EFFECT OF POTASSIUM ON NODULATION, GROWTH AND YIELD OF SOYBEAN

BY

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF POTASSIUM ON NODULATION, GROWTH AND YIELD OF SOYBEAN"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of ***MASTER OF SOIL SCIENCE*** embodies the result of a piece of bona fide research work carried out by ***SUMONA SUTRA DHAR*****, Registration No**. **18-09140** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

Dated:
Dhaka, Bangladesh.

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Dedicated

To

My Beloved

Parents

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SAU, Dhaka ***The Author***

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ABSTRACT

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from December, 2019 to March 2020 to study the effect of potassium on the nodulation, growth and yield of soybean. The experiment comprised of seven levels of potassium - T_0- 0 kg K ha^{-1} (control), T_1- 20 kg K ha^{-1}, T_2- 40 kg K ha^{-1}, T_3- 60 kg K ha^{-1}, T_4- 80 kg K ha^{-1}, T_5- 100 kg K ha^{-1}, T_6- 120 kg K ha^{-1}. The single factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. For K fertilizer, the maximum number of nodules (8.0) was found from T_4 (80 kg K ha^{-1}) treatment, while the minimum number of nodules (2.0) was found from T_0 (0 kg K ha^{-1}) treatment. The highest growth rates were found from T_4 (80 kg K ha^{-1}) treatment and lowest growth rates were found from T_1 (20 kg K ha^{-1}) treatment and T_0 (0 kg K ha^{-1}) treatment respectively. The highest seed yield (2.63 t ha-1) was observed from T_4 (80 kg K ha^{-1}) treatment and the lowest seed yield (0.9 t ha-1) was observed from T_0 (0 kg K ha^{-1}) treatment. The highest stover yield (4.00 t ha^{-1}) was found from T_5 (100 kg K ha^{-1}) treatment whereas the lowest stover yield (2.06 t ha-1) from T_0 (0 kg K ha^{-1}) treatment. The maximum harvest index (46.26%) was observed from T_4 (80 kg K ha^{-1}) treatment and the minimum (43.18%) from T_6 (120 kg K ha^{-1}) treatment. Application of 80 kg K ha^{-1} can be more beneficial for the farmers to get maximum yield and as well as economic return from the cultivation of soybean.

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ABBREVIATIONS AND ACCORONYMS

AEZ	=	Agro-ecological Zone
Agric	=	Agriculture
BAU	=	Bangladesh Agricultural University
Biol.	=	Biology
BSRI	=	Bangladesh Sugarcrop Research Institute
cm	=	Centimetre
cm^2	=	Square centimetre
CV%	=	Percent Co-efficient of Variation
DAS	=	Days after Sowing
Df	=	Degree of freedom
et al.	=	And others
etc.	=	Etcetera
g	=	Gram
i.e.	=	That is
j.	=	Journal
Kg	=	Kilogram
LSD	=	Least Significant Difference
MSS	=	Mean sum square
M. S.	=	Master of Science
m^2	=	Square meter
nm	=	nano meter
RCBD	=	Randomized Completely Block Design
R.H	=	Relative humidity
Res.	=	Research
SAU	=	Sher-e-Bangla Agricultural University
Sci.	=	Science
SRDI	=	Soil Resources Development Institute
SPAD	=	Soil-plant-Analysis Development
^0c	=	Degree Celsius
WUE	=	Water Use Efficiency

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Soybean (Glycine max L.) is a major oil and protein content crop which belongs to the family leguminosae, sub-family papilionidae. Present world production is about 176.6 million tons of beans over 75.5 million ha. Soybean is mainly grown under rainfed conditions but irrigation, specifically supplemental irrigation, is increasingly used (FAOSTAT, 2001). It has been classified more as an oil seed crop than as a pulse (Devi *et al*., 2012). The crop is grown under warm conditions in the tropics, subtropics and temperate climates. Soybean is relatively resistant to low and very high temperatures but growth rates decrease above 35°C and below 18°C. In some varieties, flowering may be delayed at temperatures below 24°C. Minimum temperatures for growth are about 10°C and for crop production about 15°C. Only 25 to 30 percent of the flowers produce set pods, the final number depending on the plant vigor during the flowering period. Year to year temperature variations can lead to differences in flowering (FAO, 2020).

