INFLUENCE OF ORGANIC MANURE AND POTASSIUM ON YIELD AND SEED QUALITY OF SOYBEAN

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CERTIFICATE

This is to certify that thesis entitled ***"INFLUENCE OF ORGANIC MANURE AND POTASSIUM ON YIELD AND SEED QUALITY OF SOYBEAN"*** *submitted to the* ***INSTITUTE OF SEED TECHNOLOGY,*** *Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) IN SEED TECHNOLOGY,*** *embodies the result of a piece of bona fide research work carried out by* ***MD. MAHABUR RAHMAN, Registration no. 14-06130*** *under my supervision and guidance. No part of the 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.

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DEDICATED
TO
MY BELOVED
PARENTS

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ABSTRACT

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2019 to March, 2020 to study the influence of organic manure and potassium on yield and seed quality of soybean. The experiment was laid out in Split plot Design (2 factor) replicated with three times. For this study, factor A- V_1: BARI Soybean 6 and V_2: BINA Soybean 1 and factor B- T_1: Trichoderma (2 t/ha); T_2: Trichoderma (2 t/ha) + 70 kg/ha K; T_3: Trichoderma (2 t/ha) + 90 kg/ha K, T_4: Biochar (10 t/ha), T_5: Biochar (10 t/ha) + 70 kg/ha K, T_6: Biochar (10 t/ha) + 90 kg/ha K, T_7: Recommended dose of fertilizer (50, 150, 100, 50 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively) and T_0: Control. The yield attributing characteristics (i.e. plant height (52.18 cm), number of leaves/plant (13.80 leaves), number of pods/plant (49.88 pods), pod length (3.14 cm), seeds per pod (2.50 seeds), 1000 seeds weight (123.5 g), seed yield (2.23 t/ha), stover yield (3.96 t/ha), biological yield (6.19 t/ha) and harvest index (35.90 %)) and seed quality (seed viability (71.88 %) and seed germination (85.00 %)) were highest and the timing of 1^{st} flowering (30.88 days) and timing of pod maturity (51.63 days) were lowest for BARI Soybean 6. The yield attributing characteristics (i.e. plant height (54.60 cm), number of leaves/plant (15.22 leaves), number of pods/plant (61.50 pods), pod length (3.36 cm), seeds per pod (3.50 seeds), 1000 seeds weight (137.9 g), seed yield (2.55 t/ha), stover yield (4.41 t/ha), biological yield (6.96 t/ha) and harvest index (36.65 %)) and seed quality (seed viability (78.50 %) and seed germination (93.00 %)) were highest and the timing of 1^{st} flowering (28.50 days) and timing of pod maturity (49.50 days) were lowest for Biochar (10 t/ha) + 70 kg/ha K treatment. Again, BARI Soybean6 along with Biochar (10 t/ha) + 70 kg/ha K showed the best performance in the yield attributing characteristics (i.e. plant height (55.89 cm), number of leaves/plant (15.47 leaves), number of pods/plant (66.00 pods), pod length (3.45 cm), seeds per pod (4.00 seeds), 1000 seeds weight (138.8 g), seed yield (2.63 t/ha), stover yield (4.49 t/ha) and biological yield (7.12 t/ha)) and seed quality (seed viability (84.00 %) and seed germination (94.00 %)) and the timing of 1^{st} flowering (28.00 days) and timing of pod maturity (49.00 days) were lowest. The combined effect of BARI Soybean 6 with Biochar + 70 kg/ha K showed the best performance in case of increasing soybean growth, yield and seed quality compared to other treatments.

LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Full meaning
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
CV	Coefficient of variation
^{o}C	Degree Celsius
et al.	And others
FAO	Food and Agriculture Organization
G	Gram
Ha	Hectare
J.	Journal
K	Potassium
Kg	Kilogram
LSD	Least Significant Difference
Mg	Milligram
Ml	Milliliter
MP	Muriate of Potash
N	Nitrogen
P	Phosphorus
%	Percent
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Soybean (*Glycine max*) belongs to Fabaceae family native to East Asia, widely grown for its edible bean which has numerous use. Soybean is one of the most important oil seed crop in the world. Oil seed and protein rich soybean has now been recognized all over the world as a potential supplementary source of edible oil and nutrient (Kaul and Das, 1986). The world production of soybean as estimated in 2008 was 231.27 million ton from an area of 96.47 million hectares (FAO, 2009). In 2018, roughly 398 million tons of soybeans were produced worldwide which accounted for 61% of overall oilseed production and 6% of the world's arable land use (Shea *et al.,* 2020, Hartman *et al.,* 2011). It is the most important grain legume of the world and a new prospective crop for Bangladesh (Rahman *et al.*, 2011). Nowadays soybean production area is increasing day by day and in the year 2013 it reaches above 61000 ha (Chowdhury *et al.*, 2014). The world average yield of soybean is about 3 t ha^{-1} while that in Bangladesh 1.2 t ha^{-1} (SAIC, 2007). The oil of soybean contains 85% unsaturated fatty acid and is cholesterol free. Soybean seeds contain 43.2% protein, 19.5% fat, 20.9% carbohydrate and good amount of other nutrient like calcium, phosphorus, iron and vitamins. The oil content of soybeans is about 20%, while all other pulse contains about 1-2% oil (Rahman, 1992). Malik *et al.* (2006) and Dugje *et al.* (2009) depicted that soybean oil is consisted of 85% cholesterol free unsaturated fatty acids. For its nutritive value soybean has been called miracle golden bean, the golden nugget, the nugget of nutrition etc. soybean being a good source of protein, unsaturated fatty acids, minerals like Ca and P and vitamin A, B, C and D can meet up different nutritional needs of human being. Soybean can be used in various ways. It can be used as a pulse crop, can also be used for making nutritious food items like soya dal, soya khechuri, soya pollao, soya bori, soya biscuits, soya bread etc. (Mondal and Wahhab, 2001; Khaleque, 1985). For the agriculture development fertilizer management is an important factor. Judicious use of fertilizer provides to be responsible for higher yield and with reduced fertilizer pollution (Bodbe *et al.*, 1998). The use of organic manure alone is not sufficient for seed viability (Prasad, 1996). It has also been brought out that the use of organic manure in combination of potassium fertilizer.

The continuous use of high level of chemical fertilizers has led to problem of soil reduce the need for chemical degradation, which is proving detrimental to crop production in our country. Conventional farming systems contain higher levels of nitrate, which is a nutritional disadvantage (Mader, *et al.*, 2002). So we need balanced organic nutrient for crop production. But combined application of poultry manure as an organic fertilizer may reduce chemical fertilizer dependency to a great extent, allowing the small farmers to save a part of the cost of production. Soybean N_2 requirements are met in a complex manner, as this crop is capable of utilizing both soil nitrogen and atmospheric nitrogen (Falodun and Osaigbovo, 2010). Biofertilizers are ecofriendly, cost effective and a renewable source of plant nutrients in sustainable agricultural systems (Mohammadi and Sohrabi, 2012). Organic manures and biochar have been associated with desirable soil properties, improve the higher plant available water holding capacity, can foster beneficial microorganisms (Lehmann, 2007; Drinkwater *et al.*, 1995) and lead to high crop productivity.

Potassium is involved in nearly all process needed to sustain the plant life. Potassium plays roles in flowering and pollen germination as well as in seed development. A full dose of K helps to increase the flowering, the number of grains and early physiological maturity. Potassium plays vital role to keep seed viability. For more production we need seed that has high viability. Viability is the measure of percentage of seed that are alive after storage. High viability gives high plant production in the field of nursery (Bicksler, 2011). So we need to improve the seed viability of soybean. Soybean has been found to respond to K application at varying rates under different agro-situations (Silva and Bohnen, 1991; Kundu *et al.*, 1990; Jones *et al.*, 1977). Soybean takes up and accumulates K throughout the growing season (Hanway and Weber, 1971). Potassium deficiency is reported to cause stunted growth and chlorosis (George and Michael, 2002). Tiwani *et al.* (2001) reported K as an important macro-nutrient for metabolic, growth and stress adaptation. Therefore the overall functioning of the plant parts depends on mobility of K as it is responsible for sustaining the movement of other ions like H+ , sugars and nitrates throughout the whole plant (Marschner, 1995). Thus, deficiency of K at any time during the growing season of soybean may reduce its yields. Applied K increased the number of nodules, total and individual weight of nodules, and the number of pods plant^{-1}. These results indicate that soybean response to organic fertilizers and potassium fertilization varies greatly among environments and the plant-soil-climate interactions are not well understood. Also, published information related to effects of organic fertilizers and potassium on seed quality of soybeans is in Bangladesh. So, further investigation is needed to assess changes in seed growth, yield and quality due to use of organic fertilizers and potassium fertilization in many of today's production environments. Therefore, the present study has been conducted with the following objectives:

1. To observe the varietal performance on seed viability and yield of soybean,
2. To find out the influence of nutrient management on seed viability and yield of soybean, and
3. To observe the interaction effect of variety and nutrient management on seed viability and yield of soybean.

CHAPTER II

REVIEW OF LITERATURE

Soybean is an important grain legume crop in the world. Researches on the organic fertilizers and K fertilization rate have been carried out by a large number of researchers throughout the world. In Bangladesh, researches on the organic fertilizers and K fertilization rate of soybean are not adequate. However, some important findings have been reviewed in this chapter under the following headings.

2.1. Effect of organic fertilizers

Hardarson *et al.* (1984) reported that the % N derived from atmosphere was much more affected when the soybean were inoculated with *B. Japonicum* strain RCR 3412 compared to inoculation with 61A24a, when 20 or 100 kg N ha^{-1} were applied to the soybean and the N_2 nitrogen fixation measured using 15N methodology. In this context, starter N doses as low as 20-40 kg of N ha^{-1} may decrease nodulation and N_2 fixation rates, with no benefits to yield. Indeed, in more than 50 experiments where inoculation and fertilization with 200 kg of N ha^{-1} have been compared (split application of N at sowing and flowering), no increases in yield due to N-fertilizer use have been observed. Similarly, there were no benefits when N-fertilizer was applied at a rate of 400 kg N ha^{-1}, split across ten applications (Hungria *et al.*, 2006).

Afza *et al.* (1987) found that foliar application of N may slightly increase soybean yields without significantly decreasing biological N_2 fixation. They carried out a field experiment, which shown that it is possible to increase soybean yields by applying 40 kg N ha^{-1} as a foliar spray without significantly reducing the amount of N_2 fixed. Clearly, biological nitrogen fixation (BNF) is the most sustainable and lowest cost source of N, and in many cases there is no response to added N. Hence, the issues of when, where and why soybean sometimes responds to applied N remains an important research issue.

Nitrogen (N) is required for protein production in plants and animals and is a component of the nucleic acids DNA and RNA. It is a component of chlorophyll, which gives the green color to plants and is vital for photosynthesis. Crops do not use N very efficiently, and significant quantities are often lost to leaching, volatilization, or denitrification. The bacteria infect their roots and convert nitrogen in the air into a form the plants can use. It is important to inoculate legumes with proper N-fixing bacteria if that particular crop has not been grown in the field for several years. Therefore, legumes that has active N-fixing bacteria do not need additional N fertilization. The bacteria will produce less N if it is provided (Hellal and Abdelhamid, 2013).

Manna *et al.*, (2001) observed, in a 3-year field study (1996-99), the performance of four different composts obtained from legume straw (*Glycine max* Merr. L.), cereal straw (*Triticurn aestivum*), oilseed straw (*Brassica juncea* L.), city rubbish and compared with chemical fertilizers in terms of degree of maturity, quality of compost, improvement in soil organic matter, biological activities of soil and yields of soybean and wheat. The matured compost increased total P, water soluble P, citrate soluble P, total N and NO_3-N and the application of phosphocompost at the rate of 10 t/ha gave plant growth, dry matter accumulation, seed yield and P uptake by soybean equivalent to single super phosphate at 26.2 kg P/ha.

Vessey (2003) reported that combined application of 5 kg Zn and 10 t FYM /ha increased grain yield, NPK contents and uptake by soybean seed. The highest grain yield (1790 kg/ha) was recorded in Zn +FYM treatment with a record of 18.2% increase over control (1515 kg/ha) while the application of B +FYM (13.6%) was on with seed treatment with Na molybdate (13.1%).

A long-term experiment was conducted by Behera (2003) during 1995-2002 under the fine-textured Vertisols at Indore, India to study the effect of combined use of Farm Yard Manure (FYM), poultry manure, vermicompost and biofertilizers (Azotobacter - phosphate solubilizing bacteria) with 50 and 100% NPK on wheat, and residual effect on following soybean. Grain yield of aestivum wheat in the initial 2 years and durum wheat in the later 3 years was significantly increased with 50% NPK + poultry manure @: 2.5 t/ha or FYM @ 10 vim compared with 50 or 100% NPK alone. Soybean did not show much response to residual effect of treatments in most years, although the yield were comparatively better under the combined use of 100% NPK -FYM or poultry manure given to wheat.

Reddy *et al.* (2004) conducted a field experiment on a Typic Haplustert from 1992 to 1995 where in the annual treatments included four rates of fertilizer P (0, 11, 22 and 44kg ha applied to both soybean and wheat) in the absence and presence of 16 t ha^{-1} of manure (applied to soybean only). They observed that with regular application of fertilizer P to each crop the level of Olsen P increased significantly and linearly through the years in both manured and unmanured plots. The mean P balance required to raise Olsen P by 1 mg kg^{-1} was 17.9 kg ha^{-1} of fertilizer P in unmanured plots and 5.6 kg ha^{-1} of manure plus fertilizer P in manured plots.

Hati *et al.* (2006) found that application of 10 mg farmyard manure and recommended NPK (NPK + FYM) to soybean for three consecutive years improved the organic carbon content of the surface (0-15 cm) soil from an initial value of 4.4 g kg^{-1} to 6.2 g kg^{-1} and also increased seed yield and water-use efficiency by 103% and 76%, respectively over the control. Root length density (RLD) up to the 30cm depth was highest in the NPK + FYM plots and it was 31.9% and 70.5% more than NPK and control plots.

Ghosh *et al.* (2006) observed that yield and land equivalent ratio (LER) of the intercrops increased over sole crops though based on aggressively and relative crowding coefficient (RCC), sorghum is more competitive than soybean. Soybean did not benefit from intercropping to the same degree as sorghum tinder N-P-K. Nutrient application influenced LFR, RCC and monetary advantage index and was found in the order of N-P-K plus farmyard manure (FYM)> N-P-K plus poultry manure (PM) > N-P-K plus phosphocompost (PC) > N-P-K > control. However, based on competition ratio, yield advantage was greater under N-P-K plus PM.

