^{-1} (Appendix VI and Table 4). It was observed that number of pod plant^{-1} increased gradually with the increase of fertilizer and spacing. The table shows that highest number of pod plant^{-1} (20.15) was recorded from the combination of F_3S_3, which was statistically similar in F_3S_2 (18.63) treatment. On the other hand, the lowest number of pod plant^{-1} (13.36) was recorded with F_0S_1, which was statistically identical with F_0S_2 (13.73) treatment.

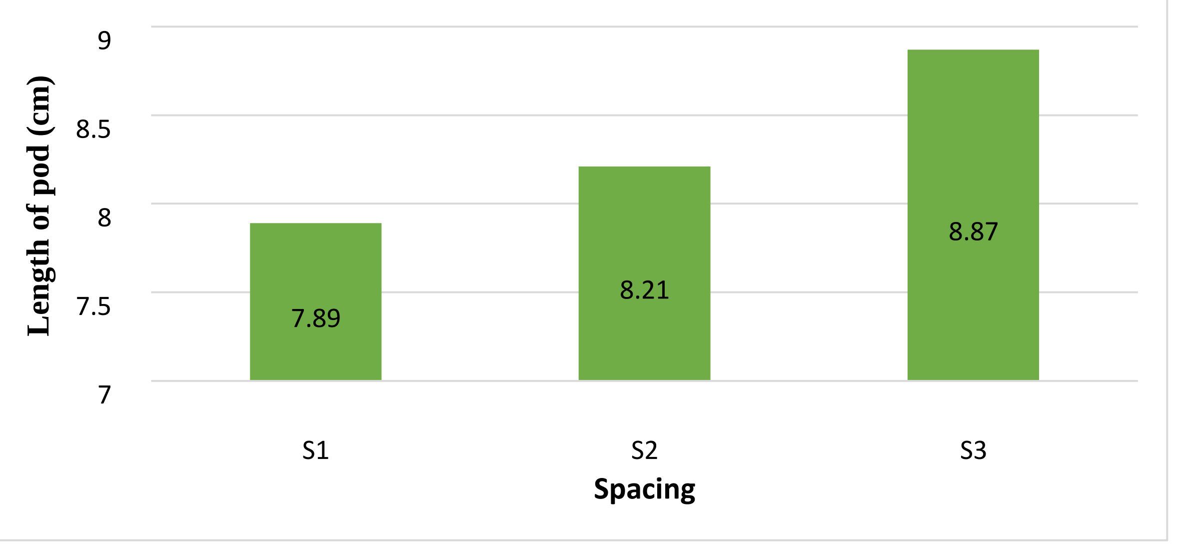
4.2.2. Length of pod

4.2.2.1. Effect of fertilizer

Significant variation was observed in the length of pod of mungbean when different levels of fertilizer were applied (Appendix VI and Table 3). The highest length of pod (9.65 cm) was recorded in F_3 treatment. On the other hand, the lowest length of pod (7.08 cm) was recorded with F_0 treatment. Azadi *et al.* (2013) also found that the highest pod length was obtained from higher fertilizer dose upto a certain limit.

4.2.2.2. Effect of spacing

The effect of spacing on length of pod of mungbean was found significant (Appendix VI and Fig. 5). It was observed that number of pod plant^{-1} increased gradually with the increase of spacing. The highest length of pod (8.87 cm) was recorded in S_3 treatment which was statistically similar to S_2 (8.21 cm). On the other hand, the lowest length of pod (7.89 cm) was recorded with S_1 treatment.



S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

Figure 5. Effect of spacing on length of pod of mungbean (LSD $_{(0.05)}$ = 0.66)

4.2.2.3. Combined effect of fertilizer and spacing

Combined application of different management of nitrogen and spacing had significant effect on the length of pod (Appendix VI and Table 4). The highest length of pod (10.30 cm) was observed in the treatment combination of F_3S_3 which was statistically similar to F_3S_2 (9.44 cm), F_3S_1 (9.20 cm) and F_2S_3 (9.00 cm). On the other hand, the lowest length of pod (6.53 cm) was recorded with F_0S_1 treatment, which was statistically similar to F_0S_2 (7.22 cm), F_0S_3 (7.48 cm) and F_1S_1 (7.27 cm).

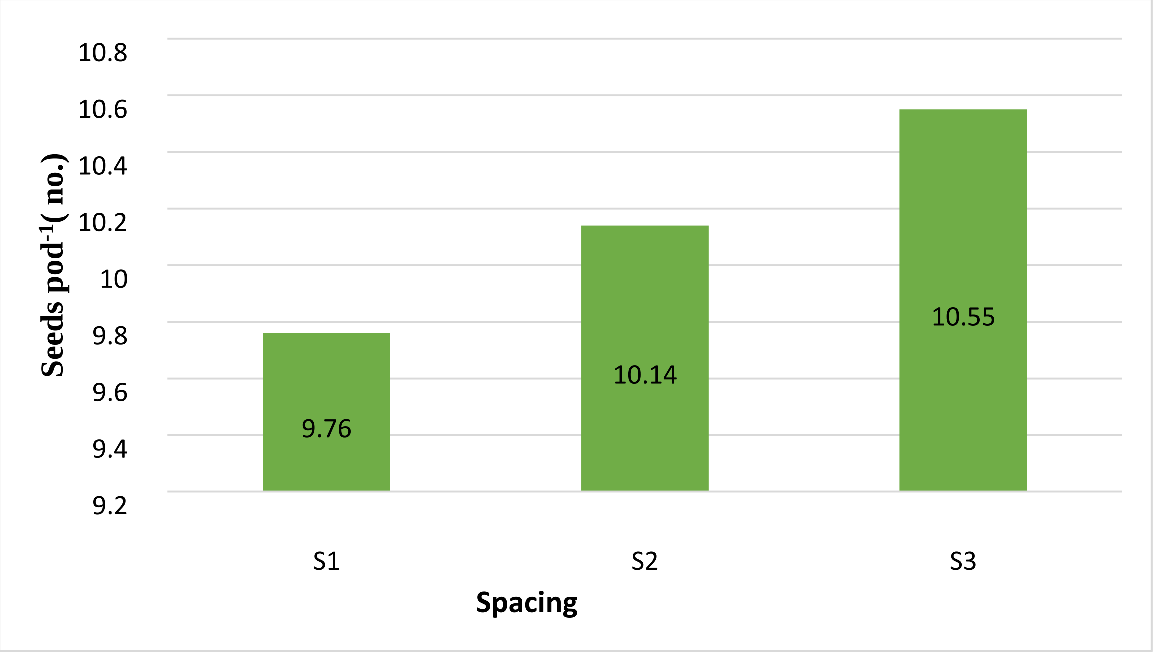
4.2.3. Number of seeds pod^{-1}

4.2.3.1. Effect of fertilizer

Statistically significant differences were found for number of seeds pod^{-1} of mungbean due to fertilizer levels (Appendix VI and Table 3). It was observed from the table that number of seeds pod^{-1} increased gradually with the increase of fertilizer. This might be due to higher availability of N & P_2O_5 and their uptake that progressively enhanced the reproductive growth of the plant. The maximum number of seeds pod^{-1} (11.51) was recorded from F_3 treatment and the minimum (8.80) was observed from F_0 treatment. The result are supported by the findings of Malik *et al*. (2003), who also found that number seeds pod^{-1} was significantly affected by varying level of nitrogen and phosphorous.

4.2.3.2. Effect of spacing

Number of seeds pod^{-1} of mungbean differed significantly due to spacing (Appendix VI and Fig. 6). It was observed from the table that number of seeds pod^{-1} increased steadily with increases of spacing. This might be due to lower plant density that progressively enhanced the reproductive growth of the plant. However, the highest number of seeds pod^{-1} (10.55) was recorded from S_3 treatment, which was statistically similar to S_2 (11.14). The lowest number of seeds pod^{-1} (9.76) was found S_1 treatment.



S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

Figure 6. Effect of spacing on number of seeds pod^{-1} mungbean (LSD $_{(0.05)}$ = 0.65)

4.2.3.3. Combined effect of fertilizer and spacing

The number of seeds pod^{-1} was significantly influenced by the interaction of fertilizer and spacing (Appendix VI and Table 4). The table shows that number of seeds pod^{-1} increased gradually with the increase of fertilizer and spacing. This might be due to higher availability of fertilizer and their uptake with the combination of lower plant density that progressively enhanced the reproductive growth of the plant. The maximum number of seeds pod^{-1} (12.13) was recorded from the combination of F_3S_3 treatment which was statistically similar to F_3S_2 (11.63). The lowest number of seeds pod^{-1} (8.63) was found F_0S_1 treatment, which was statistically identical to F_0S_2 (8.86), F_0S_3 (8.90) and statistically similar to F_1S_1 (9.56) and F_1S_1 (9.70).