It is also recognized as an important grain legume of the world and a new prospective crop for Bangladesh (Rahman *et al*., 2011). Bangladesh has to import 1.8 million tonnes of soybean cooking oil in each year at the cost of more than 1.5 billion USD and soybean meal with about 25.51 million USD per year (Quaiyum *et al*., 2015). Soybean area and production levels for marketing year (MY) 2018/19 -July to June) in Bangladesh are projected to increase to 80,000 hectare and 152,000 tonnes respectively, due to a switch from Boro rice production. According to a USDA GAIN report, soybean planting area and production estimates for MY 2017/18 are lowered to 60,000ha and 114,000 tonnes due to unsuitable conditions for planting at the optimal time, and the shift of land to Boro rice cultivation due to probable higher harvest price. Meanwhile, MY 2018/19 soybean and soymeal imports are estimated to increase to 1.1 million tonnes and 550,000 tonnes respectively, to keep pace with demand in the feed industry, as well as growth in the livestock and fisheries sectors (Anon, 2018). The world average yield of soybean is about 3 t ha-1 while it is only 1.2 t ha-1 in Bangladesh (SAIC, 2007). This is mainly due to use of low yield potential varieties and poor agronomic management practices. However, there is a scope for improvement of this yield through judicious application of chemical fertilizers. It is reported that Bangladesh could meet 40 percent of its soybean oil demand by producing soybean locally (Anon, 2009).

Soybean is the second largest crop in cash sales. The majority of soybean crops are processed for oil and meal, and soybean is the only plant food that contains complete protein that provides all essential amino acids required for human health. Soybean is also a good source of protein, unsaturated fatty acids, minerals like Ca and P including vitamin A, B, C and D (Rahman, 1982). It seeds contain 42-45% protein and 20-22% edible oil (Wahhab *et al*, 2001), 24-26% carbohydrate (Gowda and Kaul, 1982) and 3.3-6.4% ash (Purseglove, 1984). Polyunsaturated fatty acids in diet have been shown to actively lower serum cholesterol levels (Hegstad, 2008). As a grain legume crop it is gaining an important position in the agriculture of tropical countries including India, Sri Lanka, Thailand and Bangladesh. Besides, it also contains various vitamins and minerals. It provides around 60% of the world supply of vegetable protein and 30% of the oil (Fehr *et al.*, 1989). Furthermore, soybean oil is cholesterol free and is easily acceptable in our daily diet. On an average, about 8-10% of the protein intake in Bangladesh diet originates from animal sources (Begum, 1989) and the rest can be met from plant sources especially from the pulse crops like soybean. Soybean is originating from the hot areas of South-East Asia, but more than 50% of its production today comes from the United States and South America (James *et al*., 1999).

Yield of soybean is very low in Bangladesh and such low yield however is not an indication of low yielding potentiality of this crop, but may be qualified to a number of reasons, viz., unavailability of seeds of high yielding varieties with indicative quality, delayed sowing, fertilizer management, disease and insect infestation, modern cultivation and improper or limited irrigation facilities.

There are 17 essential elements, among them some elements required in relatively high amounts, are called macronutrients and some in trace amounts are called micronutrients. Potassium (K) play an important role in increasing yield of pulses and oilseed legumes and if it is lacking in the soil or not adequately balanced, growth suppression or even complete inhibition may result (Mengel *et al.*, 2001). Micronutrients are involved in the key physiological processes of photosynthesis and respiration and their deficiency can also impede vital physiological processes thus limiting yield (Marschner, 1995).

Potassium is an essential nutrient involved in regulating water balance (Mehdi *et al.*, 2007) and enhancing water uptake. Potassium is involved in nearly all processes needed to sustain plant life besides its role in conferring pest and disease resistance. Soybean crop takes up and removes large amounts of K from soil than any other nutrient (Tiwari *et al.*, 2001). Potassium application have shown to increase the number of pods as well as used a beneficial influence on retaining pods until harvest in soybean (Coale and Grove, 1990). Fertilizer of K can be either applied to soil or as foliar spray to plants. Soil application is the standard form of application and has its own advantages unless soil pH and other factors affect the movement and uptake from soil to the plants. Foliar application can rapidly help plants to recover from stress due to drought, high heat, pests and diseases.