A field experiment on maize with soybean intercropping system was done by Shil *et al.* (2007) during rabi season of 2005-2006. There were 8 treatments comprising 2 sets of planting geometry (PG_1 & PG_2) and 4 doses (NM_1, NM_2, NM_3 and NM_4) of nutrient management package. The interaction effect between planting geometry and nutrient management was statistically non-significant for the main crop (hybrid maize). In case of companion crop (soybean), the highest seed yield (564 and 504 kg/ha) was obtained with NM_3 x PG_2, which was significantly higher over rest of the combinations.

A long-term (30 years) soybean-wheat experiment was conducted by Kundu *et al.* (2006) at Hawalbagh, Almora and observed that maximum yields of soybean (2.84 Mg ha^{-1}) and residual wheat (1.88 Mg ha^{-1}) were obtained in the plots tinder NPK farmyard manure (FYM) treatment, which were significantly higher than yields observed tinder other treatments.

During 2002 and 2003, a study was carried out by Miladinovic *et al.* (2004) to determine the effects of yield, oil content and growing season duration on protein content in new soybean varieties' seeds. In both years, high negative correlations were found between protein content and the other traits under investigation. Path coefficient analysis showed that only oil content had a significant direct effect on protein content.

The effects of irrigation (40, 60, 80 and 100 mm of water evaporated from a class A pan) and plant density (30, 40, 50 and 60 plants/m^2) on the seed yield, and protein and oil content of soyabean cultivars Hobbit. Williams and Hill were determined in a field experiment conducted in Iran during 2000-01. Grain yield per plant and per hectare, as well as 100-seed weight were highest in cv. Williams and with 60 mm irrigation. Grain yield per plant, 100-seed weight and seed oil content decreased, whereas seed protein content increased with increasing plant density. Seed oil content decreased, whereas seed protein content increased with increasing irrigation regimes. Seed protein content was highest in cv. Hobbit (Khajouci-Nejad *et al.*, 2004).

Deshmukh *et al.* (2005) reported that application of recommended dose of NPK (20:40:20 kg ha^{-1}) along with FYM (2.5 tonnes ha^{-1}) recorded the highest grain yield of soybean (12.49 q ha^{-1}), energy (183.60 MJ ha^{-1}) and protein (502.30 kg ha^{-1}) yields as compared to other treatments and farmer's practice. Similar trends were also observed in the uptake of N, P and K (118.79, 5.61 and 66.61 kg ha^{-1}, respectively).

Application of organic manure, biofertilizer and yeast (*Candida tropicales*) on growth, yield and seed quality of soybean (*Glycine max* L.). The results indicated that application of organic manure at a rate of 20 ton per acre as a sole treatment and also when it is associated with biofertilizer as one treatment had more plant height and dry weight per plant. Seed yield (g per plant), pods weight (g per plant), as well as, number of pods per plant, seeds per pod and 1000-seed weight were decreased by adding bio-fertilizer singly, but when it was associated with organic manure it showed the highest seed and pods weight. Application of organic manure + yeast as one treatment resulted in increased yield and yield attributes of soybean plants. P concentration was only increased when plants received yeast only and also when yeast was associated with bio-fertilizer. Zn concentration tended to increase as plants were treated by bio + organic manure + yeast followed by bio + organic as one treatment. Mn concentration was high when plants received yeast singly or when it was associated with bio-fertilizer, while Fe concentration tended to increase due to adding bio + organic manure + yeast followed by bio + organic as one treatment (Mekki and Ahmed, 2005).

Rao *et al.* (2000) from a field experiment carried out at the Indian Agricultural Research Institute, New Delhi, revealed that application of 3 t vermicompost ha^{-1} to chickpea improved dry mailer accumulation, grain yield and grain protein content in chickpea, soil N and P and bacterial count, dry fodder yield of succeeding maize, total N and P uptake by the cropping system over no vermicompost.

An experiment was conducted in India on two wheat cultivars to investigate the effect of chemical fertilizers (NPK fertilizer), and organic manure (vermicompost). Results showed that plant height, dry matter production and grain yield were higher at higher dose of vermicompost. Number of tillers and leaves per plant were very low at early stages of growth and suddenly increased after adding different concentrations of vennicompost and organic manure (Khandal and Nagendra, 2002).

The combined application of organic and inorganic N sustained the productivity. Soil available nutrients like N, P and K increased significantly with the application of various organic sources of nutrients in combination with fertilizers over the fertilizer alone. The highest grain yields of rabi sorghum and chickpea were obtained with 50 percent N through green manure plus 50 percent fertilizer N (Tolanur and Badanur, 2003).

PGPR present in bio-fertilizer and organic manures enhance the plant growth by producing growth regulators that enhance the activity of other beneficial microorganisms, accelerating the mineralization of plant nutrients and uptake of certain nutrients. Increased leaf area, chlorophyll concentration and total biomass production in wheat was observed (Panwar *et al.*, 2000).

Bio-fertilizer and organic manures that contain PGPR affect nutrient uptake in plant and enhance growth and development of plant roots, leading to root systems with larger surface area and increased number of root hairs, which are then able to access more nutrients (Adesemoye *et al.*, 2008).

Mehasen and Saeed (2005) studied the effects of bacterial inoculation as well as mineral and organic fertilization on the yield and yield components of soybean Giza 22 and Giza 111 cultivars. They concluded that there is a significant effect for the interaction between soybean cultivars and fertilization treatments on seed weight per plant only.

Integrated use of organic manure with efficient microbes and half dosage NPK fertilizer yielded similar to the yield obtained from full recommended NPK fertilizer (Khaliq *et al.*, 2006).

Asewar *et al.* (2003) carried out man experiment to investigate the integrated use of vermicompost and inorganic fertilizer in chickpea cv. Vijay during 2000-01 and 2001-02 in Badnapur, Maharastra, India. Treatments comprised: four vermicompost levels (0.1-2.3 t ha^{-1}) and three fertilizer levels 0 (control); 50% and 100% recommended rate of fertilizer (REF, 25 kg N and 50 kg P ha^{-1}). They found that, vermicaompost application increased the growth characters, plant height and number of branches plant^{-1} and yield contributing characters, pods per plant, grain yield and straw yield compare to the control.

The performance of 3 kabli gram (*Cicer arietinum*) genotypes under various organic manures was in Faisalabad, Pakistan, during 1999-2000 and 2000-01. The fertilizer levels had significant effects on the seed yield of gram genotypes. The difference among the varietal means were not significant during the 1st year but significant during resulted in the greatest seed yield (Muhammad *et al.*, 2004).

Kumari and Kumari (2002) from an experiment stated that verrnicompost is a potential source of organic manure due to the presence of readily available plant nutrients, growth enhancing substances and number of beneficial microorganisms like N fixing, P solubilizing and celulose decomposing organisms.

Vermicompost contains 2.29 folds more organic carbon. 1.76 times total nitrogen. 3.02 folds phosphorous and 1.60 times potassium than normal compost. Earthworms decrease the C:N ratio from 14.21 to 10.11 and an average 56.03% of organic waste can be converted into vermicompost by the activities of earthworms in short time (Sohrab and Sarwar, 2001).

Vermicompost contain high organic matter, N, P, S, Ca and Mg. It was shown that worm-worked coinposts have better lexture and soil enhancing properties, hold typically higher percentages of N, P and K (Fatma and Sweelam, 2000).

Santos *et al.* (1996) studied five soybean genotypes and six osmotic potential levels induced by manitol and reported that the increase in vigour in the less vigourous seeds under this condition could be explained by the reduction in the water entry speed in the cells during the seed imbibition process (Peske and Delouche, 1985), bearing in mind that not very vigourous seeds have disarrangements in the cell membranes that favor faster water absorption and solute loss, that can result in tissue death.

2.2. Effect of potassium fertilizers

Mokoena (2013) studied the effect of potassium fertilizer (0, 50 and 100 kg K ha^{-1}) on soybean and observed that soybean plant height was only significantly impacted by the effect of K. Plant height was significantly increased by applying K (50 or 100 kg ha^{-1}), as compared to where zero K was applied.

Xiang *et al.* (2012) stated that the maximum (81.6) pods $plant^{-1}$ of soybean was produced by when K was used at the rate of 112.5 kg ha^{-1} and the minimum (72.1) pods $plant^{-1}$ (72.1) was found when no potassium was applied.

Azizi and Sorouri (2014) conducted an experiment to evaluate the effect of potassium, zinc and manganese on agronomic traits of soybean and they used potassium in three levels (0, 80 and 160 kg ha^{-1}). They observed that maximum number of seeds pod^{-1} was obtained from 160 kg ha^{-1} K_2O + Solopotash.

Xiang *et al.* (2012) conducted an experiment and they were observed that the highest (1.28) seeds pod^{-1} was produced by relay strip intercropping soybean at the rate of 112.5 kg K ha^{-1} whereas, the lowest was recorded in the zero-K control.

Mokoena (2013) stated that effect of K significantly influenced 1000-seed mass. The application of 100 kg K ha^{-1} resulted in a 1000-seed mass of 143.3 g and the lowest obtained from where zero K was applied.

Khan *et al.* (2004) conducted an experiment to assess the influence of different levels of potassium fertilization (0, 25, 50, 75, 100, 125 and 150 kg ha^{-1}) on growth, seed yield and oil contents of soybean. They revealed that K fertilizers had a significant influence on 1000-seed weight. The highest values of 1000-seed weight were recorded in when potassium was applied @ 150 kg ha^{-1} and the lowest value of was noted in control treatment.

Nelson *et al.* (2012) conducted an experiment to know the effect of potassium on glyphosate resistant soybean response and weed control. The treatments were consisted of 2.2, 8.8 and 17.6 kg K ha^{-1}. They found that seed yield increased with fertilizer additives at 8.8 kg K ha^{-1}.

Xiang *et al.* (2012) also observed that the highest seed yield (2695 kg ha^{-1}) was produced by relay strip intercropping soybean at the rate of 112.5 kg ha^{-1} and the lowest seed yield was recorded in the zero-K control.

Camargo *et al.* (2012) conducted an experiment to evaluate the effects of P and K on yield and quality of soybean. The treatments were consisted of 0, 26, 35 and 53 kg ha^{-1} of P and o, 33, 50 and 66 kg ha^{-1} of K. They found that maximum soybean yield was obtained with 30.3 to 36 kg ha^{-1} of K.

Pettigrew (2008) conducted an experiment to know the effect of potassium on seed yield and quality production for maize, wheat, soybean and cotton. He reported that potassium deficiency reduced both the number of leaves and the size of leaf area. So, the photosynthetic rate also reduced and ultimately seed yield was hampered. He also found that potassium significantly increased the seed yield of soybean.

Xiang *et al.* (2012) stated observed that the highest harvest index (42.8%) was produced by relay strip intercropping soybean at the rate of 112.5 kg K ha^{-1} .and the lowest (40.0%) was recorded in the zero-K control.

CHAPTER III

MATERIALS AND METHOD

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, intercultural operations, data collection and statistical analyses.

3.1. Location

The field experiment was conducted at the Agronomy research field, SAU, Dhaka during the period from October 2019 to March 2020. Geographically the experimental field is located at 23°46' N latitude and 90°22' E longitude at an elevation of 8.2 m above from the sea level belonging to the Agro-ecological Zone "AEZ-28" of Madhupur Tract. The location of the experimental site has been shown in Appendix I.

3.2. Climate

The experimental area is situated in the sub-tropical climatic zone and characterized by heavy rainfall during the months of April to September (kharif season) and scanty rainfall during the rest period of the year. The Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February. The weather data during the study period at the experimental site are shown in Appendix II.

3.3. Soil

The soil of the research field is slightly acidic in reaction with low organic matter content. The selected plot was above flood level and sufficient sunshine was available having available irrigation and drainage system during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done from Soil Resources Development Institute (SRDI), Dhaka. The experimental plot was also high land, having pH 5.8. The physicochemical property and nutrient status of soil of the experimental plots are given in Appendix III.

3.4. Plant materials and features

The varieties of soybean used in this experiment was BARI Soybean 6 and BINA Soyabean-1. The seed of this variety was collected from Bangladesh Agricultural Research Institute, Joydebpur, Gazipur and Bangladesh Institute of Nuclear Agriculture, Mymensingh, respectively. These released varieties has excellent seed quality and superior to others.

3.5. Experimental treatments

The experiment consisted of two treatment factors as mentioned below:

Factor A: Varieties

V_1 = BARI Soybean 6

V_2= Bina soybean 1

Factor B: Different organic fertilizers and manure

T_0 = Control

T_1 = Trichoderma (2 t/ha) (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP. Gypsum and boric acid, respectively)

T_2 = Trichoderma + 70 kg/ha K (50, 150, 80 & 8 kg/ha of urea, TSP, Gypsum and boric acid, respectively)

T_3 =Trichoderma + 90 kg/ha K (50, 150, 80 & 8 kg/ha of urea, TSP, Gypsum and boric acid, respectively)

T_4 = Biochar (10 t/ha) (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP. Gypsum and boric acid, respectively)

T_5 = Biochar + 70 kg/ha K (50, 150, 80 & 8 kg/ha of urea, TSP, Gypsum and boric acid, respectively)

T_6 = Biochar + 90 kg/ha K (50, 150, 80 & 8 kg/ha of urea, TSP, Gypsum and boric acid, respectively)

T_7 = Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP. Gypsum and boric acid, respectively)

3.6. Design and layout

The experiment was laid out in two factor Split Plot Design with three replications. The size of the individual plot was 4 m x 2.5 m and total numbers of plots were 48. There were 16 treatment combinations. Each block was divided into 16 unit plots. Varieties along the main plot and organic fertilizers and manures were placed in the sub plot. Layout of the experiment was done on October 27, 2019 with inter plot spacing of 0.50 m and inter block spacing of 0.75 m.

3.7. Land preparation

The land of the experimental field was first opened on October 21, 2019 with a power tiller. Then it was exposed to the sunshine for 7 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed to obtain good tilth. Deep ploughing was done to produce a good tilth, which was necessary to get better yield of the crop. Laddering was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubbles were removed from the experimental field.

3.8. Fertilizer application

The fertilizers were applied as per treatment. All fertilizers except MoP were applied at the time of final plough of field preparation but half amount of the recommended doses were applied. Rest urea was divided into two portions and were top dressed that after 15 DAS and 30 DAS respectively. Cow dung was applied into the field at the time of first ploughing.

3.9. Seed sowing

Sowing was done on 29 October, 2019. Seeds were sown in 30 cm apart rows and seed to seed distances were maintained at first in 5cm and later in 10 cm to conform the exact plant density. Furrows were made by hand rake and seeds were placed in the furrows by hand and then covered properly with soil.

3.10. Intercultural operations

The following intercultural operations were done for ensuring the normal growth of the crop.

3.10.1. Thinning

At 15 DAS, excess plants were thinned out and maintained plant to plant distance 10 cm.