Table 4. Combined effect of fertilizer and spacing management on number of pod plant^{-1}, length of pod, number of seed pod^{-1} and 1000 seed weight

Interaction (Fertilizer x Spacing)	Pods plant^{-1} (no.)	Length of pod (cm)	Seeds pod^{-1} (no.)	1000 seeds weight (g)
F_0S_1	13.36 g	6.53 e	8.63 e	48.50 d
F_0S_2	13.73 g	7.22 de	8.86 e	49.13 d
F_0S_3	14.71 e-g	7.48 c-e	8.90 e	49.90 b-d
F_1S_1	15.30 d-g	7.27 c-e	9.56 de	50.13 b-d
F_1S_2	15.46 d-g	8.05 b-d	9.70 c-e	50.96 b-d
F_1S_3	15.54 d-g	8.31 b-d	10.56 b-d	52.06 a-c
F_2S_1	15.86 c-f	8.36 b-d	10.10 cd	51.16 a-d
F_2S_2	16.37 b-e	8.72 bc	10.36 cd	51.96 a-c
F_2S_3	17.26 b-d	9.00 ab	10.60 b-d	52.80 ab
F_3S_1	18.13 bc	9.20 ab	10.76 bc	52.30 a-c
F_3S_2	18.63 ab	9.45 ab	11.63 ab	53.23 ab
F_3S_3	20.15 a	10.30 a	12.13 a	54.46 a
$LSD_{(0.05)}$	**2.34**	**1.51**	**1.31**	**3.34**
CV (%)	**6.63**	**10.50**	**7.50**	**3.75**

Means in a column followed by the same letter(s) are not significantly different at 5% level

F_0: N + P_2O_5 (0 + 0) kg ha^{-1}
F_1: N + P_2O_5 (15 + 30) kg ha^{-1}
F_2: N + P_2O_5 (20 + 40) kg ha^{-1}
F_3: N + P_2O_5 (25 + 50) kg ha^{-1}

S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

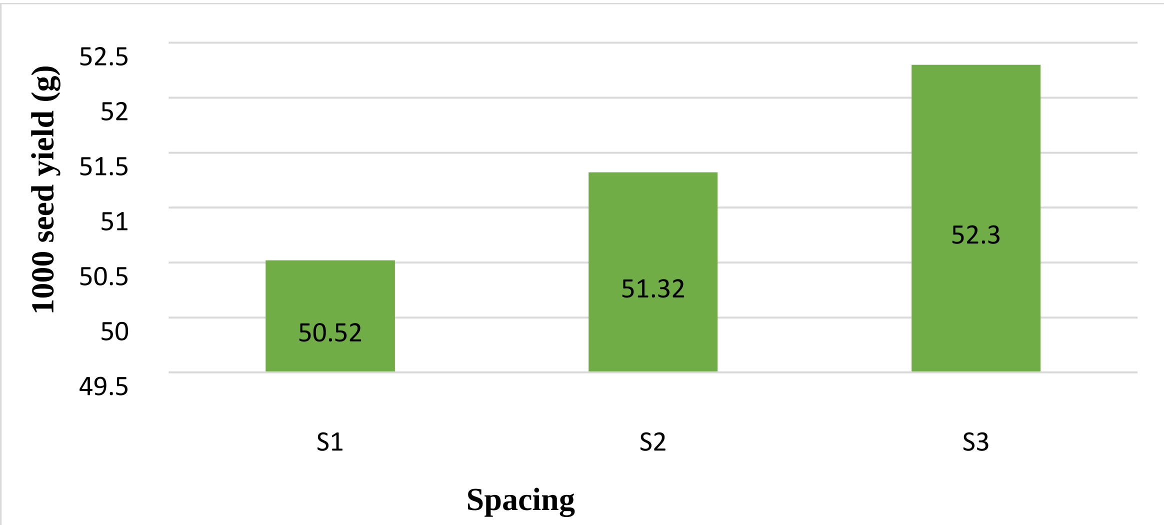
4.2.4. 1000 seed weight

4.2.4.1. Effect of fertilizer

Statistically significant differences were found for 1000 grains weight of mungbean due to fertilizer level (Appendix VI and Table 3). The maximum 1000 seed weight (53.33g) was recorded from F_3 treatment which was statistically similar to that of the F_2 (51.97 g) treatment. The lowest (49.17 g) was recorded from F_0 treatment. The result corroborates with the findings of Bali *et al.* (1991), who revealed that 1000 seeds weight increased with the increase of nitrogen and phosphorus while working with different dose of fertilizer treatment.

4.2.4.2. Effect of spacing

Statistically significant differences were found for 1000 seed weight of mungbean due to spacing (Appendix VI and Fig.7). The maximum 1000 grains weight (52.30 g) was recorded from S_3 treatment which was statistically similar to that of the S_2 (51.32 g) treatment. The lowest (50.52 g) was recorded from S_1 treatment. Ahmed *et al.* (2010) reported that decreased plant population had a significant increase on most yield components and increased 100 seeds weight which corroborates with the present findings.



S_1: 30 cm ×10 cm
S_2: 30 cm ×15 cm
S_3: 30 cm ×20 cm

Figure 7. Effect of spacing on 1000 seed weight of mungbean (LSD $_{(0.05)}$ = 1.66)

4.2.5.3. Combined effect of fertilizer and spacing

Interaction effect of fertilizer and spacing showed significant variation in 1000 grains weight of mungbean (Appendix VI and Table 4). The highest 1000 grains weight (54.46 g) was recorded from the combination of F_3S_3 treatment which was statistically similar to F_3S_2 (53.23 g), F_2S_3 (52.80 g), F_3S_1 (52.30 g), F_1S_3 (52.06 g), F_2S_2 (51.96 g) and F_2S_1 (51.16 g). The lowest (48.50 g) was recorded from the combination of F_0S_1 treatment, which was statistically identical to F_0S_2 (49.13 g) and F_0S_3 (49.90 g).

4.3. Yield of mungbean

4.3.1. Grain yield

4.3.1.1 Effect of fertilizer

Statistically significant differences were found for seed grain weight of mungbean due to fertilizer level (Appendix VII and Table 5). It can be inferred from the table that grain yield increased gradually with the increase of fertilizer doses. However, the maximum grain yield (1.49 t ha^{-1}) was recorded from F_3 treatment. On the other hand the lowest (0.61 t ha^{-1}) was recorded from F_0 treatment. The result is in agreement with the findings of Sadeghipour *et al.* (2010), who found that the maximum seed yield was obtained at higher fertilizer level.

4.3.1.2. Effect of spacing

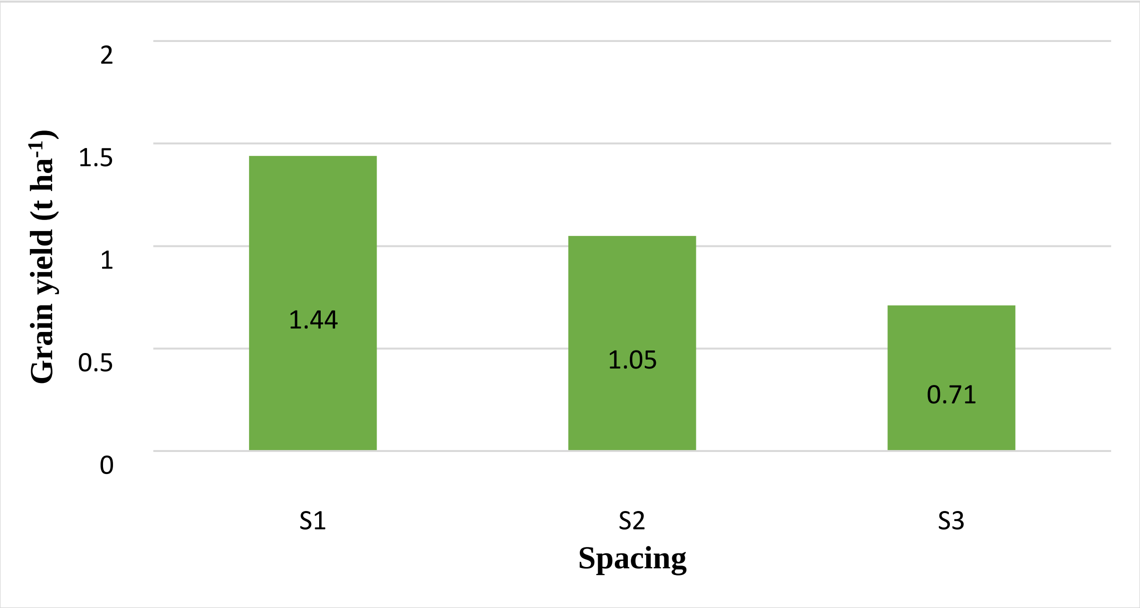
Statistically significant differences were found for seed grain weight of mungbean due to spacing (Appendix VII and Fig. 8). The figure indicates that grain yield reduced steadily with the increase of spacing. The maximum seed grain weight (1.44 t ha^{-1}) was recorded from S_1 treatment. The lowest (0.71 t ha^{-1}) was recorded from S_3 treatment. The increase in grain yield at higher plant densities was mainly due to the increased number of plants per unit area, which ultimately helped to produce higher yield. The result is in agreement with the findings of Osman *et al.* (2010), who stated that the maximum yield was obtained with the highest density of plants ha^{-1}.

Table 5. Effect of fertilizer on grain yield, stover yield, biological yield and harvest index of mungbean

Fertilizer	Grain yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
F_0	0.618 d	1.345 d	1.964 d	31.45 c
F_1	0.962 c	1.928 c	2.891 c	33.34 c
F_2	1.204 b	2.161 b	3.365 b	35.994 b
F_3	1.497 a	2.380 a	3.877 a	38.671 a
$LSD_{(0.05)}$	**0.068**	**0.17**	**0.19**	**2.46**
CV (%)	**5.56**	**7.76**	**5.47**	**6.14**

Means in a column followed by the same letter(s) are not significantly different at 5% level

F_0: N + P_2O_5 (0 + 0) kg ha^{-1}
F_1: N + P_2O_5 (15 + 30) kg ha^{-1}
F_2: N + P_2O_5 (20 + 40) kg ha^{-1}
F_3: N + P_2O_5 (25 + 50) kg ha^{-1}



S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

Figure 8. Effect of spacing on seed grains weight of mungbean (LSD $_{(0.05)}$ = 0.072)

4.3.1.3. Combined effect of fertilizer and spacing

Interaction effect of fertilizer and spacing showed significant variation in grains yield of mungbean (Appendix VII and Table 6). It can be inferred from the table that grain yield increased gradually with the increase of fertilizer doses and higher plant density. This might be due to higher availability of fertilizer and their uptake with the combination of higher plant density that progressively enhanced the seed production of the plant. The highest seed grains weight (1.97 t ha^{-1}) was recorded from the combination of F_3S_1 treatment. The lowest (0.46 t ha^{-1}) was recorded from the combination of F_0S_3 treatment which, was statistically similar to F_0S_2 (0.556 t ha^{-1}).