Potassium serves as an activator of enzymes used in photosynthesis and respiration, helps to build cellulose and aids in photosynthesis by the formation of a chlorophyll precursor and finally results in quality fruits (Nziguheba *et al.*, 1998). The relatively large amounts of K is required for high yielding soybean. Soybean has been found to respond to various level of K under different agroclimatic-situations (Silva and Bohnen, 1991). The deficiency of K at any time during the growing season of soybean reduced its pod yields; whereas, application of K fertilizers increased the number of nodules, and weight of nodules, and the number of pods plant-1 (Jhones *et al*., 1977).

Considering the above all situation a study was conducted with different levels of potassium on soybean with the following objectives:

1. To observe the effect of K on the growth and yield of Soybean.

2. To find out the suitable doses of K for maximum nodulation, growth and yield of Soybean.

Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Soybean is a well-known oil and protein containing crop which has received less attention by the local researchers on various aspects of production technology. However, researches in home and abroad trying to maximize the yield of soybean with different management practices especially on NPK fertilizer, spacing, variety, weeding, bio-fertilizers etc., but not other macro and micro nutrients. Potassium play an important role in improving soybean growth, nodulation, quality and yield. But research works related to K is limited in Bangladesh context. However, some of the important and informative works and research findings related to the K up to now been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Effect of K on plant growth of soybean

Khanam *et al.* (2016) was conducted a field experiment at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh to evaluate the effect of phosphorus (P_0: 0 kg TSP ha^{-1}, P_1: 100 kg TSP ha^{-1}, P_2: 175 kg TSP ha^{-1}, P_3: 250 kg TSP ha^{-1}) and potassium (K_0: 0 kg MoP ha^{-1}, K_1: 60 kg MoP ha^{-1}, K_2: 120 kg MoP ha^{-1}, K_3: 180 kg MoP ha^{-1}), and their combinations on growth of soybean (*Glycine max*). Numbers of nodules plant^{-1}, number of filled pods plant^{-1}, length of pod, number of seeds pod^{-1}, were enhanced significantly up to 120 kg ha^{-1} MoP. The treatment of combined phosphorus @ 175 kg ha^{-1} and potassium @ 120 kg MoP ha^{-1} depicted the highest number of filled pods plant^{-1} (63.00), length of pod (3.16 cm).

The experiment was conducted by Ansary (2014) at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh to study the effect of potassium and molybdenum on the growth of BARI soybean 5. The experiment comprised the four levels of potassium - K_0: 0 kg K_2O ha^{-1} (control); K_1: 30 kg K_2O ha^{-1}, K_2: 40 kg K_2O ha^{-1}, K_3: 50 kg K_2O ha^{-1}. Application of 40 kg K_2O ha^{-1} can be more beneficial for the farmers to get highest growth rate as well as economic return from the cultivation of BARI soybean 5.

Xiang *et al*. (2012) observed a field experiment to determine the effect of Phosphorus (P) application and Potassium (K) application (0, 37.5, 75.0 and 112.5 kg ha^{-1}) on growth of soybean (*Glycine max* (L.) Merr.) and found that by applying K from 0 to 112.5 kg K ha^{-1}, plant height, lodging rate, unfilled pod ratio and 100 seeds weight were significantly reduced, even though pods per plant, seeds per pod, and harvest index remarkably increased.

Farhad *et al*. (2010) concluded a field experiment at the Sher-e-Bangla Agricultural University Farm, Dhaka 1207 during the period from December 2008 to April 2009 to study the role of potassium and sulphur on the growth of soybean (*Glycine max* var. BARI Soybean-5). The experimental soil was clay loam in texture having pH of 6.3. The experiment included four levels of potassium viz. 0, 20, 40 and 70 kg K ha^{-1} and four levels of sulphur viz. 0, 10, 20 and 40 kg S ha^{-1}. Application of potassium @ 40 kg ha^{-1} produced the highest plant height.