3.10.2. Weeding

The crop was weeded twice. First weeding was done at 25 days after sowing (DAS) and second weeding was done at 45 DAS. Demarcation boundaries and drainage channels were also kept weed free.

3.10.3. Irrigation

Irrigation was done at 30 DAS after sowing (pre-flowering) stage and then at 60 DAS (pod formation stages) as per recommendation. Proper drainage system was also made for draining out excess water.

3.10.4. Plant protections

The soybean plants were infested by cutworms at early growth stage which were controlled by applying insecticides. Diseased or off type plants were uprooted as and when required.

3.11. General observations of the experimental field

Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants which were vigorous and luxuriant in the treatment plots than that of control plots.

3.12. Sampling and harvesting

Maturity of crop was determined when 95 % of the pods become brown in colour. Three sample plants were collected from each plot before harvesting for taking yield attributes data. The plants of central 1 m^2 area were harvested by placing quadrates at random for recording yield data. Harvesting was done on 29 February, 2020. The harvested crops from each plot were tied up into bundles separately, tagged and brought to the clean threshing floor. The same procedure was followed for sample plants.

3.12.1. Threshing

The crop bundles were sun dried for four days by spreading them on the threshing floor. Seeds were separated from the stover by hand machine and rubbing.

3.12.2. Drying

Seeds and stover were cleaned and dried in the sun for four consecutive days. After proper drying of seeds to a moisture content of 12% were kept in polythene bags. Moisture contents were determined by moisture meter.

3.12.3. Cleaning and weighing

Dried seeds and stover was weighed plot wise. After that the weights were converted into t ha^{-1}.

3.13. Collection of data

Three plants in each plot were selected and tagged. All the growth data (except dry weight) were recorded from those three selected plants.

The following data were collected –

A. Crop growth characters

1. Plant height (cm) at harvest

2. Number of leaves $plant^{-1}$

3. Time of flowering (days)

B. Yield contributing characters

1. Number of pods $plant^{-1}$

2. Length of pod (cm)

3. Number of seeds pod^{-1}

4. Time of maturity (days)

5. 1000-seed weight (g)

C. Yield and harvest index

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

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

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

4. Harvest index (%)

D. Seed quality test

1. Seed germination (%)

2. Seed viability (%)

3.14. Methods of recording data

A. Crop growth parameters

1. Plant height (cm): The height of soybean plants was recorded at harvest. The heights of three preselected sample plants were measured from the ground level to the tip of the shoot. Then the data was averaged and expressed in cm.

2. Number of leaves plant^{-1}: All the leaves of the preselected three sample plants in each plot were counted and averaged them to have number of leaves plant^{-1} and recorded it separately.

3. Time of flowering (days): Each plant of the experiment plot was kept under close observation to count days of flowering of soybean. Total number of days from the date of sowing to the flowering was recorded.

B. Yield contributing characters

1. Number of pods plants^{-1}: All the pods of the preselected three sample plants in each plot were counted and averaged them to have pods plant^{-1}.

2. Pod length (cm): The lengths of three randomly selected pods taken from sample plants were measured. Mean data was expressed in centimeter (cm).

3. Number of seeds pod^{-1}: Number of total seeds of three sample plants from each plot was noted and the mean number was expressed pod^{-1} basis.

4. Time of maturity (days): Each plant of the experiment plot was kept under close observation to count days of pod maturity of soybean. Total number of days from the date of sowing to the pod maturity was recorded.

5. Weight of 1000-seed (g): One thousand sun dried cleaned seeds were counted randomly from the seed stock of sample plants. Weight of 1000 seeds were then recorded by means of a digital electrical balance and expressed in gram (g).

C. Yield and harvest index

1. Seed yield: Seeds obtained from harvested (1.0 m^2) area of each unit plot were dried in the sun and weighed. The seed weight was expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using digital moisture meter.

2. Stover yield: The Stover yield obtained from the harvested 1.0 m^2 area of each unit plot were dried separately and weights were recorded. These weights were converted to t ha^{-1}.

3. Biological yield: Biological yield was calculated by using the following formula:

Biological yield= Grain yield + Stover yield

4. Harvest index (%): Harvest index is the relationship between grain yield and biological yield (Gardner *et al.*, 1985). It was calculated by using the following formula:

$$HI\ (\%) = \frac{Grain\ yield}{Biological\ yield} \times 100$$

D. Seed quality test

Carried out with two sub-samples of 50 seeds for each treatment and replication, which were preconditioned on paper towels moistened with distilled water for 16 hr in a germinator set at 25°C ± 2°C. After this period, the seeds were transferred to plastic cups (50 ml) and were completely submerged in 0.075% tetrazolium solution for three hours, in an incubator set at 40°C in the dark. After staining, the seeds were classified for germination and viability at levels from 1 to 8, according to the criteria proposed by França-Neto *et al.* (1998). The viability and germination potentials were expressed as a percentage (França-Neto *et al.*, 1999).

3.15. Statistical analysis

The data collected on different parameters were statistically analyzed to obtain the level of significance by using MSTAT-C computer package program. The significant differences among the treatment means were compared by LSD and Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

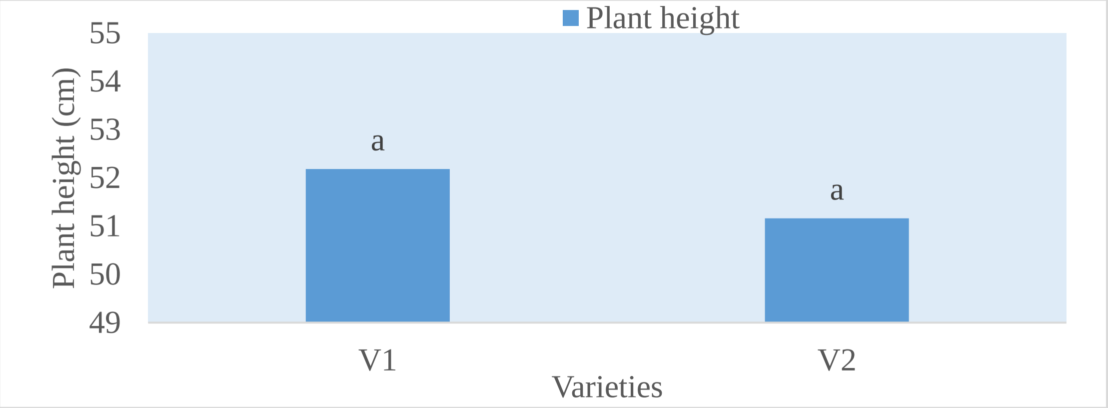
RESULTS AND DISCUSSION

The experiment was conducted at the farm condition of Sher-e-Bangla Agricultural University, Dhaka to find out the enhancement of seed viability and yield of soybean through organic nutrient management. Data on different growth parameter, yield and seed vigority and viability in laboratory. The analyses of variance (ANOVA) of the data on different recorded parameters are presented in Appendix III-XVI. The findings of the experiment have been presented and discusses with the help of Table and Graphs and possible interpretations were given under the following headings:

4.1. Crop growth parameters

4.1.1. Plant height

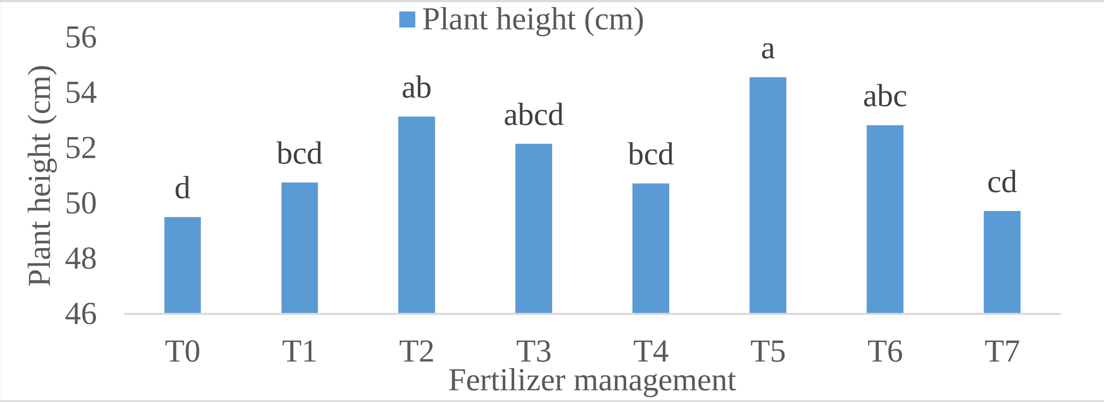
Plant height of soybean showed statistically significant variation due to different varieties at harvest. The tallest plant (52.18 cm) was recorded from V_1 (BARI Soybean 6), which was shortest plant (51.16 cm) in V_2 (Bina soybean 1) (Figure 1). From this figure it was revealed that, BARI Soybean 6 showed the best performance in terms of plant height in field condition.



[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1]

Figure 1: Variation in plant height of two soybean varieties ($LSD_{(0.05)}$ = 2.87)

Fertilizer management differed significantly in terms of plant height of soybean at harvest. The tallest plant (54.60 cm) was found from T_5 (Biochar + 70 kg/ha K) which was statistically similar to T_2, T_3 and T_6 and different from others, while the shortest plant (49.50 cm) was observed from T_0 (Control) treatment (Figure 2). From this figure it can be revealed that, potassium fertilizer with organic manure increases the plant height of soybean.



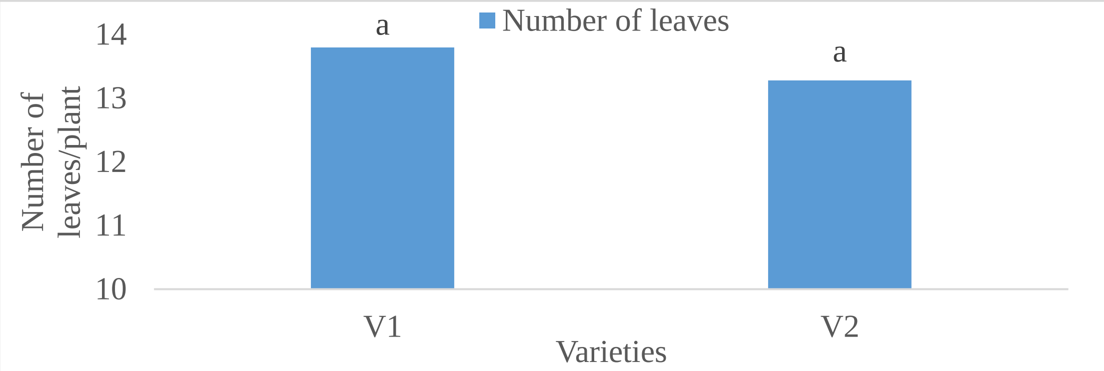
[Here, T_0= Control, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

Figure 2: Effect of fertilizer management on plant height of soybean ($LSD_{(0.05)}$ = 2.87)

Interaction effect of varieties and fertilizer management showed statistically significant variation on plant height of soybean at harvest. The tallest plant (55.89 cm) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K), which was statistically similar with V_1T_6 (53.67), V_1T_2 (53.55), V_2T_5 (53.23) and V_2T_2 (52.72) followed by V_1T_3 (52.33), V_2T_6 (51.99), V_2T_3 (51.96), V_1T_1 (51.23) and V_1T_4 (50.78 cm). On the other hand the lowest plant height (48.89 cm) was recorded from V_2T_0 (Bina soybean 1 with control), which was statistically similar with V_2T_7 (49.56), V_1T_7 (49.88), V_1T_0 (50.11), V_2T_1 (50.27) and V_2T_4 (50.66 cm) (Table 1).

4.1.2. Number of leaves plant^{-1}

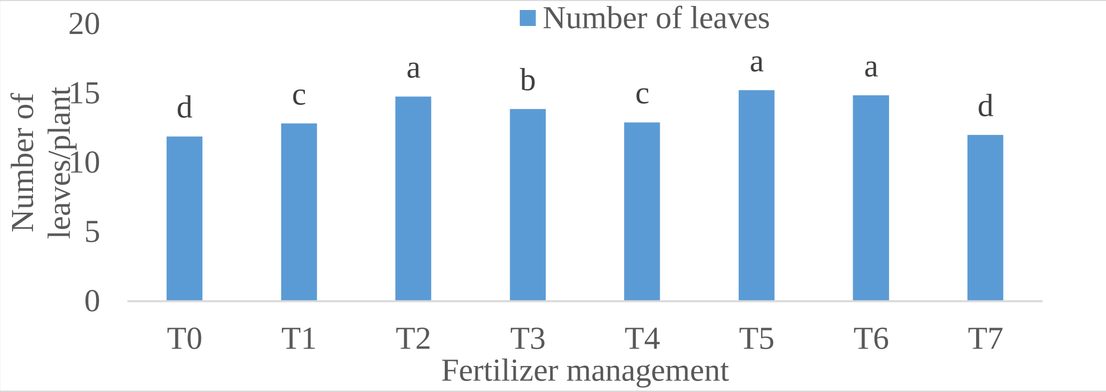
Number of leaves per plant of soybean showed statistically non-significant variation due to different varieties at harvest. The highest number of leaves (13.80 leaves) was recorded from V_1 (BARI Soybean 6), which was statistically similar (13.28 leaves) with V_2 (Bina soybean 1) (Figure 3). From this figure it was revealed that, BARI Soybean 6 showed the better performance in terms of number of leaves of soybean in field condition.



[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1]

Figure 3: Effect of different varieties on the number of leaves per plant of soybean ($LSD_{(0.05)}$ = 0.24)

Fertilizer management differed significantly in terms of number of leaves per plant of soybean at harvest. The highest number of leaves (15.22 leaves) was found from T_5 (Biochar + 70 kg/ha K) which was statistically similar to T_2, and T_6 and different from others, while the lowest number of leaves (11.89 leaves) was observed from T_0 (Control) treatment (Figure 4). From this figure it can be revealed that, potassium fertilizer with organic manure increases the number of leaves of soybean.