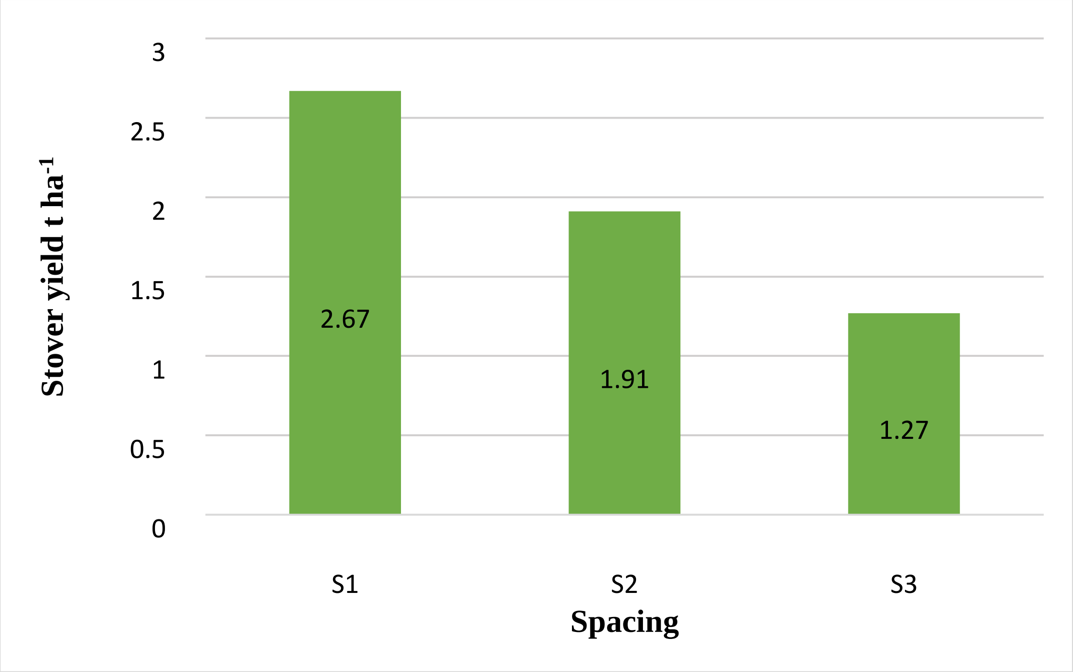
4.3.2. Stover yield

4.3.2.1. Effect of fertilizer

Stover yield of mungbean were significantly influenced by fertilizer (Appendix VII and Table 5). The maximum stover yield (2.380 t ha^{-1}) was recorded from the F_3 treatment whereas, the minimum (1.345 t ha^{-1}) was found in the F_0 treatment. It was observed that stover yield increased gradually with the increase of fertilizer doses. Srinivas *et al.* (2002) stated almost similar result that the stover yield increased with increasing of fertilizer while working with different dose of fertilizer which supports the present findings.

4.3.2.2. Effect of spacing

Stover yield of mungbean were significantly influenced by spacing (Appendix VII and Fig. 9). It was observed from the figure that stover yield decreased gradually with the increase spacing due to lower number of plant. The increase in stover yield at higher plant densities was mainly due to the increased number of plants per unit area, which ultimately helped to produce higher yield. The maximum stover yield (2.674 t ha^{-1}) was recorded from the S_1 treatment whereas, the minimum (1.27 t ha^{-1}) was found in the S_3 treatment.



S_1: 30 × 10 cm
S_2: 30 × 15 cm
S_3: 30 × 20 cm

Figure 9. Effect of spacing on stover yield of mungbean (LSD $_{(0.05)}$ = 0.16)

4.3.2.1. Combined effect of fertilizer and spacing

The interaction effect of fertilizer and spacing on stover yield of mungbean was significant (Appendix VII and Table 6). It can be inferred from the table that stover yield increased gradually with the increase of fertilizer doses and higher plant density. This might be due to higher availability of fertilizer and their uptake with the combination of higher plant density that progressively enhanced the stover yield of the plant. The highest stover yield (3.160 t ha^{-1}) was recorded from the combination of F_3S_1 treatment which was statistically similar to F_2S_1 (2.966 t ha^{-1}), and the lowest (0.966 t ha^{-1}) was found in the combination of F_0S_3 treatment, which was statistically similar to F_0S_2 (1.22 t ha^{-1}) and F_1S_3 (1.24 t ha^{-1}).

Table 6. Combined effect of fertilizer and spacing management on grain yield, stover yield, biological yield and harvest index of mungbean

Interaction (Fertilizer x Spacing)	Grain yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
F_0S_1	0.840 ef	1.850 e	2.690 e	31.17 d
F_0S_2	0.556 hi	1.220 gh	1.776 fg	31.30 d
F_0S_3	0.460 i	0.966 h	1.426 g	31.87 cd
F_1S_1	1.346 c	2.716 bc	4.063 c	33.14 b-d
F_1S_2	0.906 de	1.823 e	2.730 e	33.41 b-d
F_1S_3	0.633 gh	1.246 gh	1.880 f	33.47 b-d
F_2S_1	1.626 b	2.966 ab	4.593 b	35.57 a-c
F_2S_2	1.233 c	2.206 d	3.440 d	35.86 ab
F_2S_3	0.753 fg	1.310 g	2.063 f	36.54 ab
F_3S_1	1.970 a	3.163 a	5.133 a	38.32 a
F_3S_2	1.526 b	2.400 cd	3.926 c	38.81 a
F_3S_3	0.996 d	1.576 ef	2.573 e	38.87 a
$LSD_{(0.05)}$	**0.13**	**0.32**	**0.39**	**3.80**
CV (%)	**7.79**	**9.75**	**8.01**	**5.91**

Means in a column followed by the same letter(s) are not significantly different at 5% level

F_0: N + P_2O_5 (0 + 0) kg ha^{-1}
F_1: N + P_2O_5 (15 + 30) kg ha^{-1}
F_2: N + P_2O_5 (20 + 40) kg ha^{-1}
F_3: N + P_2O_5 (25 + 50) kg ha^{-1}

S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

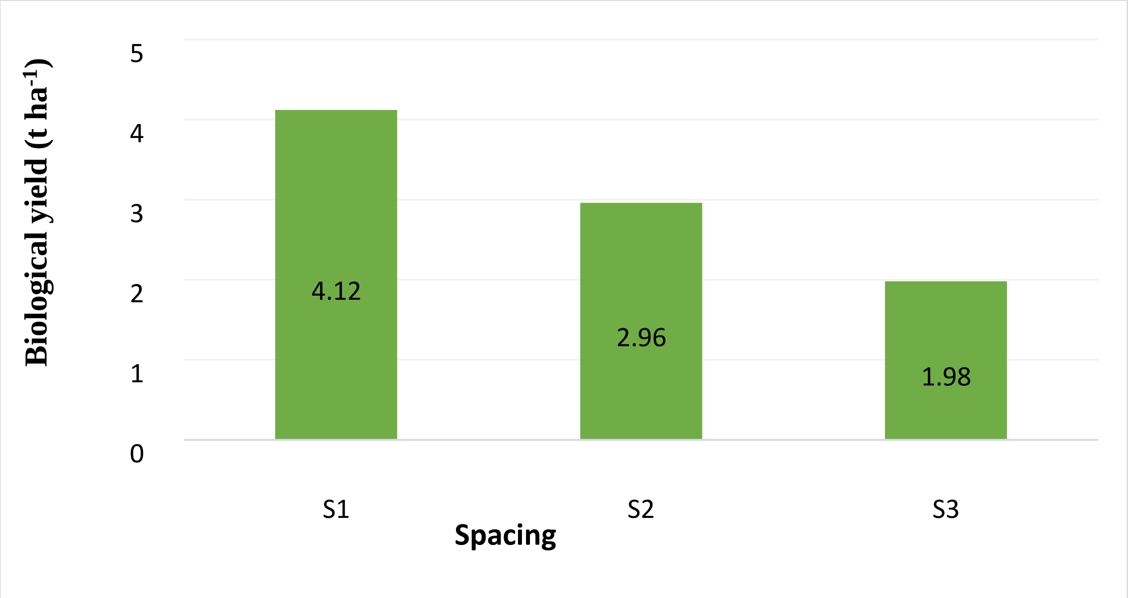
4.3.3. Biological yield

4.3.3.1. Effect of fertilizer

The effect of fertilizer on biological yield of mungbean was also significant (Appendix VII and Table 5). It was observed from the table that biological yield increased gradually with the increase of fertilizer doses. The highest biological yield (3.877 t ha^{-1}) was produced from $F_{3.}$ On the other hand, the lowest (1.964 t ha^{-1}) was observed in $F_{0.}$ Sardana *et al.* (1987) stated that the application of nitrogen, phosphorus and potassium fertilizers in combination resulted in the significant increase in biological yield of mungbean which supports the present findings.

4.3.3.2. Effect of spacing

Significant variation was observed on biological yield of mungbean of due to the spacing (Appendix VII and Fig. 10).). It was observed from the figure that biological yield decreased gradually with the increase spacing due to lower number of plant. Among the different spacing, S_1 showed the maximum yield (4.120 t ha^{-1}). On the other hand, the minimum yield (1.985 t ha^{-1}) was observed in the S_3.



S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

Figure 10. Effect of spacing on biological yield of mungbean (LSD $_{(0.05)}$ = 0.209)

4.3.3.3 Combined effect of fertilizer and spacing

Combined application of different management of fertilizer and spacing had significant effect on biological yield of mungbean (Appendix VII and Table 6). It can be inferred from the table that biological yield increased gradually with the increase of fertilizer doses and higher plant density. This might be due to higher availability of fertilizer and their uptake with the combination of higher plant density that progressively increase the biological yield of the plant. The maximum biological yield (5.133 t ha^{-1}) was observed in the treatment combination of F_3S_1. On the other hand, the lowest plant height (1.426 t ha^{-1}) was recorded with F_0S_3 treatment which was statistically similar to F_0S_2 (1.776 t ha^{-1}).