Nita *et al.* (2002) carried out a field experiment during the summer of 1998-99 study the effect of K at 0, 20 and 40 kg ha^{-1} on the growth and productive attributes of soybean in West Bengal, India. They reported that leaf area index, plant height, nodule $plant^{-1}$, nodule dry weight, pods $plant^{-1}$, seed yield, harvest index and net production value increased with increasing rates of potassium.

Sangakkara *et al*. (2001) carried out a field experiment to determine the benefits of potassium in overcoming water stress in soybean. They found that potassium increased shoot growth, root growth and as a significant factor in overcoming soils moisture stress in tropical cropping systems.

Gurkirpal and Singh (2001) conducted a field experiment during the Kharif season in Punjab, India, to evaluate the response of soybean to the application of K (30 and 60 kg K ha^{-1}). The growth attributes of soybean significantly increased with the application of the fertilizers. The highest number of pods plant^{-1} were obtained at 60 kg K_2O.

Chawdhury and Mohamood (1999) laid out a field experiment to study the effect of optimum potassium levels on growth of soybean and reported that 50 kg K_2O gave the highest growth rate and the optimum level of K_2O was between 50 to 100 kg ha^{-1}.

Sangakkara (1990) carried out a field experiment to study the effects of 0-120 kg K_2O ha^{-1} on growth of soybean and reported that K application increased plant growth rate, flowers plant^{-1}, percentage pod set.

Sardana and Verma (1987) made a field trial in Delhi. India, with application of potassium fertilizers and reported that plant height, leaf surface area, number and length of pods were significantly increased.

2.2 Effect of K on nodulation of soybean

Khanam *et al.* (2016) was conducted a field experiment at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh to evaluate the effect of phosphorus (P_0: 0 kg TSP ha^{-1}, P_1: 100 kg TSP ha^{-1}, P_2: 175 kg TSP ha^{-1}, P_3: 250 kg TSP ha^{-1}) and potassium (K_0: 0 kg MoP ha^{-1}, K_1: 60 kg MoP ha^{-1}, K_2: 120 kg MoP ha^{-1}, K_3: 180 kg MoP ha^{-1}), and their combinations on growth and yield of soybean (*Glycine max*). Numbers of nodules plant^{-1}, number of filled pods plant^{-1}, length of pod, number of seeds pod^{-1}, 1000-seed weight, seed yield, stover yield and biological yield were enhanced significantly up to 120 kg ha^{-1} MoP.

Nita *et al.* (2002) carried out a field experiment during the summer of 1998-99 study the effect of K at 0, 20 and 40 kg ha^{-1} on the growth and productive attributes of soybean in West Bengal, India. They reported that leaf area index, plant height, nodule plant^{-1}, nodule dry weight, pods plant^{-1}, seed yield, harvest index and net production value increased with increasing rates of potassium.

Jones *et al.* (1977) investigated an experiment about effects of Phosphorus and Potassium on Soybean Nodules and Seed Yield. The purpose of this investigation was to determine under field conditions the effects of P and K fertilization on number and weight of soybean nodules; the chemical composition of leaves, nodules, and seed; the number of pods per plant; and seed yield. Annual P rates of 0, 15, 30, and 60 kg/ha were applied with 0 and 112 kg K/ha in one field experiment. In another, annual K rates of 0, 28, 56, and 112 kg/ha were applied with 0 and 60 kg P/ha. Either P or K applied alone increased the number of nodules per plant and per unit volume of soil. Applied K increased the number of nodules, total and individual weight of nodules, and the number of pods per plant more than P, but increases were largest when both P and K were applied. These experiment showed that application of both P and K individually increased nodulation and pod formation with more response from K than P.