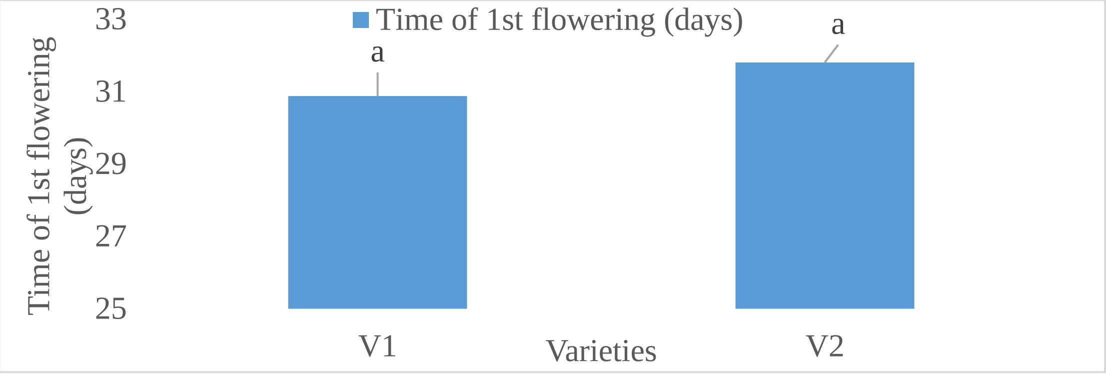
[Here, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

Figure 4: Effect of fertilizer management on number of leaves per plant of soybean ($LSD_{(0.05)}$ = 0.24)

Interaction effect of varieties and fertilizer management showed statistically significant variation on number of leaves per plant of soybean at harvest. The highest number of leaves (15.47 leaves) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K), which was statistically similar with V_1T_6 (15.23), V_2T_5 (14.96), V_1T_2 (14.89) and V_2T_2 (14.65) followed by V_2T_6 (14.47), V_1T_3 (14.36), V_2T_3 (13.36), V_1T_1 (13.07) and V_1T_4 (13.03 leaves). On the other hand the lowest number of leaves (11.67 leaves) was recorded from V_2T_0 (Bina soybean 1 with control), which was statistically similar with V_2T_7 (11.78), V_1T_0 (12.11), V_1T_7 (12.21), V_2T_1 (12.57) and V_2T_4 (12.79 leaves) (Table 1).

3. Time of 1st flowering (days)

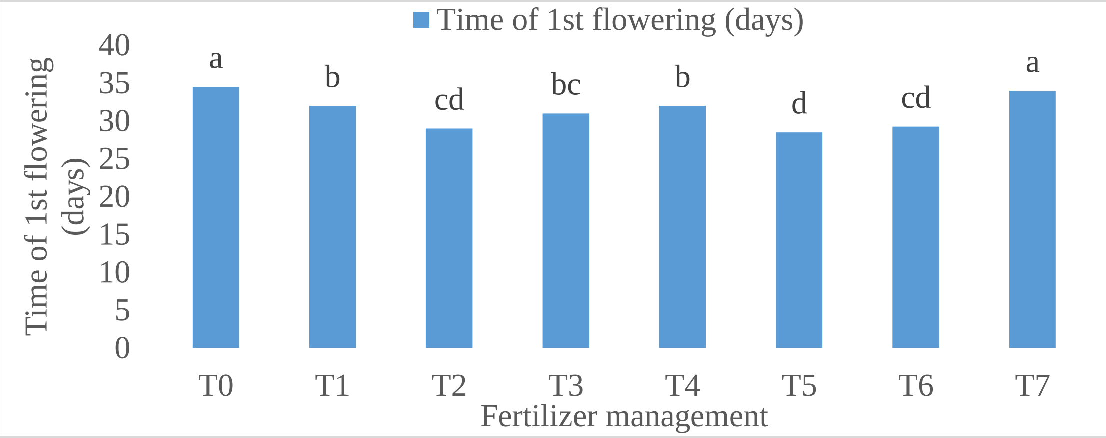
Time of 1st flowering of soybean showed statistically non-significant variation due to different varieties. The lowest time for 1st flowering (30.88 days) was recorded from V_1 (BARI Soybean 6), which was statistically similar (31.81 days) with V_2 (Bina soybean 1) (Figure 5). From this figure it was revealed that, BARI Soybean 6 showed the better performance in terms of time for 1st flowering of soybean in field condition.



[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1

Figure 5: Effect of different varieties on the 1st flowering of soybean ($LSD_{(0.05)}$ = 1.77)

Fertilizer management differed significantly in terms of time of 1st flowering of soybean. The lowest time for 1st flowering (28.50 days) was found from T_5 (Biochar + 70 kg/ha K) which was statistically similar to T_7 and different from others, while the highest time for 1st flowering (34.50 days) was observed from T_0 (Control) treatment (Figure 6). From this figure it can be revealed that, potassium fertilizer with organic manure decreases the time for 1st flowering of soybean.



[Here, T_0= Control, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

Figure 6: Effect of fertilizer management on time of 1st flowering of soybean ($LSD_{(0.05)}$ = 1.77)

Interaction effect of varieties and fertilizer management showed statistically significant variation on time for 1st flowering of soybean. The lowest time sfor 1st flowering (28.00

days) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K), which was statistically similar with V_1T_6 (29.00), V_1T_2 (29.00), V_2T_5 (29.00) and V_2T_6 (29.50) followed by V_2T_2 (30.00), V_1T_3 (31.00), V_2T_3 (31.00), V_1T_1 (31.00) and V_1T_4 (32.00 days). On the other hand the highest time for 1st flowering (36.00 days) was recorded from V_2T_0 (Bina soybean 1 with control), which was statistically different from others and followed by V_2T_7 (34.00), V_1T_7 (34.00), V_1T_0 (33.00), V_2T_1 (33.00) and V_2T_4 (32.00 days) (Table 1).

Table 1: Combined effect of varieties and fertilizer management on plant height, number of leaves per plant and time of 1st flowering of soybean

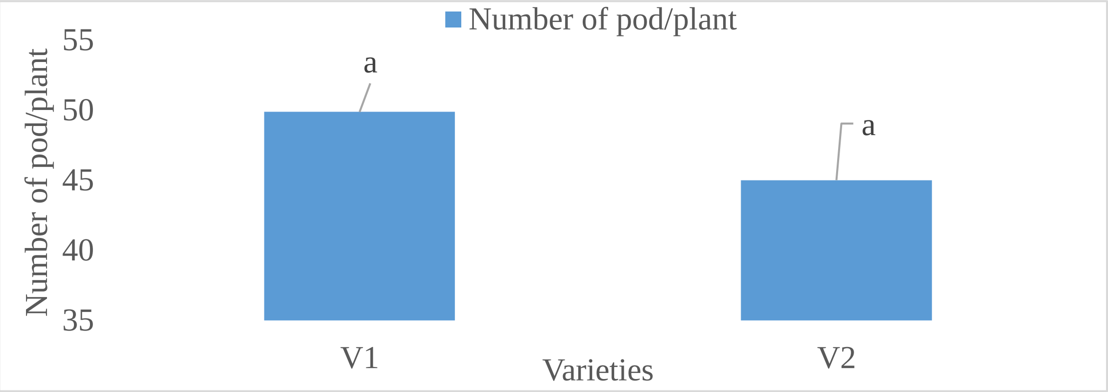
Varieties	Treatments	Plant height (cm)	Number of leaves/ plant	Time of 1st flowering (days)
V_1	T_0	50.11 d-f	12.11 e-g	33.00 bc
	T_1	51.23 b-f	13.07 cd	31.00 de
	T_2	53.55 a-c	14.89 ab	29.00 fg
	T_3	52.33 b-e	14.36 b	31.00 de
	T_4	50.78 b-f	13.03 cd	32.00 cd
	T_5	55.89 a	15.47 a	28.00 g
	T_6	53.67 ab	15.23 ab	29.00 e-g
	T_7	49.88 d-f	12.21 d-g	34.00 b
V_2	T_0	48.89 f	11.67 g	36.00 a
	T_1	50.27 c-f	12.57 c-f	33.00 bc
	T_2	52.72 a-e	14.65 ab	30.00 ef
	T_3	51.96 b-f	13.36 c	31.00 de
	T_4	50.66 b-f	12.79 c-e	32.00 cd
	T_5	53.23 a-d	14.96 ab	29.00 e-g
	T_6	51.99 b-f	14.47 b	29.50 e-g
	T_7	49.56 ef	11.78 fg	34.00 b
$LSD_{(0.05)}$		2.87	0.24	1.77
CV (%)		3.38	3.63	3.43

[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1, T_0= Control, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

4.2. Yield contributing characters

4.2.1. Number of pods plants^{-1}

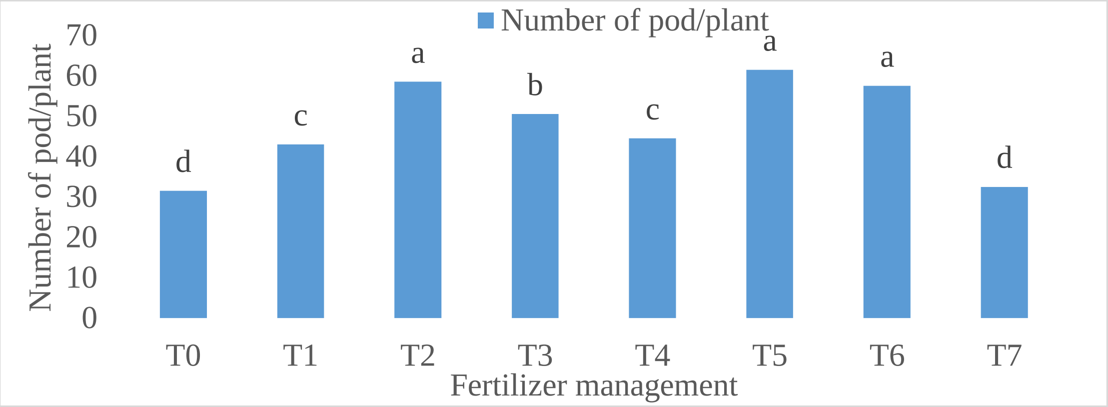
Number of pods per plant of soybean showed statistically significant variation due to different varieties at harvest. The highest number of pods (49.88 pods) was recorded from V_1 (BARI Soybean 6), whereas the lowest number of pods (45.01 pods) was recorded from V_2 (Bina soybean 1) (Figure 7). From this figure it was revealed that, BARI Soybean 6 showed the better performance in terms of number of pods per plant of soybean in field condition.



[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1]

Figure 7: Effect of different varieties on the number of pod/plant of soybean ($LSD_{(0.05)}$ = 5.84)

Fertilizer management differed significantly in terms of number of pods per plant of soybean at harvest. The highest number of pods (61.50 pods) was found from T_5 (Biochar + 70 kg/ha K) which was statistically similar to T_2, and T_6 and different from others, while the lowest number of pods (31.50 pods) was observed from T_0 (Control) treatment (Figure 8). From this figure it can be revealed that, potassium fertilizer with organic manure increases the number of pod per plant of soybean.



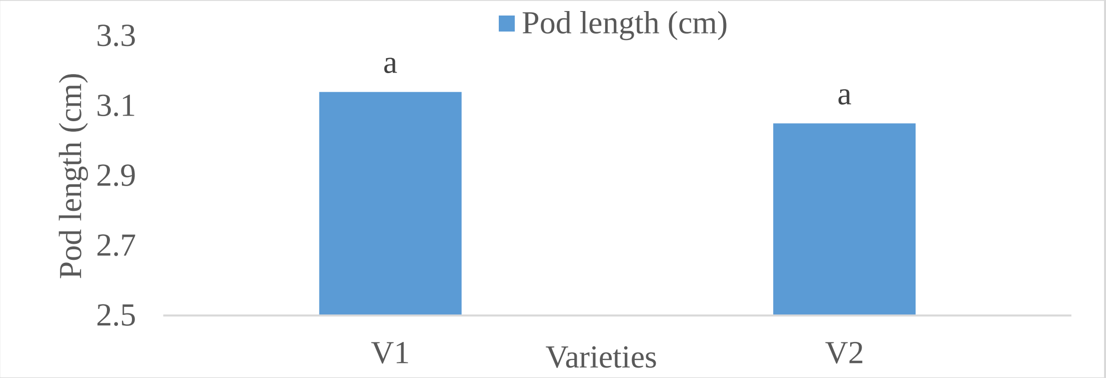
[Here, T_0= Control, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

Figure 8: Effect of fertilizer management on number of pod per plant of soybean ($LSD_{(0.05)}$ = 5.84)

Interaction effect of varieties and fertilizer management showed statistically significant variation on number of pods per plant of soybean at harvest. The highest number of pods (66.00 pods) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K), which was statistically similar with V_2T_6 (63.00) followed by V_1T_6 (61.00), V_2T_5 (57.00), V_2T_6 (54.08), V_2T_2 (54.00), V_1T_3 (51.00), V_2T_3 (50.00) and V_1T_4 (47.00 pods). On the other hand the lowest number of pods (28.00 pods) was recorded from V_2T_0 (Bina soybean 1 with control), which was statistically different from others and followed by V_1T_7 (32.00), V_2T_7 (33.00), V_1T_0 (35.00), V_2T_1 (42.00), V_2T_4 (42.00) and V_1T_1 (44.00 pods) (Table 2).

4.2.2. Pod length

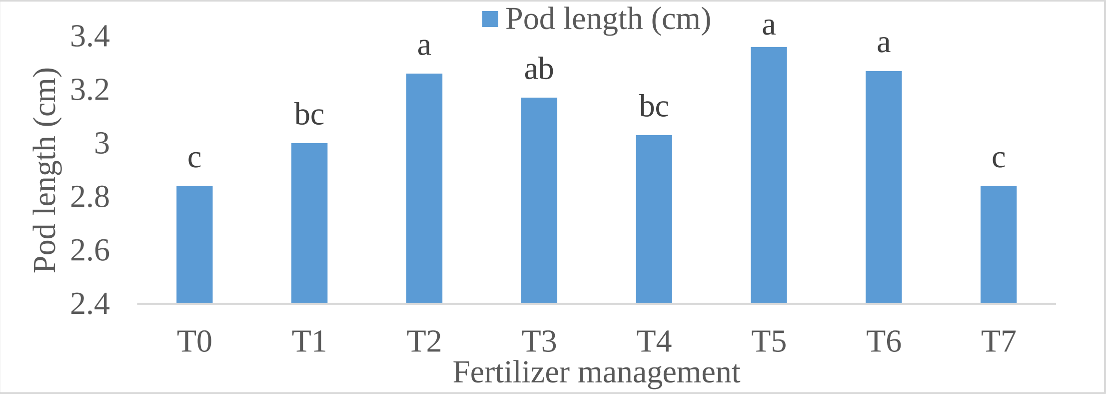
Pod length of soybean showed statistically non-significant variation due to different varieties at harvest. The highest pod length (3.14 cm) was recorded from V_1 (BARI Soybean 6), whereas the lowest pod length (3.05 cm) was recorded from V_2 (Bina soybean 1) (Figure 9). From this figure it was revealed that, BARI Soybean 6 showed the better performance in terms of pod length of soybean in field condition.



[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1]

Figure 9: Effect of different varieties on pod length of soybean ($LSD_{(0.05)}$ = 0.18)

Fertilizer management differed significantly in terms of pod length of soybean at harvest. The highest pod length (3.36 cm) was found from T_5 (Biochar + 70 kg/ha K) which was statistically similar to T_2, T_3 and T_6 and different from others, while the lowest pod length (2.84 cm) was observed from T_0 (Control) treatment (Figure 10). From this figure it can be revealed that, potassium fertilizer with organic manure increases the pod length of soybean.