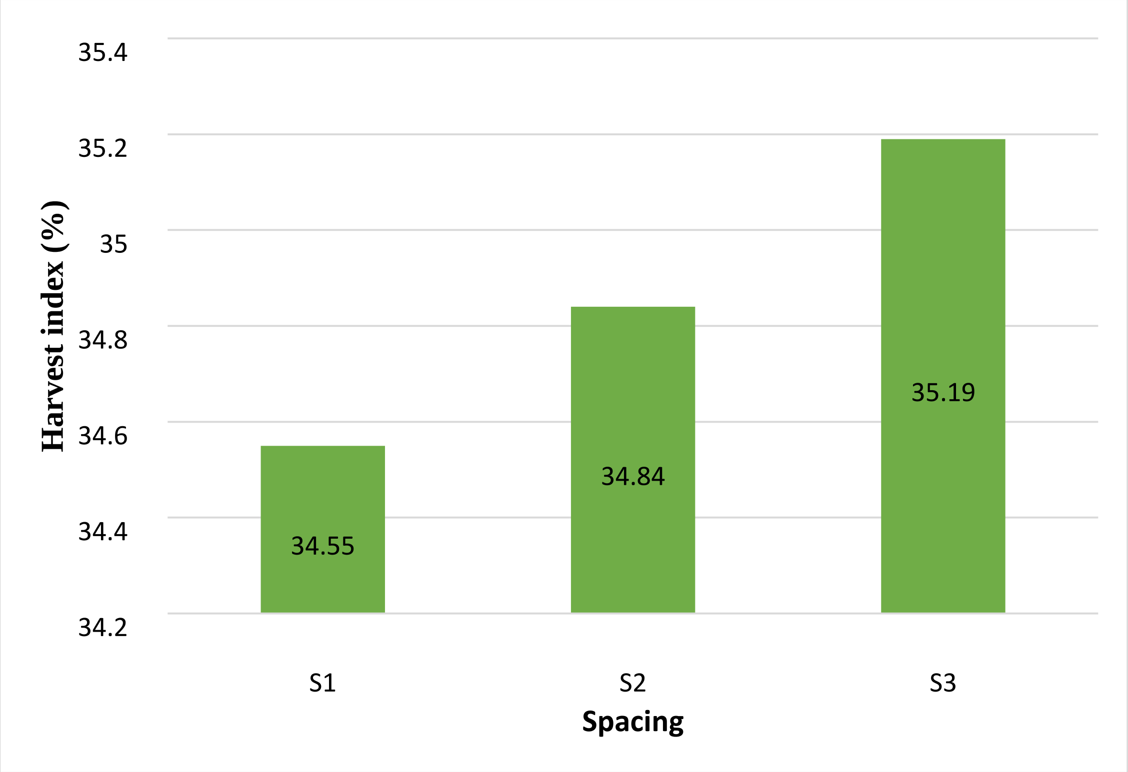
4.3.4. Harvest index

4.3.4.1. Effect of fertilizer

A significant difference was found in harvest index due to fertilizer level (Appendix VII and Table 5). It was observed that harvest index increased gradually with the increase of fertilizer doses. This might be due to higher availability of fertilizer that progressively increase the harvest index of the plant The maximum harvest index (38.67 %) was recorded from treatment F_3 whereas, the minimum (31.45 %) was found in (F_0) treatment which was statistically similar to F_1 (33.34 %).

4.3.3.2. Effect of spacing

A significant difference was found in harvest index due to spacing (Appendix VII and Fig. 11). It was observed from the figure that stover yield increased gradually with the increase of spacing. This might be due lower plant density that progressively increase the harvest index of the plant. The maximum harvest index (35.19 %) was recorded from (S_3) treatment whereas, the minimum (34.55 %) was found from (S_1) treatment.



S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

Figure 11. Effect of spacing on harvest index of mungbean (LSD $_{(0.05)}$ = 0.61)

4.3.3.3. Combined effect of fertilizer and spacing

The interaction effect of fertilizer and spacing was significant on harvest index of mungbean (Appendix VII and Table 6). It can be inferred from the table that harvest index increased gradually with the increase of fertilizer doses and lower plant density. This might be due to higher availability of fertilizer and their uptake with the combination of lower plant density that progressively increase the harvest index of the plant. The highest harvest index (38.87 %) was recorded from the combination (F_3S_3) treatment which was statistically similar to F_3S_2 (38.81 %), F_3S_1 (38.32 %), F_2S_3 (36.54 %), F_2S_2 (35.86 %) and F_2S_1 (35.57 %). On the other hand, the lowest plant height (31.178) was recorded with treatment F_0S_1 which was statistically identical to F_0S_2 (31.30 %).

4.4. Seed quality test

4.4.1. Germination percentage

4.4.1.1 Effect of fertilizer

A significant difference was found in germination percentage due to fertilizer level (Appendix VIII and Table 7). The data presented in the table showed an increasing trend with the increases of fertilizer rate. This might be due to higher availability of fertilizer that progressively increase the germination percentage of the plant. The maximum germination percentage (95.11 %) was recorded from treatment F_3 which, was statistically similar to F_2 (90.66 %) and the minimum (81.77 %) was found in treatment (F_0).

Table 7. Effect of fertilizer on germination percentage, germination index, shoot length, root length, dry matter and electrical conductivity test of mungbean

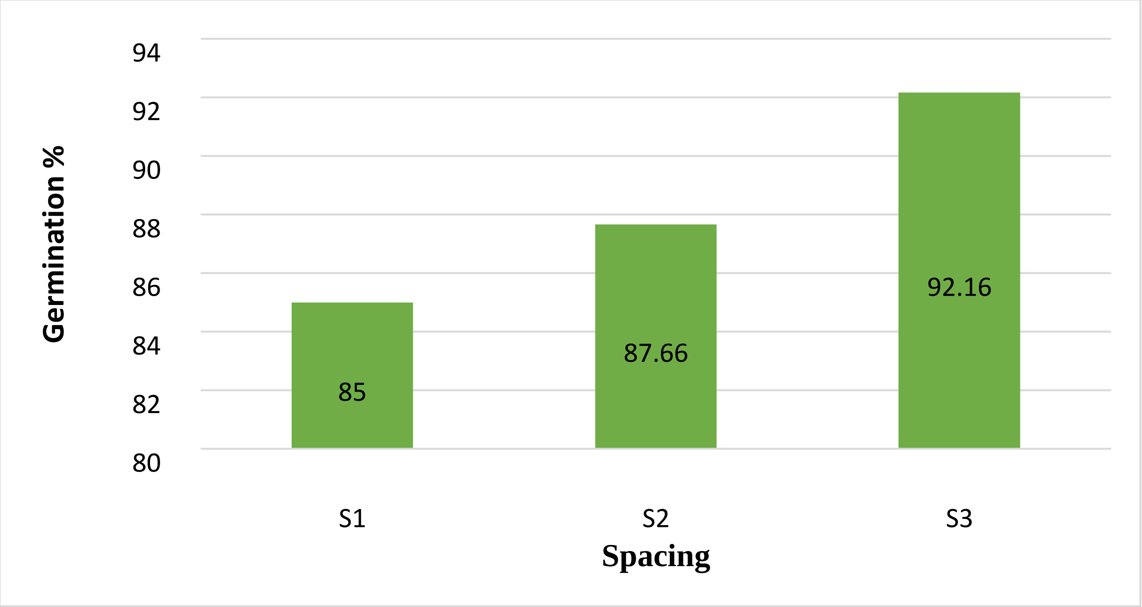
Fertilizer	Germination (%)	Germination index (%)	Shoot length (cm)	Root length (cm)	Seedling dry weight (%)	Electrical conductivity Test (mS cm^{-1})
F_0	81.77 c	14.98 c	19.61 c	4.02 d	19.2 c	6.60 a
F_1	85.55 bc	16.07 c	20.56 bc	4.92 c	19.76 bc	6.00 b
F_2	90.66 ab	17.30 b	21.80 b	6.03 b	21.64 ab	5.28 c
F_3	95.11 a	19.04 a	23.13 a	6.88 a	23.13 a	4.61 d
$LSD_{(0.05)}$	**6.93**	**1.16**	**1.2**	**0.65**	**2.14**	**0.39**
CV (%)	**6.81**	**6.02**	**5.22**	**10.41**	**8.88**	**6.14**

Means in a column followed by the same letter(s) are not significantly different at 5% level

F_0: N + P_2O_5 (0 + 0) kg ha^{-1}
F_1: N + P_2O_5 (15 + 30) kg ha^{-1}
F_2: N + P_2O_5 (20 + 40) kg ha^{-1}
F_3: N + P_2O_5 (25 + 50) kg ha^{-1}

4.4.1.2. Effect of spacing

A significant difference was found in germination percentage due to spacing (Appendix VIII and Fig. 12). The maximum germination percentage (92.16 %) was recorded from (S_3) treatment which, was statistically similar to S_2 (87.66 %). On the other hand the minimum (85.00 %) was found from (S_1) treatment.



S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

Figure 12. Effect of spacing on germination percentage of mungbean (LSD $_{(0.05)}$ = 6.59)

4.4.1.3. Combined effect of fertilizer and spacing

The interaction effect of fertilizer and spacing was significant on germination percentage of mungbean (Appendix VIII and Table 8). The highest germination percentage (96.00 %) was recorded from the combination of F_3S_3 treatment which, was statistically similar to F_3S_2 (94.66 %), F_3S_1 (94.66 %), F_2S_3 (93.33 %), F_1S_3 (91.33 %), F_2S_2 (90.66 %), F_0S_3 (88.00 %), F_2S_1 (88.00 %) and F_1S_2 (85.33 %). On the other hand, the lowest germination percentage (77.33 %) was recorded with treatment combination of F_0S_1.