2.3 Effect of K on yield attributing characters of soybean

Khanam *et al.* (2016) was conducted a field experiment at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh to evaluate the effect of phosphorus (P_0: 0 kg TSP ha^{-1}, P_1: 100 kg TSP ha^{-1}, P_2: 175 kg TSP ha^{-1}, P_3: 250 kg TSP ha^{-1}) and potassium (K_0: 0 kg MoP ha^{-1}, K_1: 60 kg MoP ha^{-1}, K_2: 120 kg MoP ha^{-1}, K_3: 180 kg MoP ha^{-1}), and their combinations on yield of soybean (*Glycine max*). The treatment of combined phosphorus @ 175 kg ha^{-1} and potassium @ 120 kg MoP ha^{-1} depicted the highest number of filled pods plant-1 (63.00), length of pod (3.16 cm), number of seeds pod^{-1} (3.11) vis a vis the highest (3.67 t ha^{-1}) seed yield. Thus, the combined application of 175 kg ha^{-1} TSP and 120 kg ha^{-1} MoP could be the optimum for getting maximum yield of soybean.

Semina *et al*. (2014) observed and experiment to study aimed to evaluate the production of soybean seeds (cv. Monsoy 9350) in Piaui Cerrado under the influence of times and doses of potassium and the treatments consisted of the combination of five doses of potassium (30, 60, 90, 120 and 150 kg K_2O ha^{-1}) with additional treatment (zero kg ha^{-1}). The yield and harvest index of grain, thousand seed weight, seedling length, seedling dry weight, rate of germination,

germination and first count. Not including the germination and germination speed index, all other parameters were significantly influenced by K rates. The length and seedling dry weight increased with the increasing use of K and showing greater seed vigor. Doses of 80 to 95 kg ha^{-1} K_2O provide the best results for all parameters evaluated.

Xiang *et al*. (2012) observed a field experiment to determine the effect of Phosphorus (P) application and Potassium (K) application (0, 37.5, 75.0 and 112.5 kg ha^{-1}) on growth and yield of soybean (*Glycine max* (L.) Merr.) and found that by applying K from 0 to 112.5 kg K ha^{-1}, plant height, lodging rate, unfilled pod ratio and 100 seeds weight were significantly reduced, even though pods per plant, seeds per pod, and harvest index remarkably increased.

Habibzadeh *et al.* (2004) conducted a field experiment during the 2001 summer season in Mazandaran on the yield and yield components of soybean cv. BP 692. The treatments comprised: 0, 75, 150 and 225 kg K ha^{-1}; The K fertilizer rates had significant effect on yield, number of pods $plant^{-1}$ and 1000-seed weight. The highest yield (2962.5 kg ha^{-1}) and 1000-seed weight (146.6 g) were obtained with 225 kg K ha^{-1}.

Menaria *et al.* (2004) conducted a field experiment during at Udaipur, Rajasthan, India to study the effect of chemical fertilizer K on the yield attributes and both seed and stover yields of soybean. Application of 40 kg K ha^{-1} significantly increased all yield attributes and both seed and stover yields.

Nita *et al.* (2002) carried out a field experiment during the summer of 1998-99 study the effect of K at 0, 20 and 40 kg ha^{-1} on the productive attributes of soybean in West Bengal, India. They reported that pods $plant^{-1}$, seed yield, harvest index and net production value increased with increasing rates of potassium.

Gurkirpal and Singh (2001) conducted a field experiment during the Kharif season in Punjab, India, to evaluate the response of soybean to the application of K (30 and 60 kg K ha^{-1}). The grain yield of soybean significantly increased with the application of the fertilizers. The highest number of pods plant^{-1}, seed yield and 100-seed weight were obtained at 60 kg K_2O.

Asghar *et al.* (1996) conducted a field experiment to study the influence of various doses of potassium on yield of soybean. They reported that the number of pods plant^{-1}, number of seeds pod^{-1}, seed yield ha^{-1} were influence significantly by potassium application and the highest seed yield (1.67 t ha^{-1}) was obtained with application of 75 kg K_2O ha^{-1}.

Dinata *et al*. (1992) studied the effect of 0, 12.5, 25, 37.5, 50 and 75 kg K_2O ha^{-1} and reported that application of potassium significantly increased the entire yield contributing characters, grain yield and dry matter with increasing levels of potassium.