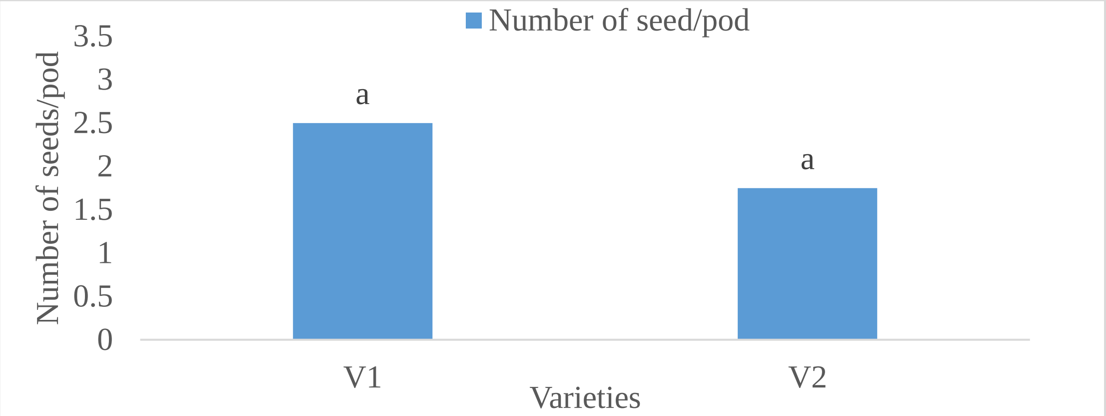
[Here, T_0= Control, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

Figure 10: Effect of fertilizer management on pod length of soybean ($LSD_{(0.05)}$ = 0.18)

Interaction effect of varieties and fertilizer management showed statistically significant variation on pod length of soybean at harvest. The highest pod length (3.45 cm) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K), which was statistically similar with V_1T_2 (3.29), V_1T_6 (3.27), V_2T_5 (3.27) and V_2T_6 (3.27) followed by V_2T_2 (3.22), V_1T_3 (3.17), V_2T_3 (3.16), V_1T_1 (3.11) and V_1T_4 (3.07 cm). On the other hand the lowest pod length (2.73 cm) was recorded from V_2T_0 (Bina soybean 1 with control), which was statistically similar with V_1T_7 (2.81), V_2T_7 (2.87), V_2T_1 (2.89), V_1T_0 (2.94) and V_2T_4 (2.98 cm) (Table 2).

4.2.3. Number of seeds pod^{-1}

Number of seeds per pod of soybean showed statistically non-significant to different varieties at harvest. The highest number of seeds per pod (2.50 seeds) was recorded from V_1 (BARI Soybean 6), whereas the lowest number of seeds per pod (1.75 seeds) was recorded from V_2 (Bina soybean 1) (Figure 11). From this figure it was revealed that, BARI Soybean 6 showed the better performance in terms of number of seeds per pod of soybean in field condition.

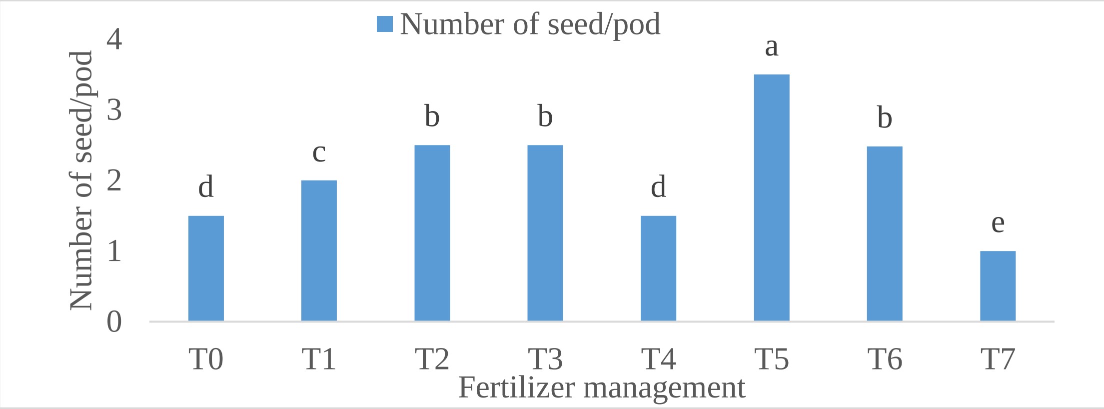


[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1]

Figure 11: Effect of different varieties on the number of seeds/pod of soybean ($LSD_{(0.05)}$ = 0.24)

Fertilizer management differed significantly in terms of number of seeds per pod of soybean at harvest. The highest number of seeds per pod (3.50 seeds) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the lowest number of seeds per pod (1.00 seed) was observed from T_0 (Control) treatment (Figure

12). From this figure it can be revealed that, potassium fertilizer with organic manure increases the number of seeds per pod of soybean.



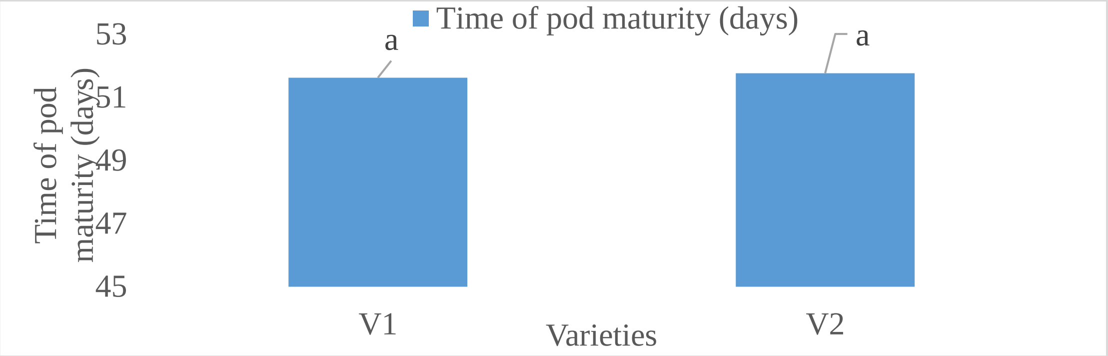
[Here, T_0= Control, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

Figure 12: Effect of fertilizer management on number of seed per pod of soybean ($LSD_{(0.05)}$ = 0.24)

Interaction effect of varieties and fertilizer management showed statistically significant variation on number of seeds per pod of soybean at harvest. The highest number of seeds per plot (4.00 seeds) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K), which was statistically different from others and followed by V_1T_6 (3.00), V_1T_2 (3.00), V_2T_5 (3.00), V_1T_6 (3.00), V_2T_2 (2.00), V_2T_3 (2.00), V_1T_3 (2.00) and V_2T_1 (2.00 seeds). On the other hand the lowest number of pods (1.00 seed) was recorded from V_2T_0 (Bina soybean 1 with control), which was statistically similar with V_1T_7 (1.00), V_2T_7 (1.00), V_2T_4 (1.00), V_1T_1 (1.97), V_1T_0 (2.00) and V_2T_4 (2.00 seeds) (Table 2).

4.2.4. Time of pod maturity (days)

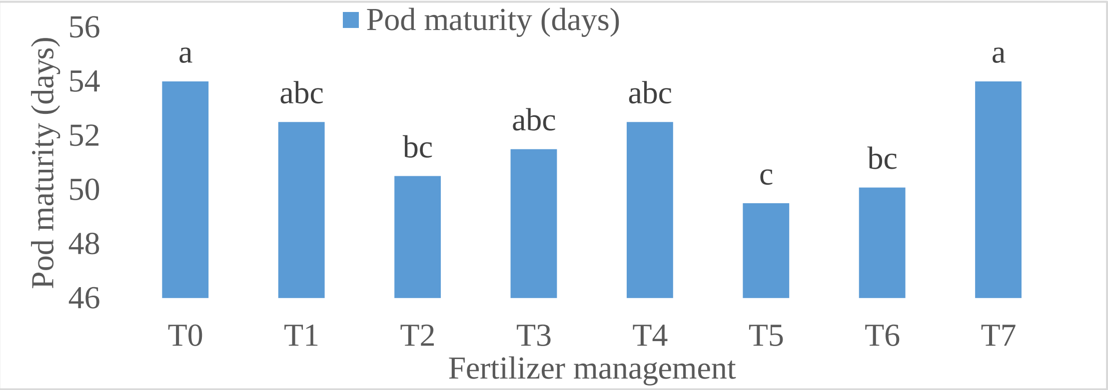
Time of pod maturity of soybean showed statistically non-significant variation due to different varieties. The lowest time for pod maturity (51.63 days) was recorded from V_1 (BARI Soybean 6), which was statistically similar (51.77 days) with V_2 (Bina soybean 1) (Figure 13). From this figure it was revealed that, BARI Soybean 6 showed the better performance in terms of time for pod maturity of soybean in field condition.



[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1]

Figure 13: Effect of different varieties on the timing of pod maturity of soybean ($LSD_{(0.05)}$ = 2.81)

Fertilizer management differed significantly in terms of time of pod maturity of soybean. The lowest time for pod maturity (49.50 days) was found from T_5 (Biochar + 70 kg/ha K) which was statistically similar to T_1, T_2, T_4, T_3 and T_7 and different from others, while the highest time for pod maturity (54.00 days) was observed from T_0 (Control) treatment (Figure 14). From this figure it can be revealed that, application of organic manure with potassium fertilizer increases the time for pod maturity of soybean.



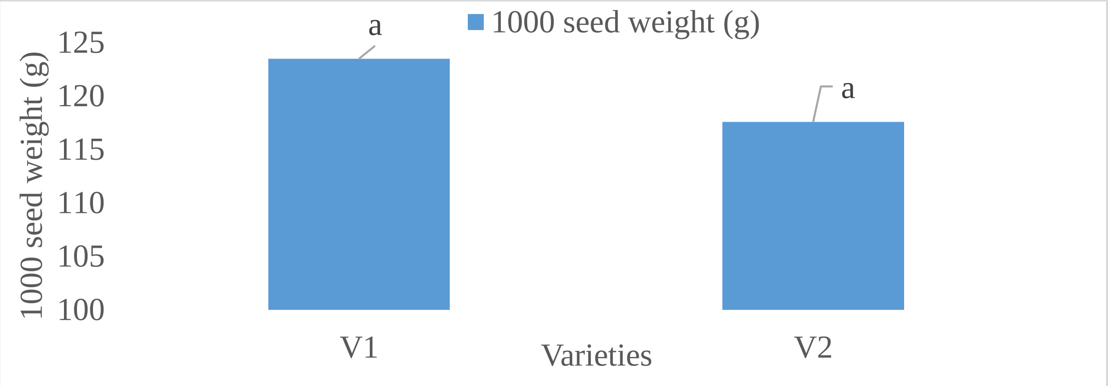
[Here, T_0= Control, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

Figure 14: Effect of fertilizer management on pod maturity of soybean ($LSD_{(0.05)}$ = 2.81)

Interaction effect of varieties and fertilizer management showed statistically significant variation on time for pod maturity of soybean. The lowest time for pod maturity (49.00 days) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K), which was statistically similar with V_1T_6 (49.17), V_1T_2 (50.00), V_2T_5 (50.00), V_2T_3 (51.00), V_2T_2 (51.00), V_1T_3 (51.00), V_2T_6 (52.00) and V_2T_1 (52.00 seeds). On the other hand the highest time for pod maturity (55.00 days) was recorded from V_2T_0 (Bina soybean 1 with control) which was statistically similar with V_1T_7 (54.00), V_2T_7 (53.00), V_1T_0 (53.00), V_1T_1 (53.00), V_2T_4 (52.00) and V_1T_4 (52.00 days) (Table 2).

4.2.5. Weight of 1000-seed (g)

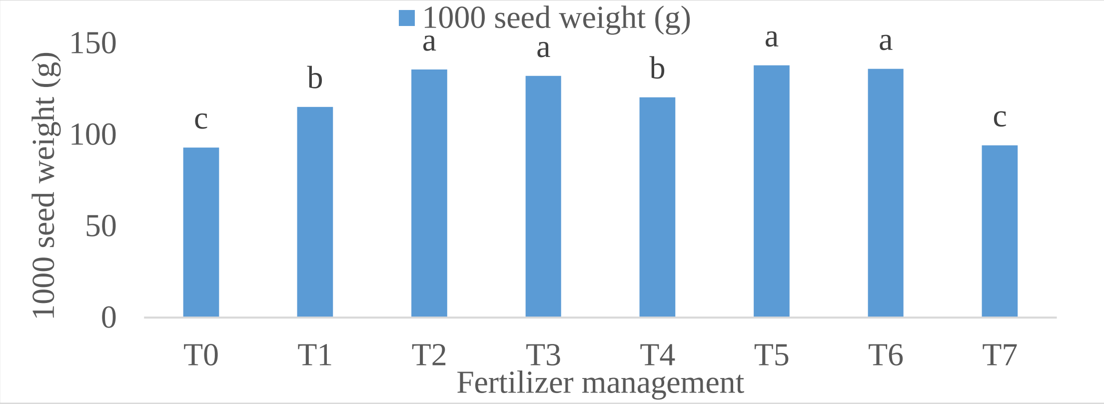
Weight of 1000 seeds of soybean showed statistically significant variation due to different varieties at harvest. The highest weight (123.5 g) was recorded from V_1 (BARI Soybean 6), whereas the lowest weight (117.6 g) was recorded from V_2 (Bina soybean 1) (Figure 15). From this figure it was revealed that, BARI Soybean 6 showed the better performance in terms of weight of 1000 seeds of soybean in field condition.



[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1]

Figure 15: Effect of different varieties on 1000 seed weight of soybean ($LSD_{(0.05)}$ = 7.68)

Fertilizer management differed significantly in terms of weight of 1000 seeds of soybean. The highest weight (137.9 g) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the lowest weight (93.00 g) was observed from T_0 (Control) treatment (Figure 16). From this figure it can be revealed that, application of organic fertilizer with potassium fertilizer increases the weight of 1000 seeds of soybean.



[Here, T_0= Control, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

Figure 16: Effect of fertilizer management on 1000 seed weight of soybean ($LSD_{(0.05)}$ = 7.68)

Interaction effect of varieties and fertilizer management showed statistically significant variation on weight of 1000 seeds of soybean. The highest weight (138.80 g) was recorded from V_2T_5 (BARI Soybean 6 with Biochar+70 kg/ha K), which was statistically similar with V_2T_6 (137.90), V_2T_2 (137.30), V_2T_5 (136.90), V_1T_6 (134.00), V_1T_2 (133.80), V_2T_3 (132.70) and V_1T_3 (131.40) followed by V_2T_1 (125.40), V_2T_4 (123.50) and V_1T_4 (117.40 g). On the other hand the lowest weight (89.30 g) was recorded from V_2T_0 (Bina soybean 1 with control), which was statistically similar with V_1T_7 (92.80), V_2T_7 (95.60) and V_1T_0 (96.70) followed by V_1T_1 (104.80 g) (Table 2).