Table 8. Combined effect of fertilizer and spacing management on germination percentage, germination index, shoot length, root length, dry matter and EC test of mungbean

Interaction (Fertilizer x spacing)	Germination (%)	Germination index (%)	Shoot length (cm)	Root length (cm)	Dry matter (%)	EC test (dS/cm)
F_0S_1	77.33 c	14.62 g	18.98 e	3.76 g	18.98 d	6.86 a
F_0S_2	80.00 bc	15.00 fg	19.79 de	4.02 fg	19.18 d	6.59 ab
F_0S_3	88.00 a-c	15.33 e-g	20.06 de	4.27 fg	19.43 d	6.37 ab
F_1S_1	80.00 bc	15.56 d-g	20.13 de	4.46 fg	19.50 d	6.19 a-c
F_1S_2	85.33 a-c	16.15 c-g	20.60 c-e	4.926 ef	19.76 cd	5.97 b-d
F_1S_3	91.33 ab	16.51 c-g	20.96 b-e	5.40 de	20.02 cd	5.83 b-d
F_2S_1	88.00 a-c	16.93 b-f	21.06 b-e	5.78 c-e	20.60 b-d	5.51 c-e
F_2S_2	90.66 ab	17.33 b-e	21.60 b-c	5.98 b-c	21.60 a-d	5.30 d-f
F_2S_3	93.33 a	17.64 b-d	22.73 a-c	6.33 bc	22.73 a-c	5.03 e-g
F_3S_1	94.66 a	17.83 bc	21.60 b-c	6.36 bc	21.60 b-d	4.76 e-g
F_3S_2	94.66 a	18.80 ab	23.43 ab	6.86 ab	23.43 ab	4.59 fg
F_3S_3	96.00 a	20.48 a	24.36 a	7.41 a	24.36 a	4.46 g
$LSD_{(0.05)}$	**5.81**	**2.24**	**2.57**	**0.91**	**2.97**	**0.75**
CV (%)	**8.63**	**8.05**	**7.44**	**8.36**	**7.02**	**8.14**

Means in a column followed by the same letter(s) are not significantly different at 0.5% level

F_0: N + P_2O_5 (0 + 0) kg ha^{-1}
F_1: N + P_2O_5 (15 + 30) kg ha^{-1}
F_2: N + P_2O_5 (20 + 40) kg ha^{-1}
F_3: N + P_2O_5 (25 + 50) kg ha^{-1}

S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

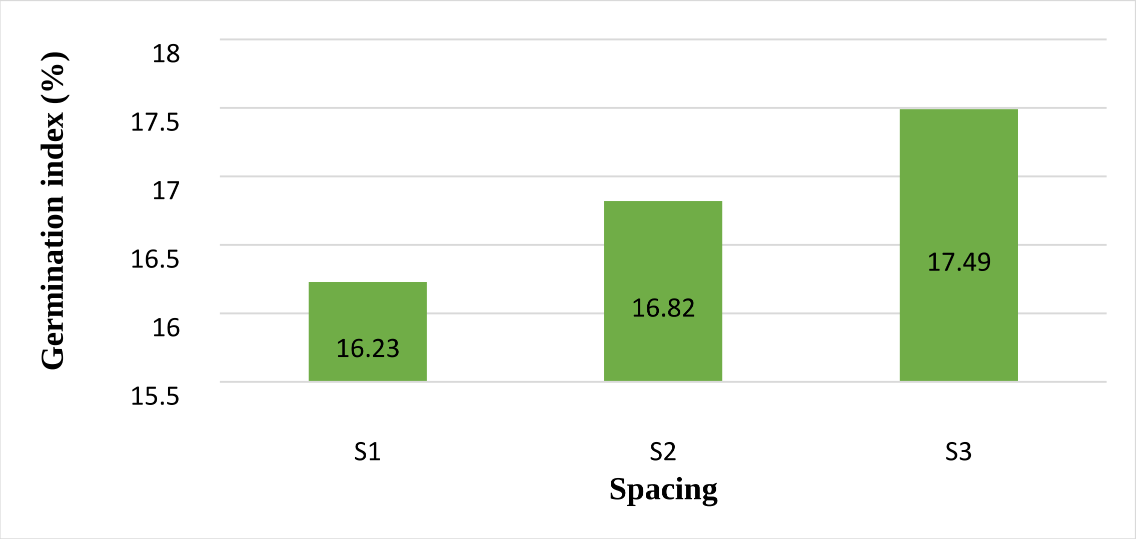
4.4.2. Germination index

4.4.2.1 Effect of fertilizer

A significant difference was found in germination index due to fertilizer level (Appendix VIII and Table 7). The data presented in the table showed an increasing trend with the increases of fertilizer rate. This might be due to higher availability of fertilizer and their uptake that progressively increase the germination index of the plant. The maximum harvest index (19.04 %) was recorded from treatment F_3 whereas, the minimum (14.98 %) was found in (F_0) treatment which was statistically similar to F_1 (16.07 %).

4.4.2.2. Effect of spacing

A significant difference was found in germination index due to spacing (Appendix VIII and Fig. 13). The data presented in the table showed an increasing trend with the increases of spacing. The highest germination index (17.49 %) was recorded from the widest spacing (S_3) treatment which was statistically similar to F_1 (16.82 %). The minimum (16.23 %) was found from the closest (S_1) treatment.



S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

Figure 13. Effect of spacing on germination index % of mungbean (LSD $_{(0.05)}$ = 1.17)

4.4.2.3. Combined effect of fertilizer and spacing on germination index

The interaction effect of fertilizer and spacing was significant on germination index of mungbean (Appendix VIII and Table 8). The highest germination index (20.48) was recorded from the combination (F_3S_3) treatment which, was statistically similar to F_3S_2 (18.80). On the other hand, the lowest plant height (14.62) was recorded with treatment F_0S_1 was statistically similar to F_0S_2 (15.00 %), F_0S_3 (15.33 %), F_1S_1 (15.56 %), F_1S_2 (16.15 %) and F_1S_3 (16.51 %).

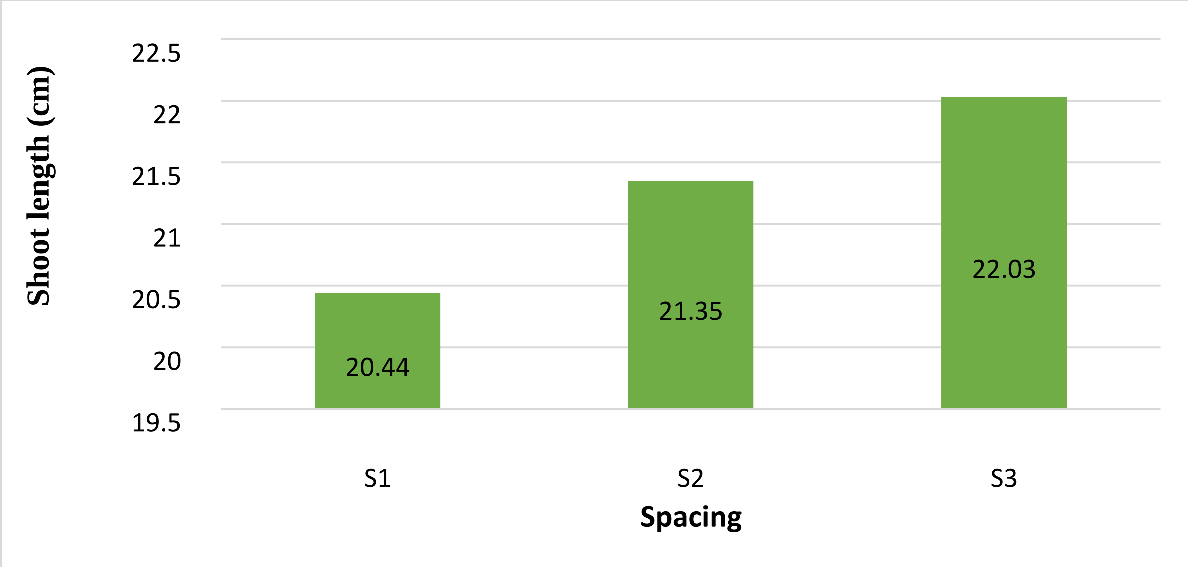
4.4.3. Shoot length

4.4.3.1 Effect of fertilizer

A significant difference was found in shoot length due to fertilizer level (Appendix VIII and Table 7). The data presented in the table showed an increasing trend with the increases of fertilizer rate. This might be due to higher availability of fertilizer that progressively increase the shoot length of the plant. The maximum shoot length (23.13 cm) was recorded from treatment F_3 whereas, the minimum (14.98 cm) was found in (F_0) treatment which was statistically similar to F_1 (19.61 cm).

4.4.3.2. Effect of spacing

A significant difference was found in shoot length due to spacing (Appendix VIII and Fig. 14). It was observed from the figure that shoot length increased gradually with the increase of spacing. The maximum shoot length (22.03 cm) was recorded from (S_3) treatment which, was statistically similar to S_2 (21.35 cm). The minimum (20.44 cm) was found from (S_1) treatment.



S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

Figure 14. Effect of spacing on shoot length of mungbean (LSD $_{(0.05)}$ = 1.30)

4.4.3.3. Combined effect of fertilizer and spacing on shoot length

The interaction effect of fertilizer and spacing was significant on shoot length of mungbean (Appendix VIII and Table 8). The highest shoot length (24.36 cm) was recorded from the combination (F_3S_3) treatment, which was statistically similar to F_3S_2 (23.43 cm) and F_2S_3 (22.73 cm). On the other hand, the lowest shoot length (18.98 cm) was recorded with treatment F_0S_1.

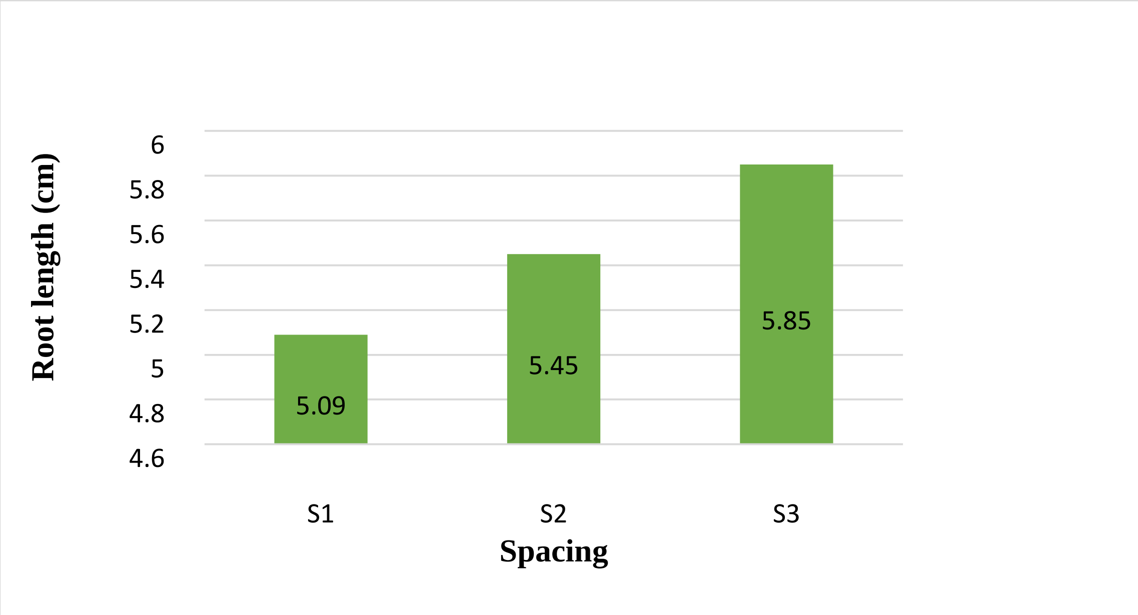
4.4.4. Root length

4.4.4.1 Effect of fertilizer

A significant difference was found in root length due to fertilizer level (Appendix VIII and Table 7). It was observed from the table that root length increased gradually with the increase of level of fertilizer. The highest root length (6.88 cm) was recorded from the highest fertilizer treatment F_3 whereas, the minimum (4.02 cm) was found in (F_0) treatment.

4.4.4.2. Effect of spacing

A significant difference was found in root length due to spacing (Appendix VIII and Fig.15). The data presented in the figure showed an increasing trend with the increases of spacing. The highest root length (5.85 cm) was recorded from (S_3) treatment. The lowest root length (5.09 cm) was found from (S_1) treatment which, was statistically similar to S_2 (5.45 cm).



S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

Figure 15. Effect of spacing on root length of mungbean (LSD $_{(0.05)}$ = 0.39)

4.4.4.3. Interaction of fertilizer and spacing

The interaction effect of fertilizer and spacing was significant on root length of mungbean (Appendix VIII and Table 8). The data presented in the table showed an increasing trend with the increases of fertilizer rate and spacing. The highest root length (7.41 cm) was recorded from the combination (F_3S_3) treatment, which was statistically similar to F_3S_2 (6.86 cm). On the other hand, lowest root length (3.76 cm) was recorded with treatment F_0S_1.

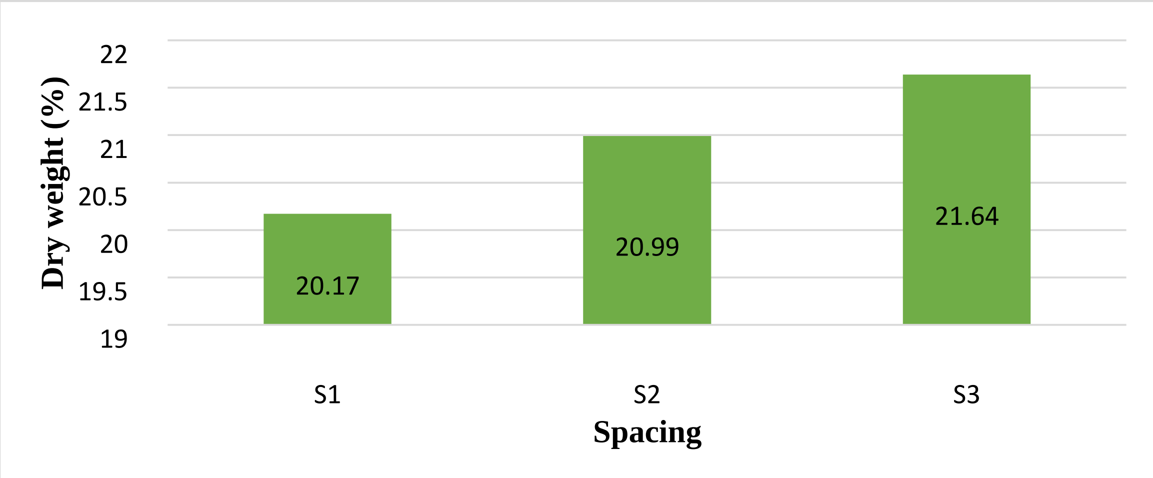
4.4.5. Dry weight of seedling

4.4.5.1. Effect of fertilizer

A significant difference was found in dry weight of seedling due to fertilizer level (Appendix VIII and Table 7). The data presented in the table showed an increasing trend with the increases of fertilizer rate. This might be due to higher availability of fertilizer that progressively increase the dry weight of the plant. The maximum dry weight of seedling (23.13 %) was recorded from treatment F_3, which was statistically similar to F_2 (21.64 %). On the other hand, the lowest dry weight of seedling (19.20%) was recorded with treatment F_0.

4.4.5.2. Effect of spacing

A significant difference was found in dry weight of seedling due to spacing (Appendix VIII and Fig.16). The data presented in the figure showed an increasing trend with the increases of spacing. This might be due to higher plant spacing that progressively increase the dry weight of the plant. The maximum dry weight of seedling (21.64 %) was recorded from treatment S_3 which, was statistically similar to S_2 (20.99 %). On the other hand, the lowest dry weight of seedling (20.17 %) was recorded with treatment S_1.



S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

Figure 16. Effect of spacing on dry weight of seedling of mungbean (LSD $_{(0.05)}$ = 1.20)

4.4.5.2. Combined effect of fertilizer and spacing on dry weight of seedling

The interaction effect of fertilizer and spacing was significant on dry weight of seedling of mungbean (Appendix VIII and Table 8). The maximum dry weight of seedling (24.36 %) was recorded from the combination (F_3S_3) treatment which, was statistically similar to F_3S_2 (23.43 %), F_2S_3 (22.73 %) and F_2S_2 (21.60 %). On the other hand, the lowest dry weight of seedling (18.98 %) was recorded with treatment F_0S_1.

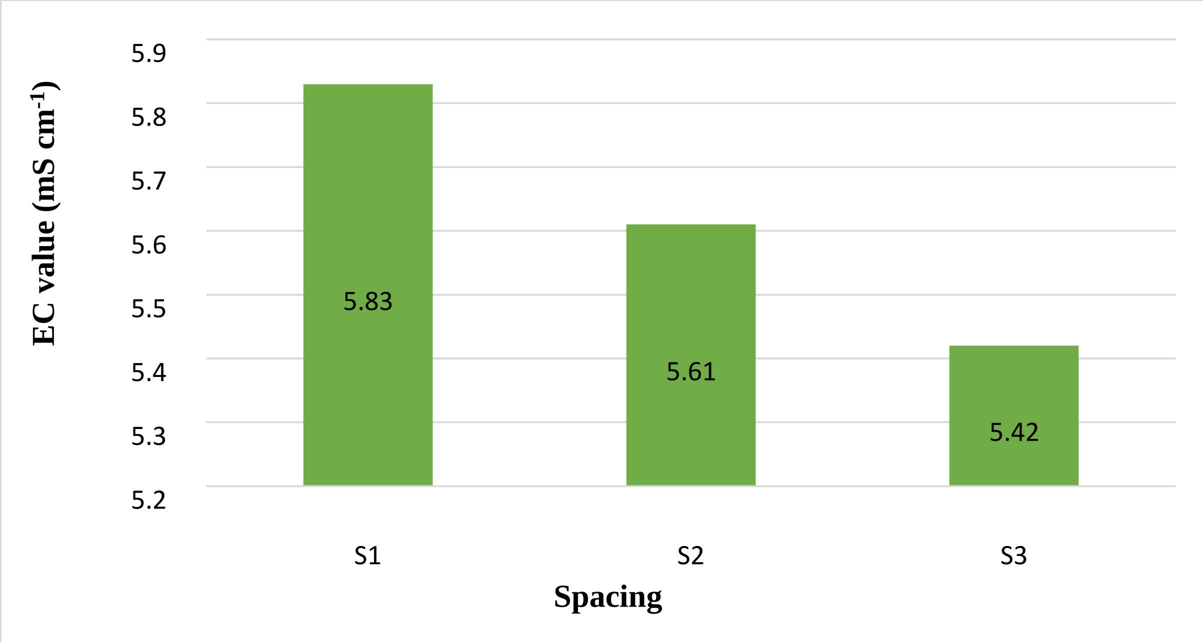
4.4.6. Electrical conductivity test

4.4.6.1 Effect of fertilizer

A significant difference was found in electrical conductivity test value due to fertilizer level (Appendix VIII and Table 7). Lowest value of the EC test indicate highest vigority of seed. The data presented in the table showed a decreasing trend with the increases of fertilizer rate. The highest EC test value (6.60 mS cm^{-1}) was recorded from treatment F_0 whereas, the minimum (4.61 mS cm^{-1}) was found in (F_3) treatment.