Table 2: Combined effect of varieties and fertilizer management on number of pod per plant, pod length, number of seeds per pod, time of pod maturity and 1000 seeds weight of soybean

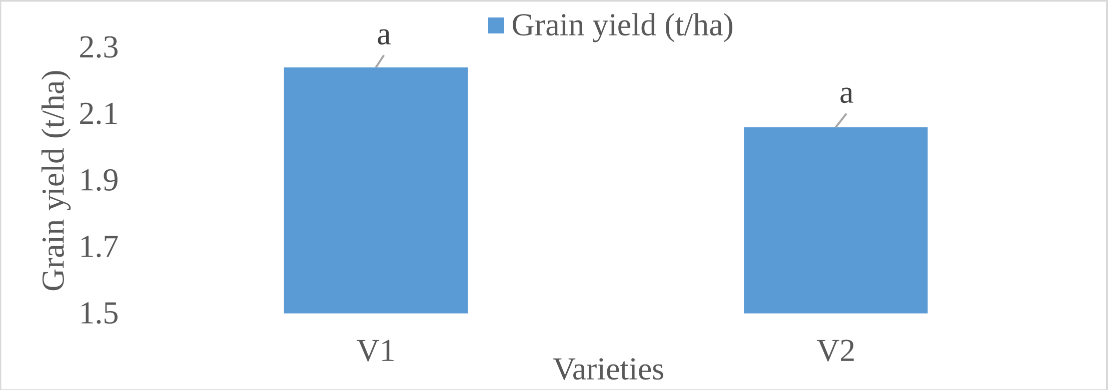
Varieties	Treatments	Number of pod/plant	Pod length (cm)	Number of seeds/pod	Time of pod maturity (days)	1000 seed weight (g)
V_1	T_0	35.00 h	2.94 e-g	2.00 c	53.00 a-c	96.70 f
	T_1	44.00 fg	3.11 b-e	2.00 c	53.00 a-c	104.80 e
	T_2	63.00 ab	3.29 ab	3.00 b	50.00 cd	133.80 a
	T_3	51.00 de	3.17 b-d	3.00 b	51.00 b-d	131.40 a-c
	T_4	47.00 ef	3.07 c-f	2.00 c	52.00 a-d	117.40 d
	T_5	66.00 a	3.45 a	4.00 a	50.00 cd	138.80 a
	T_6	61.00 b	3.27 a-c	3.00 b	49.00 d	134.00 a
	T_7	32.00 h	2.81 gh	1.00 d	54.00 ab	92.80 f
V_2	T_0	28.00 i	2.73 h	1.00 d	55.00 a	89.30 f
	T_1	42.00 g	2.89 f-h	2.00 c	52.00 a-d	125.40 b-d
	T_2	54.00 cd	3.22 bc	2.00 c	51.00 b-d	137.30 a
	T_3	50.00 de	3.16 b-d	2.00 c	51.00 b-d	132.70 ab
	T_4	42.00 g	2.98 d-g	1.00 d	52.00 a-d	123.50 cd
	T_5	57.00 c	3.27 a-c	3.00 b	49.17 d	136.90 a
	T_6	54.08 cd	3.27 a-c	1.97 c	52.00 a-d	137.90 a
	T_7	33.00 h	2.87 gh	1.00 d	53.00 a-c	95.60 f
$LSD_{(0.05)}$		5.84	0.18	0.24	2.81	7.68
CV (%)		5.10	5.65	6.97	3.31	3.88

[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1, T_0= Control, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

4.3. Yield and harvest index

4.3.1. Seed yield

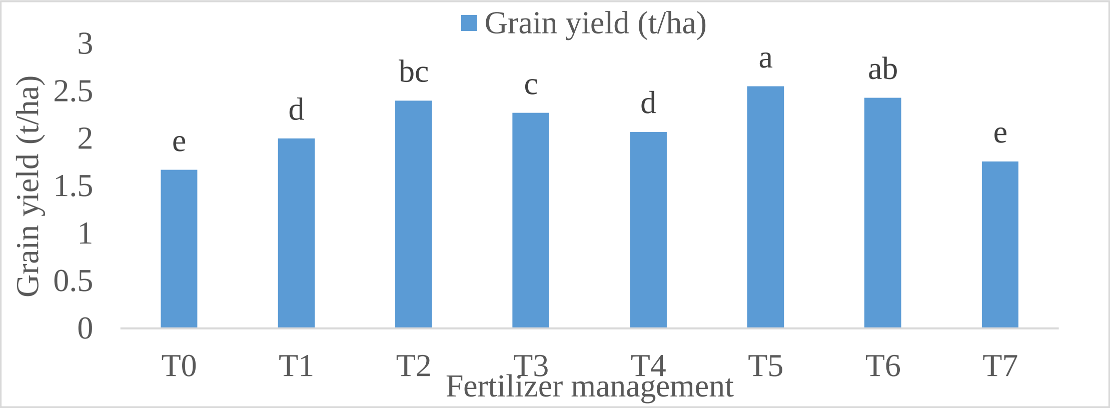
Seed (grain) yield of soybean showed statistically non-significant variation due to varieties at harvest. The highest seed yield (2.23 t/ha) was recorded from V_1 (BARI Soybean 6), whereas the lowest seed yield (2.06 t/ha) was recorded from V_2 (Bina soybean 1) (Figure 17). From this figure it was revealed that, BARI Soybean 6 showed the better performance in terms of seed yield of soybean in field condition.



[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1]

Figure 17: Effect of different varieties on grain yield of soybean ($LSD_{(0.05)}$ = 0.14)

Fertilizer management differed significantly in terms of seed yield of soybean. The highest seed yield (2.55 t/ha) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the lowest seed yield (1.67 t/ha) was observed from T_0 (Control) treatment (Figure 18). From this figure it can be concluded that, seed yield of soybean increased at Biochar + 70 kg/ha K fertilizer application.



[Here, T_0= Control, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

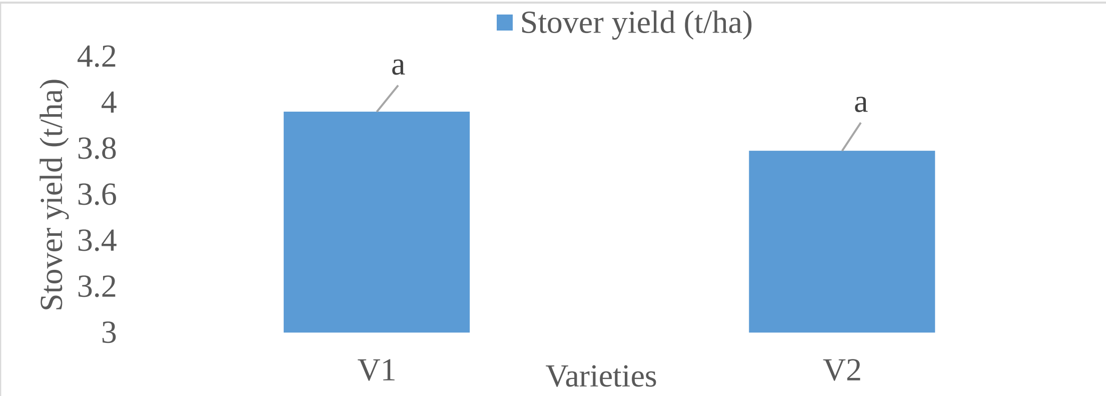
Figure 18: Effect of fertilizer management on grain yield of soybean ($LSD_{(0.05)}$ = 0.14)

Interaction effect of varieties and fertilizer management showed statistically significant variation on seed yield of soybean. The highest seed yield (2.63 t/ha) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K), which was statistically similar with

V_1T_6 (2.51), V_1T_2 (2.47) and V_2T_5 (2.47) followed by V_1T_3 (2.37), V_2T_6 (2.35), V_2T_2 (2.33), V_1T_4 (2.17) and V_2T_3 (2.17 t/ha). On the other hand the lowest seed yield (1.63 t/ha) was recorded from V_2T_0 (Bina soybean 1 with control), which was statistically similar with V_2T_7 (1.67) and V_1T_7 (1.67) followed by V_1T_0 (1.89), V_2T_1 (1.89), V_2T_4 (1.96) and V_1T_1 (2.11 t/ha) (Table 3).

4.3.2. Stover yield

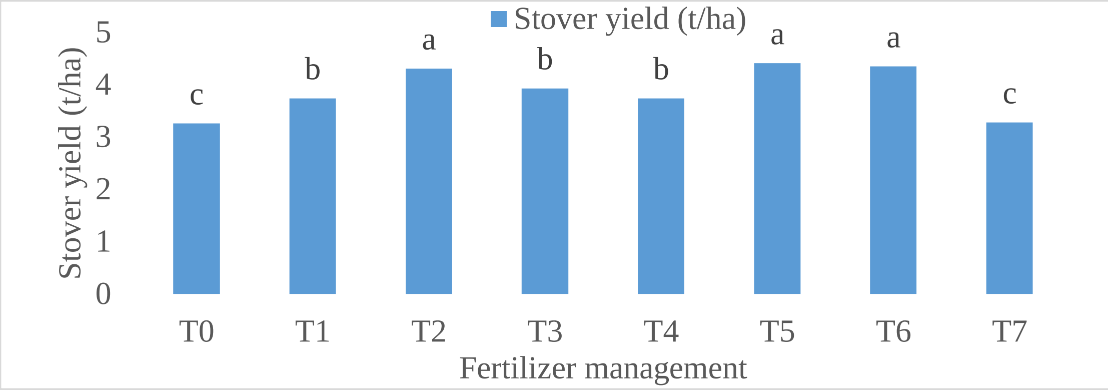
Stover yield of soybean showed statistically non-significant variation due to different varieties at harvest. The highest stover yield (3.96 t/ha) was recorded from V_1 (BARI Soybean 6), whereas the lowest stover yield (3.79 t/ha) was recorded from V_2 (Bina soybean 1) (Figure 19). From this figure it was revealed that, BARI Soybean 6 showed the better performance in terms of stover yield of soybean in field condition.



[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1]

Figure 19: Effect of different varieties on stover yield of soybean ($LSD_{(0.05)}$ = 0.24)

Fertilizer management differed significantly in terms of stover yield of soybean. The highest stover yield (4.41 t/ha) was found from T_5 (Biochar + 70 kg/ha K) which was statistically $T_{2,}$ $T_{3.}$ And T_0 different from others, while the lowest stover yield (3.26 t/ha) was observed from T_0 (Control) treatment (Figure 20). From this figure, it can be revealde that organic and bio fertilizer increases the stover yield of soybean.



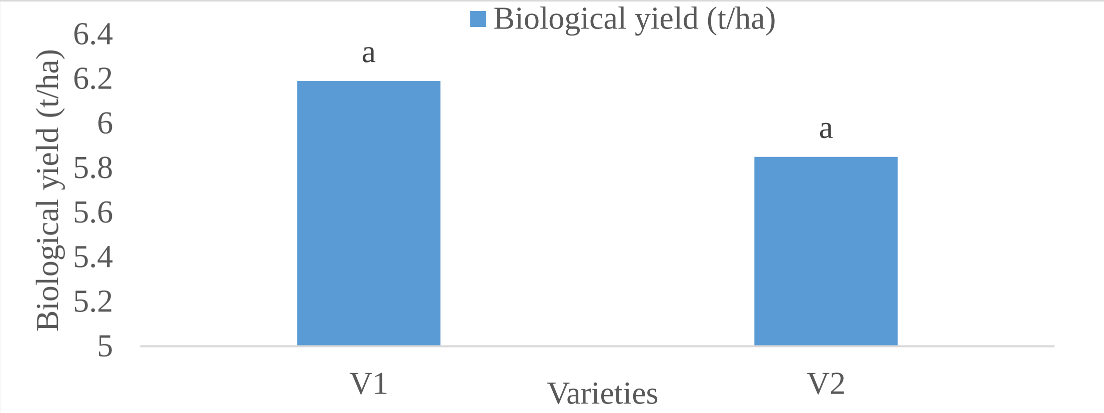
[Here, T_0= Control, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

Figure 20: Effect of fertilizer management on stover yield of soybean ($LSD_{(0.05)}$ = 0.24)

Interaction effect of varieties and fertilizer management showed statistically significant variation on stover yield of soybean. The highest stover yield (4.49 t/ha) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K), which was statistically similar with V_1T_2 (4.40), V_1T_6 (4.36), V_2T_6 (4.35), V_2T_5 (4.33) and V_2T_2 (4.22) followed by V_1T_1 (3.96), V_1T_3 (3.93) and V_2T_3 (3.92 t/ha). On the other hand the lowest stover yield (3.13 t/ha) was recorded from V_2T_0 (Bina soybean 1 with control), which was statistically similar with V_2T_7 (3.23), V_1T_7 (3.33) and V_1T_0 (3.39) followed by V_2T_1 (3.52), V_2T_4 (3.66) and V_2T_4 (3.77 t/ha) (Table 3).

4.3.3. Biological yield

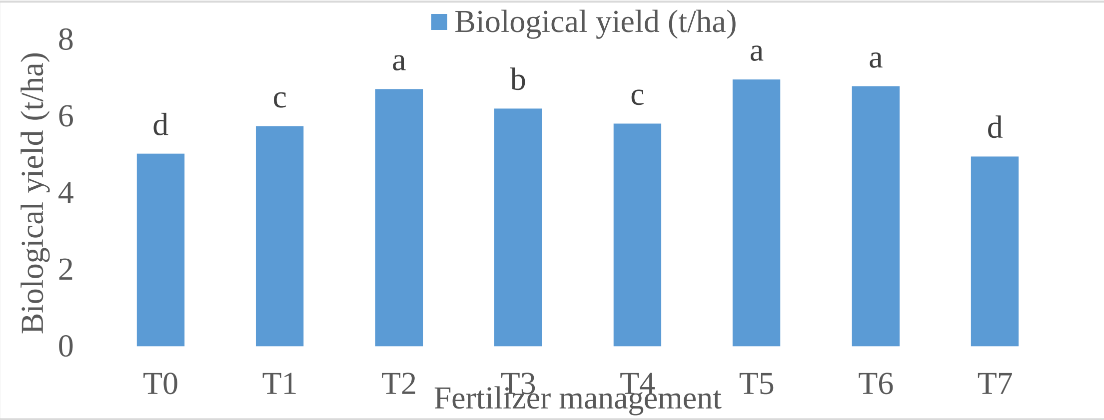
Biological yield of soybean showed statistically significant variation due to different varieties at harvest. The highest biological yield (6.19 t/ha) was recorded from V_1 (BARI Soybean 6), whereas the lowest biological yield (5.85 t/ha) was recorded from V_2 (Bina soybean 1) (Figure 21). From this figure it was revealed that, BARI Soybean 6 showed the better performance in terms of biological yield of soybean in field condition.