4.4.6.1 Effect of spacing

A significant difference was found in EC test value due to fertilizer level (Appendix VIII and Fig. 17). The data presented in the table showed a decreasing trend with the increases of spacing. The maximum EC test value (5.83 mS cm^{-1}) was recorded from treatment S_1 which, was statistically similar to S_2 (5.61 mS cm^{-1}). On the other hand, the lowest EC test value (5.42 mS cm^{-1}) was recorded with treatment S_3.



S_1: 30 cm × 10 cm
S_2: 30 cm × 15 cm
S_3: 30 cm × 20 cm

Figure 17. Effect of spacing on EC test value of mungbean (LSD $_{(0.05)}$ = 0.39)

4.2.8.3. Combined effect of fertilizer and spacing on EC test

The interaction effect of fertilizer and spacing was significant on EC test value of mungbean (Appendix VIII and Table 8).Higher value of EC test indicate low vigor of seed. The highest EC test value (6.86 mS cm^{-1}) was recorded from the combination (F_0S_1) treatment which, was statistically similar to F_0S_2 (6.59 mS cm^{-1}), F_0S_3 (6.37 mS cm^{-1}) and F_1S_1 (6.19 mS cm^{-1}). On the other hand, the lowest EC test value (4.46 mS cm^{-1}) was recorded with treatment F_3S_3 which, was statistically similar to F_3S_2 (4.59 mS cm^{-1}), F_3S_1 (4.76 mS cm^{-1}) and F_2S_3 (5.03 mS cm^{-1}).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during kharif-I (March to July, 2017) to study the effect of fertilizer and spacing on the morphological characters, yield and seed quality of mungbean. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. The soil of the experimental field belongs to the General soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of two factors. Factor A: Fertilizer management (4 levels); F_0: N + P_2O_5 (0 + 0) kg ha^{-1}, F_1: N + P_2O_5 (15 + 30) kg ha^{-1}, F_2: N + P_2O_5 (20 + 40) kg ha^{-1}, F_3: N + P_2O_5 (25 + 50) kg ha^{-1} and factor B: Plant spacing (3 levels); S_1: 30 × 10 cm, S_2: 30 ×15 cm, S_3: 30 ×20 cm. The variety, BARImung-6 was used in this experiment as the test crop. There were 12 treatment combinations. The total numbers of unit plots were 36. The size of unit plot was 3.84 m^2 (2.4 m × 1.6 m). Nitrogen and phosphorus was applied as per treatment variables and other fertilizers were applied as per BARI recommendation. Data on different yield contributing characters and yield were recorded to find out the optimum levels of fertilizer and spacing for higher yield of mungbean.

Different growth and yield parameters, seed quality were significantly influenced by different levels of fertilizer. The tallest plant (45.75 cm) was obtained from F_3, while the shortest plant (35.94 cm) was obtained from F_0 treatment at harvest. The maximum and minimum leaf plant^{-1} (6.65) and (3.70) was obtained from treatment F_3 and F_0 treatment, respectively at harvest. The highest and lowest number of plant m^{-2} (22.72 and 19.69), pods plant^{-1} (18.97 and 13.93), pod length (9.651 cm and 7.08 cm), seeds pod^{-1} (11.51 and 8.80), 1000 seed weight (53.33 g and 49.17 g), seed yield (1.49 t ha^{-1} and 0.61 t ha^{-1}), stover yield (2.38 t ha^{-1} and 1.34 t ha^{-1}), biological yield (3.87 t ha^{-1} and 1.96 t ha^{-1}) and harvest index (38.67 % and 33.34 %) was recorded in F_3 and F_0 treatment, respectively. The highest and lowest number of germination percent (95.11% and 81.77 %), germination index (19.04 % and 14.98 %), shoot length (23.13 cm and 14.98 cm), root length (6.88 cm and 4.02 cm), dry weight of seedling (23.13

% and 19.20 %) was found in F_3 and F_0 treatment, respectively. The highest and lowest EC test value (6.60 mS cm^{-1} and 4.61 mS cm^{-1}) was found in F_0 and F_3 treatment, respectively.

Different growth and yield parameters, seed quality were significantly influenced by different levels spacing. The tallest plant (42.08 cm) was obtained from S_1, while the shortest plant (39.19 cm) was obtained from S_3 treatment at harvest. The maximum and minimum leaf plant^{-1} (5.35) and (4.76) was obtained from treatment S_3 and S_1 treatment, respectively at harvest. The highest and lowest number of plant m^{-2} (29.72 and 14.60) was recorded in S_1 and S_3 treatment, respectively. The highest and lowest pods plant^{-1} (16.91 and 15.66), pod length (8.87 cm and 7.89 cm), seeds pod^{-1} (10.55 and 9.76), 1000 seed weight (52.30 g and 50.52 g) was recorded in S_3 and S_1 treatment, respectively. The highest and lowest seed yield (1.44 t ha^{-1} and 0.71 t ha^{-1}), stover yield (2.67 t ha^{-1}and 1.27 t ha^{-1}), biological yield (4.12 t ha^{-1} and 1.98 t ha^{-1}) was recorded in S_1 and S_3 treatment, respectively. The highest and lowest number of harvest index (35.19 % and 34.55 %) germination percent (92.16 % and 85.00 %), germination index (17.49 % and 16.23 %), shoot length (22.03 cm and 20.44 cm), root length (5.85 cm and 5.09 cm), dry weight of seedling (21.64 % and 20.17 %) was found in S_3 and S_1 treatment, respectively. The highest and lowest EC test value (5.83 mS cm^{-1} and 5.42 mS cm^{-1}) was found in S_1 and S_3 treatment, respectively.

Different growth and yield parameters, seed quality were significantly influenced by combined effect of fertilizer and spacing. The tallest plant (48.75 cm) was obtained from F_3S_1, while the shortest plant (35.68 cm) was obtained from F_0S_3 treatment at harvest. The maximum and minimum leaf plant^{-1} (7.06) and (3.53) was obtained from treatment F_3S_3 and F_0S_1 treatment, respectively at harvest. The highest and lowest number of plant m^{-2} (31.83 and 13.45) was recorded in F_3S_1 and F_0S_3 treatment, respectively. The highest and lowest pods plant^{-1} (20.15 and 13.36), pod length (10.30 cm and 6.53 cm), seeds pod^{-1} (12.13 and 8.63), 1000 seed weight (54.46 g and 48.50 g) was recorded in F_3S_3 and F_0S_1 treatment, respectively. The highest and lowest seed yield (1.97 t ha^{-1} and 0.46 t ha^{-1}), stover yield (3.16 t ha^{-1}and 0.96 t ha^{-1}), biological yield (5.13 t ha^{-1} and 1.42 t ha^{-1}) was recorded in F_3S_1 and F_0S_3 treatment, respectively. The highest and lowest number of harvest index (38.87 % and 31.17 %) germination percent (96.00 % and 77.33 %), germination index (20.48 %and 14.62

%), shoot length (24.36 cm and 18.98 cm), root length (7.41 cm and 3.76 cm), dry matter of seedling (24.36 % and 18.98 %) was found in F_3S_3 and F_0S_1 treatment, respectively. The highest and lowest EC test value (6.86 mS cm^{-1} and 4.46 mS cm^{-1}) was found in F_0S_1 and F_3S_3 treatment, respectively.

Based on the experimental results, it may be concluded that-

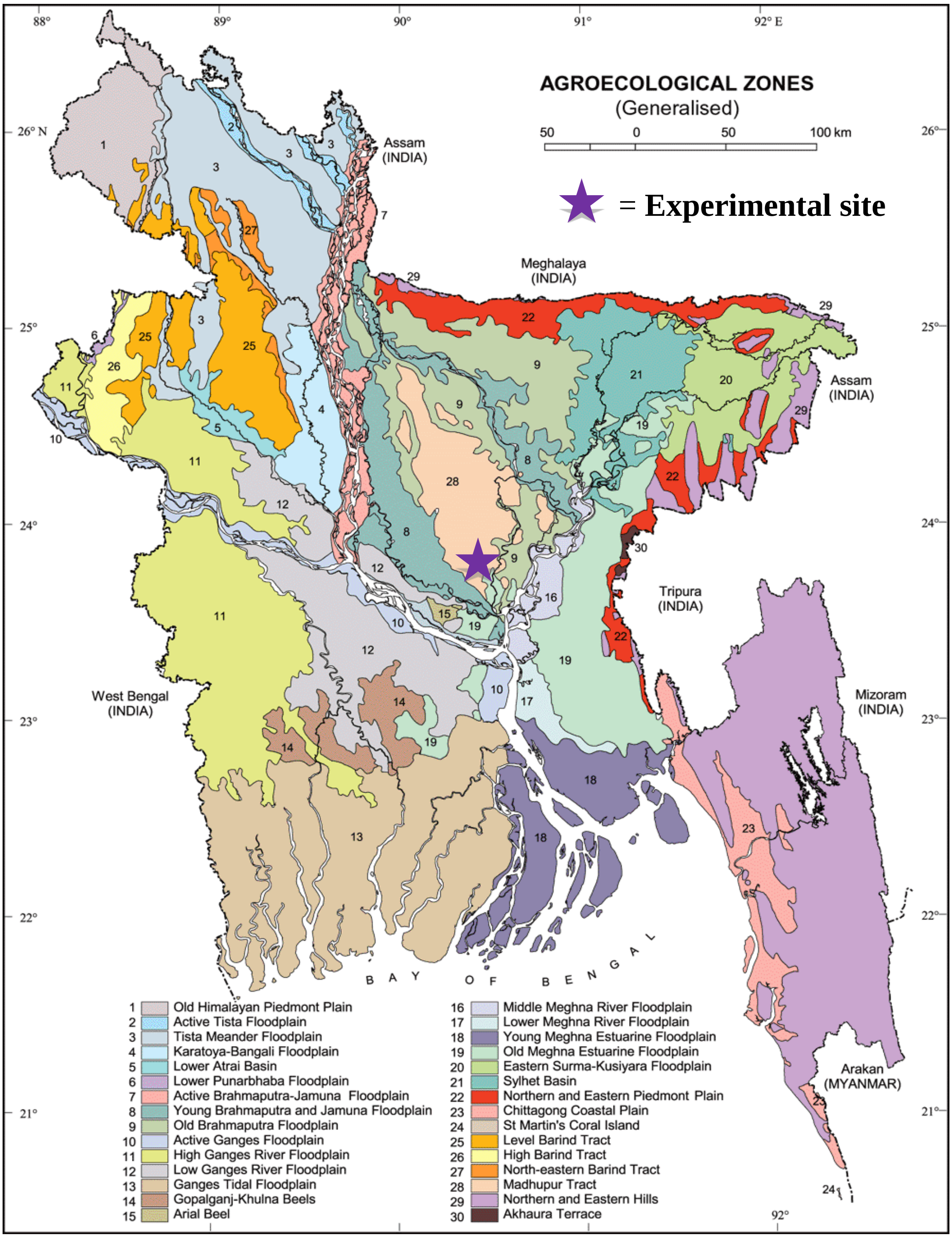
i) Fertilizer had a positive effect on morphological characters, yield contributing characters, yield and seed quality in mungbean. Application of N + P_2O_5 (25 + 50) kg ha^{-1} seemed to be suitable for higher yield and seed production.