[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1]

Figure 21: Effect of different varieties on biological yield of soybean ($LSD_{(0.05)}$ = 0.38)

Fertilizer management differed significantly in terms of biological yield of soybean. The highest biological yield (6.96 t/ha) was found from T_5 (Biochar + 70 kg/ha K) which was statistically to T_2 and T_3 different from others, while the lowest biological yield (4.95 t/ha) was observed from T_0 (Control) treatment (Figure 22). From this figure it was revealed that organic and bio fertilizer increases the biological yield of soybean.



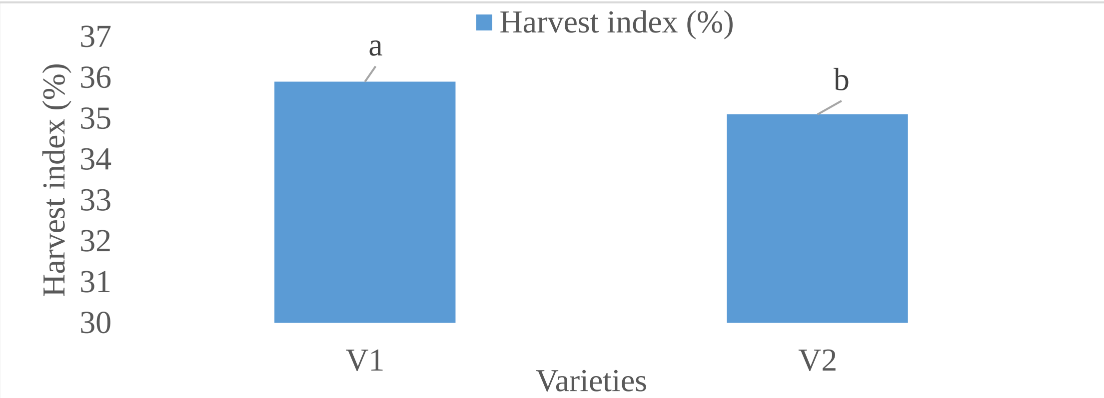
[Here, T_0= Control, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

Figure 22: Effect of fertilizer management on biological yield of soybean ($LSD_{(0.05)}$ = 0.38)

Interaction effect of varieties and fertilizer management showed statistically significant variation on biological yield of soybean. The highest biological yield (7.12 t/ha) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K), which was statistically similar with V_1T_6 (6.87), V_1T_2 (6.87), V_2T_5 (6.80) and V_2T_6 (6.70) followed by V_2T_2 (6.55), V_1T_3 (6.30), V_2T_3 (6.09) and V_1T_1 (6.07 t/ha). On the other hand the lowest biological yield (4.76 t/ha) was recorded from V_2T_0 (Bina soybean 1 with control), which was statistically similar with V_2T_7 (4.90) and V_1T_7 (5.00) followed by V_1T_0 (5.28), V_2T_1 (5.41), V_2T_4 (5.62) and V_1T_4 (5.99 t/ha) (Table 3)

.4.3.4. Harvest index (%)

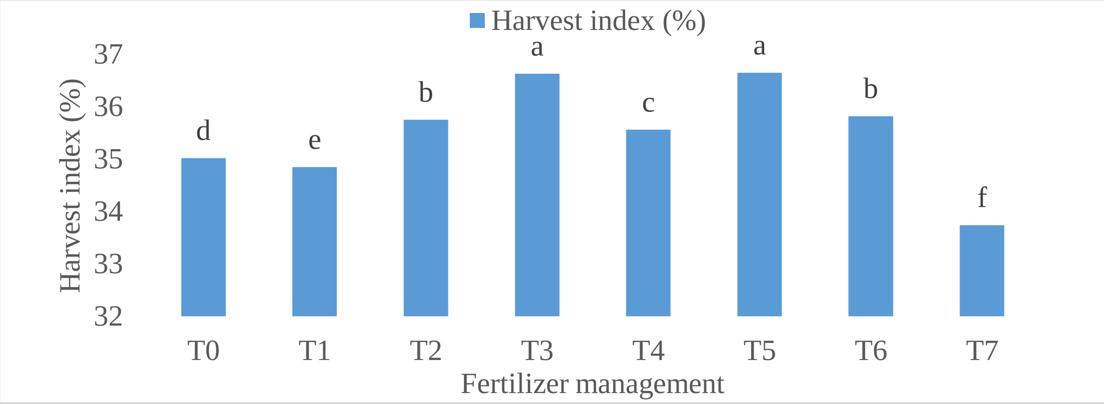
Harvest index of soybean showed statistically significant variation due to different varieties at harvest. The highest harvest index (35.90 %) was recorded from V_1 (BARI Soybean 6), whereas the lowest harvest index (35.10 %) was recorded from V_2 (Bina soybean 1) (Figure 23). From this figure it was revealed that, BARI Soybean 6 showed the better performance in terms of harvest index of soybean in field condition.



[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1]

Figure 23: Effect of different varieties on harvest index of soybean ($LSD_{(0.05)}$ = 0.10)

Fertilizer management differed significantly in terms of harvest index of soybean. The highest harvest index (36.65 %) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the lowest harvest index (33.74 %) was observed from T_0 (Control) treatment (Figure 24). From the figure it can be revealed that organic and bio fertilizer increases the harvest index of soybean.



[Here, T_0= Control, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

Figure 24: Effect of fertilizer management on harvest index of soybean ($LSD_{(0.05)}$ = 0.10)

Interaction effect of varieties and fertilizer management showed statistically significant variation on harvest index of soybean. The highest harvest index (37.62 %) was recorded from V_1T_3 (BARI Soybean 6 with Trichoderma + 90 kg/ha K), which was statistically different from others and followed by V_1T_5 (36.94), V_1T_6 (36.54), V_2T_5 (36.35), V_1T_4 (36.23), V_1T_2 (35.93), V_1T_0 (35.80), V_2T_3 (35.63) and V_2T_2 (35.57 %). On the other hand the lowest harvest index (33.40 %) was recorded from V_1T_7 (BARI Soybean 6 with recommended dose of fertilizer), which was statistically different from others and followed by V_2T_7 (34.08), V_2T_0 (34.24), V_1T_1 (34.76), V_2T_4 (34.88), V_2T_1 (34.94) and V_2T_6 (35.10 %) (Table 3).

Table 3: Combined effect of varieties and fertilizer management on seed yield, stover yield, biological yield and harvest index of soybean

Varieties	Treatments	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)
V_1	T_0	1.89 e	3.39 ef	5.28 fg	35.80 g
	T_1	2.11 d	3.96 b	6.07 d	34.76 k
	T_2	2.47 bc	4.40 a	6.87 ab	35.93 f
	T_3	2.37 bc	3.93 b	6.30 cd	37.62 a
	T_4	2.17 d	3.82 bc	5.99 de	36.23 e
	T_5	2.63 a	4.49 a	7.12 a	36.94 b
	T_6	2.51 ab	4.36 a	6.87 ab	36.54 c
	T_7	1.67 f	3.33 ef	5.00 gh	33.40 n
V_2	T_0	1.63 f	3.13 f	4.76 h	34.24 l
	T_1	1.89 e	3.52 de	5.41 f	34.94 j
	T_2	2.33 c	4.22 a	6.55 bc	35.57 h
	T_3	2.17 d	3.92 b	6.09 d	35.63 h
	T_4	1.96 e	3.66 cd	5.62 ef	34.88 j
	T_5	2.47 bc	4.33 a	6.80 ab	36.35 d
	T_6	2.35 c	4.35 a	6.70 abc	35.10 i
	T_7	1.67 f	3.23 f	4.90 gh	34.08 m
$LSD_{(0.05)}$		0.14	0.24	0.38	0.10
CV (%)		4.01	3.79	3.85	0.18

[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1, T_0= Control, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

4.4. Seed viability test

4.4.1. Seed viability

According to tetrazolium test, there was no statistically significant variation due to different varieties in case of seed viability. V_1 (BARI Soybean 6) showed the best performance (71.88 %) at seed viability, whereas the lowest performance was showed (67.85 %) by V_2 (Bina soybean 1) (Table 4). From this table it was revealed that, BARI

Soybean 6 showed the better performance in terms of seed viability in laboratory condition.

Fertilizer management differed significantly in terms of seed viability of soybean. The highest seed viability (78.50 %) was found from T_5 (Biochar + 70 kg/ha K) which was statistically similar with T_6 (74.41), while the lowest seed viability (65.00 %) was observed from T_0 (Control) treatment (Table 4).

Interaction effect of varieties and fertilizer management showed statistically significant variation on seed viability of soybean. The highest seed viability (84.00 %) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K), which was statistically different from other treatments and followed by V_1T_6 (79.00), V_1T_2 (76.00), V_2T_5 (73.00), V_2T_2 (71.00), V_2T_6 (69.82), V_1T_1 (69.00), V_1T_3 (69.00) and V_2T_3 (68.00). On the other hand the lowest seed viability (63.00 %) was recorded from V_2T_0 (Bina soybean 1 with control), which was statistically similar with V_1T_4 (65.00), V_2T_4 (66.00), V_2T_1 (66.00), V_1T_7 (66.00), V_2T_7 (66.00) and V_1T_0 (67.00 %) (Table 4).

4.4.2. Seed germination

According to tetrazolium test, there was no statistically significant variation due to different varieties in case of seed germination. V_1 (BARI Soybean 6) showed the best performance (85.00 %) at seed germination, whereas the lowest performance was showed (82.32 %) by V_2 (Bina soybean 1) (Table 4). From this table it was revealed that, BARI Soybean 6 showed the better performance in terms of seed germination in laboratory condition.

Fertilizer management differed significantly in terms of seed germination of soybean. The highest seed germination (93.00 %) was found from T_5 (Biochar + 70 kg/ha K) which was statistically similar with T_2 (90.00) and T_6 (88.28 %), while the lowest seed germination (76.50 %) was observed from T_0 (Control) treatment in laboratory condition (Table 4).

Interaction effect of varieties and fertilizer management showed statistically significant variation on seed germination of soybean. The highest seed germination (94.00 %) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K), which was statistically similar with V_1T_6 (92.00), V_2T_5 (92.00), V_1T_2 (91.00) and V_2T_2 (89.00) followed by V_1T_3 (85.00), V_2T_6 (84.57), V_2T_3 (83.00) and V_1T_1 (82.00 %). On the other hand the lowest seed germination (74.00 %) was recorded from V_2T_0 (Bina soybean 1 with control), which was statistically similar with V_1T_7 (77.00), V_2T_7 (78.00), V_1T_0 (79.00), V_2T_1 (79.00) and V_2T_4 (79.00) followed by V_1T_4 (80.00 %) (Table 4).

Table 4: Combined effect of varieties and fertilizer management on seed viability and seed germination of soybean in laboratory condition

Varieties	Treatments	Seed viability (%)	Seed germination (%)
Effect of different varieties			
V_1	-	71.88 a	85.00 a
V_2	-	67.85 a	82.32 a
Effect of fertilizer management			
-	T_0	65.00 c	76.50 d
-	T_1	67.50 c	80.50 cd
-	T_2	73.50 b	90.00 a
-	T_3	68.50 c	84.00 bc
-	T_4	65.50 c	79.50 cd
-	T_5	78.50 a	93.00 a
-	T_6	74.41 ab	88.28 ab
-	T_7	66.00 c	77.50 d
Combined effect of varieties and fertilizer management			
V_1	T_0	67.00 efg	79.00 def
	T_1	69.00 def	82.00 cde
	T_2	76.00 bc	91.00 a
	T_3	69.00 bc	85.00 bc
	T_4	65.00 fg	80.00 cde
	T_5	84.00 a	94.00 a
	T_6	79.00 b	92.00 a
	T_7	66.00 efg	77.00 ef
V_2	T_0	63.00 g	74.00 f
	T_1	66.00 fg	79.00 def
	T_2	71.00 de	89.00 ab
	T_3	68.00 ef	83.00 cd
	T_4	66.00 fg	79.00 def
	T_5	73.00 cd	92.00 a
	T_6	69.82 def	84.57 bc
	T_7	66.00 fg	78.00 def
$LSD_{(0.05)}$		4.27	4.82
CV (%)		3.72	3.51

[Here, V_1= BARI Soybean 6, V_2= Bina soybean 1, T_0= Control, T_1= Trichoderma (2 t/ha), T_2= Trichoderma + 70 kg/ha K, T_3= Trichoderma + 90 kg/ha K, T_4= Biochar (10 t/ha), T_5= Biochar + 70 kg/ha K, T_6= Biochar + 90 kg/ha K, T_7= Recommended dose of fertilizer (50, 150, 100, 80 & 8 kg/ha of urea, TSP, MoP, Gypsum and boric acid, respectively)]

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted at the Agronomy field of SAU, Dhaka, under the Modhupur Tract (AEZ-28) during the period from October 2019 to March 2020 to influence of organic fertilizer and potassium on seed viability and yield of soybean. The experiment was layout in Split Plot Design with three replications. The summary and conclusion of this study have been presented below:

5.1. Summary

5.1.1. Varietal performance

The tallest plant (52.18 cm) was recorded from V_1 (BARI Soybean 6), which was statistically similar (51.16 cm) with V_2 (Bina soybean 1).

The highest number of leaves (13.80 leaves) was recorded from V_1 (BARI Soybean 6), which was statistically similar (13.28 leaves) with V_2 (Bina soybean 1).

The lowest time for 1st flowering (30.88 days) was recorded from V_1 (BARI Soybean 6), which was statistically similar (31.81 days) with V_2 (Bina soybean 1).

The highest number of pods (49.88 pods) was recorded from V_1 (BARI Soybean 6), whereas the lowest number of pods (45.01 pods) was recorded from V_2 (Bina soybean 1).

The highest pod length (3.14 cm) was recorded from V_1 (BARI Soybean 6), whereas the lowest pod length (3.05 cm) was recorded from V_2 (Bina soybean 1).

The highest number of seeds per pod (2.50 seeds) was recorded from V_1 (BARI Soybean 6), whereas the lowest number of seeds per pod (1.75 seeds) was recorded from V_2 (Bina soybean 1).

The lowest time for pod maturity (51.63 days) was recorded from V_1 (BARI Soybean 6), which was statistically similar (51.77 days) with V_2 (Bina soybean 1).

The highest weight of 1000 seeds of soybean (123.5 g) was recorded from V_1 (BARI Soybean 6), whereas the lowest weight of 1000 seeds of soybean (117.6 g) was recorded from V_2 (Bina soybean 1).

The highest seed yield (2.23 t/ha) was recorded from V_1 (BARI Soybean 6), whereas the lowest seed yield (2.06 t/ha) was recorded from V_2 (Bina soybean 1).

The highest stover yield (3.96 t/ha) was recorded from V_1 (BARI Soybean 6), whereas the lowest stover yield (3.79 t/ha) was recorded from V_2 (Bina soybean 1).

The highest biological yield (6.19 t/ha) was recorded from V_1 (BARI Soybean 6), whereas the lowest biological yield (5.85 t/ha) was recorded from V_2 (Bina soybean 1).

The highest harvest index (35.90 %) was recorded from V_1 (BARI Soybean 6), whereas the lowest harvest index (35.10 %) was recorded from V_2 (Bina soybean 1).

V_1 (BARI Soybean 6) showed the best performance (71.88 %) at seed viability, whereas the lowest performance was showed (67.85 %) by V_2 (Bina soybean 1).

V_1 (BARI Soybean 6) showed the best performance (85.00 %) at seed germination, whereas the lowest performance was showed (82.32 %) by V_2 (Bina soybean 1).

5.1.2. Effect of fertilizer management

The tallest plant (54.60 cm) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the shortest plant (49.50 cm) was observed from T_0 (Control) treatment.

The highest number of leaves (15.22 leaves) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the lowest number of leaves (11.89 leaves) was observed from T_0 (Control) treatment.

The lowest time for 1st flowering (28.50 days) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the highest time for 1st flowering (34.50 days) was observed from T_0 (Control) treatment.

The highest number of pods (61.50 pods) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the lowest number of pods (31.50 pods) was observed from T_0 (Control) treatment.

The highest pod length (3.36 cm) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the lowest pod length (2.84 cm) was observed from T_0 (Control) treatment.

The highest number of seeds per pod (3.50 seeds) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the lowest number of seeds per pod (1.00 seed) was observed from T_0 (Control) treatment.

The lowest time for pod maturity (49.50 days) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the highest time for pod maturity (54.00 days) was observed from T_0 (Control) treatment.

The highest weight of 1000 seeds of soybean (137.9 g) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the lowest weight (93.00 g) was observed from T_0 (Control) treatment.

The highest seed yield (2.55 t/ha) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the lowest seed yield (1.67 t/ha) was observed from T_0 (Control) treatment.

The highest stover yield (4.41 t/ha) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the lowest stover yield (3.26 t/ha) was observed from T_0 (Control) treatment.

The highest biological yield (6.96 t/ha) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the lowest biological yield (4.95 t/ha) was observed from T_0 (Control) treatment.

The highest harvest index (36.65 %) was found from T_5 (Biochar + 70 kg/ha K) which was statistically different from others, while the lowest harvest index (33.74 %) was observed from T_0 (Control) treatment.

The highest seed viability (78.50 %) was found from T_5 (Biochar + 70 kg/ha K), while the lowest seed viability (65.00 %) was observed from T_0 (Control) treatment.

The highest seed germination (93.00 %) was found from T_5 (Biochar + 70 kg/ha K), while the lowest seed germination (76.50 %) was observed from T_0 (Control) treatment in laboratory condition.

5.1.3. Combined effect of varieties and fertilizer management

The tallest plant (55.89 cm) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K). On the other hand the lowest plant height (48.89 cm) was recorded from V_2T_0 (Bina soybean 1 with control).

The highest number of leaves (15.47 leaves) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K). On the other hand the lowest number of leaves (11.67 leaves) was recorded from V_2T_0 (Bina soybean 1 with control).

The lowest time for 1st flowering (28.00 days) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K). On the other hand the highest time for 1st flowering (36.00 days) was recorded from V_2T_0 (Bina soybean 1 with control).

The highest number of pods (66.00 pods) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K). On the other hand the lowest number of pods (28.00 pods) was recorded from V_2T_0 (Bina soybean 1 with control).

The highest pod length (3.45 cm) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K). On the other hand the lowest pod length (2.73 cm) was recorded from V_2T_0 (Bina soybean 1 with control).

The highest number of seeds per plot (4.00 seeds) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K). On the other hand the lowest number of seeds per pod (1.00 seed) was recorded from V_2T_0 (Bina soybean 1 with control).

The lowest time for pod maturity (49.00 days) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K). On the other hand the highest time for pod maturity (55.00 days) was recorded from V_2T_0 (Bina soybean 1 with control).

The highest weight of 1000 seeds of soybean (138.80 g) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K). On the other hand the lowest weight (89.30 g) was recorded from V_2T_0 (Bina soybean 1 with control).

The highest seed yield (2.63 t/ha) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K). On the other hand the lowest seed yield (1.63 t/ha) was recorded from V_2T_0 (Bina soybean 1 with control).

The highest stover yield (4.49 t/ha) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K). On the other hand the lowest stover yield (3.13 t/ha) was recorded from V_2T_0 (Bina soybean 1 with control).

The highest biological yield (7.12 t/ha) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K). On the other hand the lowest biological yield (4.76 t/ha) was recorded from V_2T_0 (Bina soybean 1 with control).

The highest harvest index (37.62 %) was recorded from V_1T_3 (BARI Soybean 6 with Trichoderma + 90 kg/ha K). On the other hand the lowest harvest index (33.40 %) was recorded from V_1T_7 (BARI Soybean 6 with recommended dose of fertilizer).

The highest seed viability (84.00 %) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K). On the other hand the lowest seed viability (63.00 %) was recorded from V_2T_0 (Bina soybean 1 with control).

The highest seed germination (94.00 %) was recorded from V_1T_5 (BARI Soybean 6 with Biochar + 70 kg/ha K). On the other hand the lowest seed germination (74.00 %) was recorded from V_2T_0 (Bina soybean 1 with control).

5.2. Conclusion

From this above discussion it can be concluded that, organic fertilizer with potassium fertilizer influenced soybean growth, yield and seed quality. Although different varieties have their own characteristics, the combination varieties and organic fertilizer showed the positive response. The combined effect of BARI Soybean 6 with Biochar + 70 kg/ha K showed the best performance in case of increasing soybean growth, yield and seed quality compared to other treatments.

CHAPTER VI

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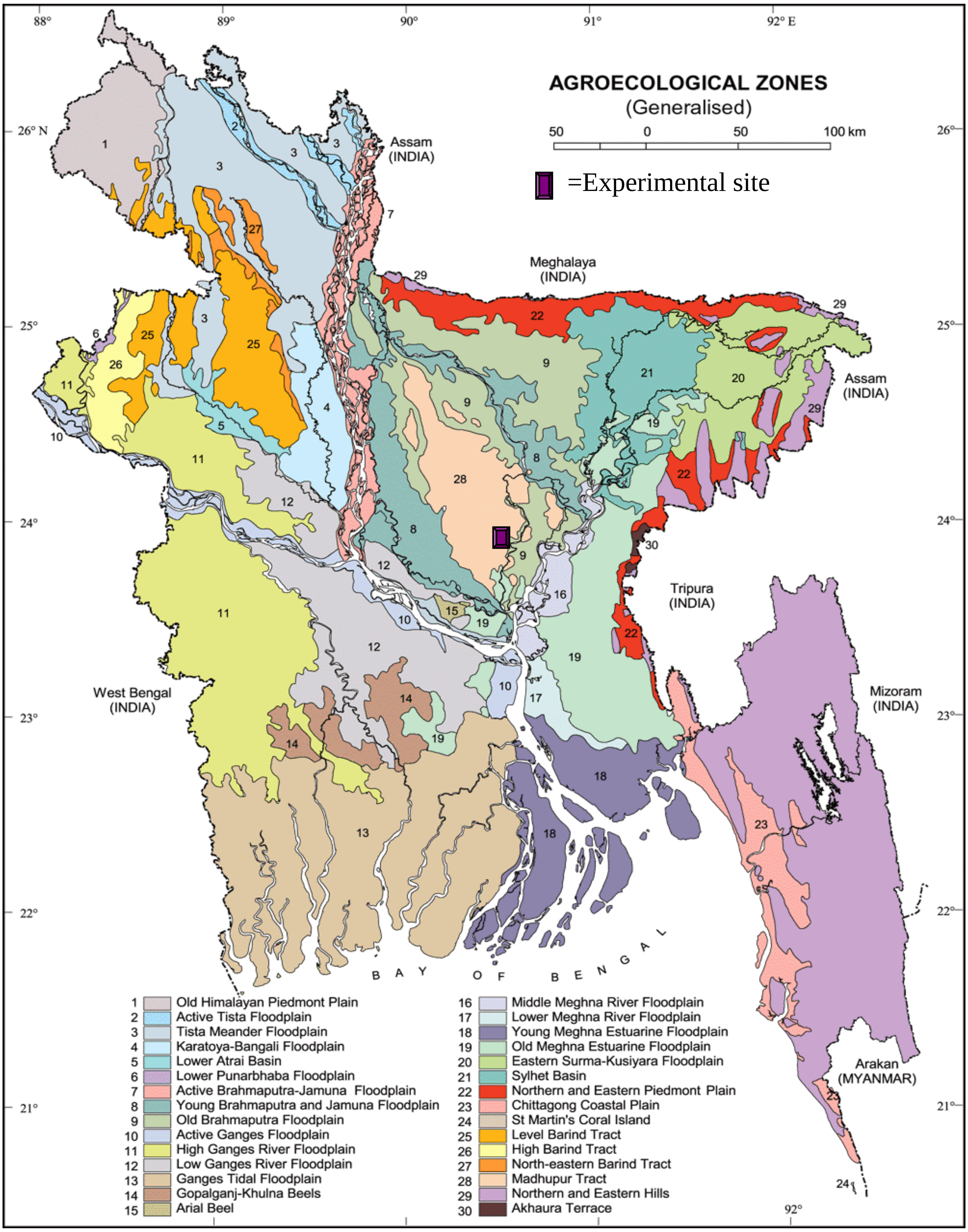
CHAPTER VII

APPENDIXES

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



Appendix II. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0-15 cm depth)

Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical composition:

Soil characters	Value
Organic carbon (%)	0.45
Organic matter (%)	0.54
Total nitrogen (%)	0.027
Phosphorus	6.3 µg/g soil
Sulphur	8.42 µg/g soil
Magnesium	1.17 meq/100 g soil
Boron	0.88 µg/g soil
Copper	1.64 µg/g soil
Zinc	1.54 µg/g soil
Potassium	0.10 meg/100g soil

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

Appendix III: Analysis of variance of the data on plant height of soybean as influenced by varieties and fertilizer management

Source of variance	Degrees of freedom	Mean square
Replication	2	761.107
Factor A	1	12.485
Error	2	80.632
Factor B	7	19.14
A×B	7	1.056
Error	28	3.043

Appendix IV: Analysis of variance of the data on number of leaves of soybean as influenced by varieties and fertilizer management

Source of variance	Degrees of freedom	Mean square
Replication	2	52.638
Factor A	1	3.178
Error	2	5.859
Factor B	7	10.428
A×B	7	0.098
Error	28	0.242

Appendix V: Analysis of variance of the data on timing of 1st flowering of soybean as influenced by varieties and fertilizer management

Source of variance	Degrees of freedom	Mean square
Replication	2	273.914
Factor A	1	10.547
Error	2	25.514
Factor B	7	29.029
A×B	7	1.761
Error	28	1.155

Appendix VI: Analysis of variance of the data on number of pod plant^{-1} of soybean as influenced by varieties and fertilizer management

Source of variance	Degrees of freedom	Mean square
Replication	2	664.068
Factor A	1	283.97
Error	2	86.646
Factor B	7	803.193
A×B	7	21.541
Error	28	5.844

Appendix VII: Analysis of variance of the data on pod length of soybean as influenced by varieties and fertilizer management

Source of variance	Degrees of freedom	Mean square
Replication	2	2.743
Factor A	1	0.096
Error	2	0.29
Factor B	7	0.239
A×B	7	0.017
Error	28	0.012

Appendix VIII: Analysis of variance of the data on seeds pod^{-1} of soybean as influenced by varieties and fertilizer management

Source of variance	Degrees of freedom	Mean square
Replication	2	1.41
Factor A	1	6.825
Error	2	0.316
Factor B	7	3.739
A×B	7	0.325
Error	28	0.022

Appendix IX: Analysis of variance of the data on pod maturity of soybean as influenced by varieties and fertilizer management

Source of variance	Degrees of freedom	Mean square
Replication	2	753.535
Factor A	1	0.255
Error	2	75.288
Factor B	7	14.809
A×B	7	3.398
Error	28	2.933

Appendix X: Analysis of variance of the data on 1000 seed weight of soybean as influenced by varieties and fertilizer management

Source of variance	Degrees of freedom	Mean square
Replication	2	4189.402
Factor A	1	422.631
Error	2	473.904
Factor B	7	2037.512
A×B	7	58.923
Error	28	21.863

Appendix XI: Analysis of variance of the data on seed yield of soybean as influenced by varieties and fertilizer management

Source of variance	Degrees of freedom	Mean square
Replication	2	1.34
Factor A	1	0.342
Error	2	0.324
Factor B	7	4.363
A×B	7	0.065
Error	28	0.207

Appendix XII: Analysis of variance of the data on stover yield of soybean as influenced by varieties and fertilizer management

Source of variance	Degrees of freedom	Mean square
Replication	2	4.301
Factor A	1	0.33
Error	2	0.457
Factor B	7	1.265
A×B	7	0.029
Error	28	0.022

Appendix XIII: Analysis of variance of the data on biological yield of soybean as influenced by varieties and fertilizer management

Source of variance	Degrees of freedom	Mean square
Replication	2	10.418
Factor A	1	1.347
Error	2	1.161
Factor B	7	3.633
A×B	7	0.051
Error	28	0.054

Appendix XIV: Analysis of variance of the data on harvest index of soybean as influenced by varieties and fertilizer management

Source of variance	Degrees of freedom	Mean square
Replication	2	0.002
Factor A	1	7.752
Error	2	0.014
Factor B	7	5.567
A×B	7	1.306
Error	28	0.004

Appendix XV: Analysis of variance of the data on seed viability of soybean as influenced by varieties and fertilizer management

Source of variance	Degrees of freedom	Mean square
Replication	2	1414.296
Factor A	1	194.206
Error	2	165.67
Factor B	7	148.744
A×B	7	27.399
Error	28	6.764

Appendix XVI: Analysis of variance of the data on seed germination of soybean as influenced by varieties and fertilizer management

Source of variance	Degrees of freedom	Mean square
Replication	2	2004.794
Factor A	1	86.135
Error	2	219.136
Factor B	7	227.507
A×B	7	9.821
Error	28	8.625