ii) Spacing also had a positive effect on morphological characters, yield contributing characters, yield and seed quality in mungbean. Spacing of 30 cm × 10 cm seemed to be more promising for getting higher yield and quality seed production, and

iii) The effect of fertilizer and spacing had positive effect on morphological characters, yield contributing characters, yield and seed quality in mungbean. Application of N + P_2O_5 (25 + 50) kg ha^{-1} with 30 cm × 10 cm combination seemed to be more suitable for getting higher yield and quality seed production in mungbean.

APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	6.1
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

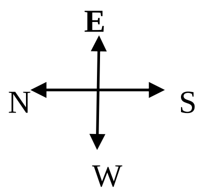
Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka

Appendix III. Monthly meteorological information during the period from March to June, 2017

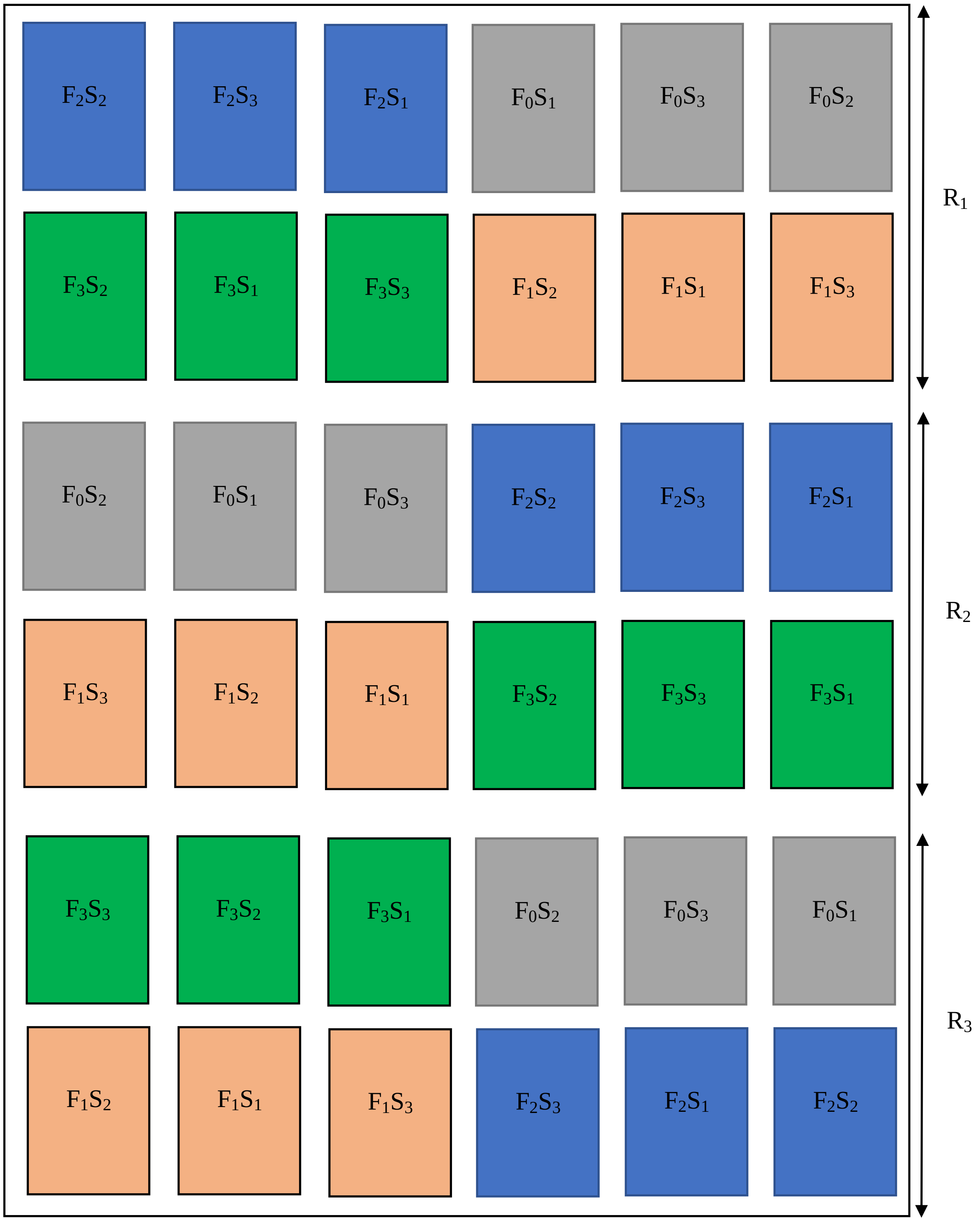
Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2017	March	33.9	12.2	55.29	76
	April	34.6	16.5	67.45	45
	May	33.4	18.6	58.18	136
	June	30.30	21.80	71.08	289

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Layout for experimental field.



Total number of unit plots: 12 × 3 = 36
Unit plot size: 2.4 m×1.6 m = 3.84 m^2
Main plot to main plot distance = 1m
Sub plot to sub plot distance = 0.5m



Appendix V. Analysis of variance of the data on plant height (cm), leaves plant^{-1} and plant m^{-2} of mungbean as influenced by combined effect of fertilizer and spacing

Source of variation	df	Mean square value		
		Plant height (cm)	Leaves plant^{-1} (no.)	Plant m^{-2} (no.)
Replication	2	19.44	0.1219	22.026
Fertilizer rate(A)	3	168.300*	15.7763*	16.473*
Error	6	12.261	0.2949	3.091
Spacing (B)	2	25.763*	1.0753*	719.120*
Fertilizer (A) X Spacing (B)	6	4.15*	0.1794*	0.680*
Error	16	10.325	0.2117	1.890

*Significant at 5% level of significance

^{NS} Non significant

Appendix VI. Analysis of variance of the data on pods plant^{-1} (no.), pod length (cm), seeds pod^{-1} (no.) and 1000 seed weight (g) of mungbean as influenced by combined effect of different level of fertilizer and spacing.

Source of variation	df	Mean square value			
		Pods plant^{-1} (no.)	Length of pod (cm)	Seeds pod^{-1} (no.)	1000 seed weight (g)
Replication	2	0.0519	2.5139	0.5386	48.3169
Fertilizer rate(A)	3	40.4492*	10.9141*	11.2788*	27.3832*
Error	6	2.4255	0.4360	0.2016	2.8744
Spacing (B)	2	4.9407*	2.6254*	1.8419*	9.5744*
Fertilizer (A) X Spacing (B)	6	0.4610*	0.0949*	0.2427*	0.0885*
Error	16	1.1541	0.8455	0.5792	3.7096

*Significant at 5% level of significance

^{NS} Non significant

Appendix VII. Analysis of variance of the data on seed yield (t ha^{-1}), stover yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index of mungbean as influenced by combined effect of different level of fertilizer and spacing

Source of variation	df	Mean square value			
		Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.10901	0.23927	0.6689	4.1969
Fertilizer rate(A)	3	1.24855*	1.78562*	5.9577*	89.1652*
Error	6	0.00355	0.02299	0.0274	4.5810
Spacing (B)	2	1.62270*	5.88842*	13.6926*	1.2112*
Fertilizer (A) X Spacing (B)	6	0.05640*	0.11004*	0.3170*	0.1018*
Error	16	0.00696	0.03629	0.0587	4.2409

*Significant at 5% level of significance

[NS] Non significant

Appendix VIII. Analysis of variance of the data on germination percentage, germination index, shoot length, root length, dry matter of seedling and EC test value as influenced by combined effect of different level of fertilizer and spacing

Source of variation	df	Mean square value					
		Germination (%)	Germination index (%)	Shoot length (cm)	Root length (cm)	Dry matter (%)	EC test (mS cm^{-1})
Replication	2	96.778	3.8440	21.5831	2.3597	42.7011	5.45166
Fertilizer rate(A)	3	306.185*	27.2326*	20.9699*	2.3597*	29.1587*	6.75377*
Error	6	36.185	1.0276	1.2316	0.3241	3.4595	0.11921
Spacing (B)	2	157.444*	4.7271*	7.5935*	1.7351*	6.5175*	0.49867*
Fertilizer (A) X Spacing (B)	6	18.185*	0.7071*	0.6602*	0.0574*	1.0684*	0.00766*
Error	16	58.000	1.8391	2.5069	0.2090	2.1591	0.20990

*Significant at 5% level of significance

^{NS} Non significant

Appendix IX: Experimental activities and photographs

Appendix IX: Experimental activities and photographs (contd.)

Appendix IX: Experimental activities and photographs (contd.)