Sangakkara (1990) carried out a field experiment to study the effects of 0-120 kg K_2Oha^{-1} on yield parameters of soybean and reported that K application increased plant growth rate, flowers plant^{-1}, percentage pod set, seeds pod^{-1}, 100-seed weight and yield plant^{-1}.

Sardana and Verma (1987) made a field trial in Delhi. India, with application of potassium fertilizers and reported that 100-grain weight and yield of green gram were significantly increased.

2.4 Effect of K on yield of soybean

A field experiment conducted Khanam *et al.* (2016) to evaluate the effect of phosphorus (P_0: 0 kg TSP ha^{-1}, P_1: 100 kg TSP ha^{-1}, P_2: 175 kg TSP ha^{-1}, P_3: 250 kg TSP ha^{-1}) and potassium (K_0: 0 kg MoP ha^{-1}, K_1: 60 kg MoP ha^{-1}, K_2: 120 kg MoP ha^{-1}, K_3: 180 kg MoP ha^{-1}), and their combinations on quality of soybean (*Glycine max*). Numbers of nodules plant^{-1}, number of filled pods plant^{-1}, length of pod, number of seeds pod^{-1}, 1000-seed weight, seed yield, stover yield and biological yield were enhanced significantly up to 120 kg ha^{-1} MoP. Thus, the combined application of 175 kg ha^{-1} TSP and 120 kg ha^{-1} MoP could be the optimum for getting maximum yield of soybean.

Ansary (2014) was conducted the field experiment to study the effect of potassium and molybdenum on the oil content of BARI soybean 5. The experiment comprised the four levels of potassium - K_0: 0 kg K_2O ha^{-1} (control); K_1: 30 kg K_2O ha^{-1}, K_2: 40 kg K_2O ha^{-1}, K_3: 50 kg K_2O ha^{-1}. For potassium fertilizer, the highest oil content (26.15%) was observed from K_2 (40 kg K_2O ha^{-1}) and the lowest oil content (16.64%) from K_0. The maximum concentration in seed for N (2.39%), P (0.506%), K (1.005%), S (0.507%) and Mo (0.086%) was found from K_2, while the minimum (1.57%), P (0.238%), K (0.382%), S (0.189%) and Mo (0.066%) was found from K_0. Application of 40 kg K_2O ha^{-1} can be more beneficial for the farmers from the cultivation of BARI soybean 5.

Batistella *et al*. (2013) were carried out the experiments in two growing seasons with five levels of phosphorus (0, 40, 80, 120, and 160 kg ha^{-1} P_2O_5 as triple superphosphate), three of potassium (0, 50, and 100 kg ha^{-1} K_2O as potassium chloride) and reported that potassium fertilization do not influence yield or K concentration in the seeds. However it may improve germination without interfering in vigor.

Xiang *et al*. (2012) observed a field experiment to determine the effect of Phosphorus (P) application and Potassium (K) application (0, 37.5, 75.0 and 112.5 kg ha^{-1}) on quality of soybean (*Glycine max* (L.) Merr.) and found that by applying K from 0 to 112.5 kg K ha^{-1}, plant height, lodging rate, unfilled pod ratio and 100 seeds weight were significantly reduced, even though pods per plant, seeds per pod, and harvest index remarkably increased.

Farhad *et al*. (2010) concluded a field experiment at the Sher-e-Bangla Agricultural University Farm, Dhaka 1207 during the period from December 2008 to April 2009 to study the role of potassium and sulphur on oil content of soybean (*Glycine max* var. BARI Soybean-5). The experimental soil was clay loam in texture having pH of 6.3. The experiment included four levels of potassium viz. 0, 20, 40 and 70 kg K ha^{-1} and four levels of sulphur viz. 0, 10, 20 and 40 kg S ha^{-1}. Potassium showed significant effect on quality attributes of soybean. Application of potassium @ 40 kg ha^{-1} produced the highest pod length, seed yield, 1000-seed weight and straw yield.

Habibzadeh *et al.* (2004) conducted a field experiment during the 2001 summer season in Mazandaran on the yield and yield components of soybean cv. BP 692. The treatments comprised: 0, 75, 150 and 225 kg K ha^{-1}; The K fertilizer rates had significant effect on yield, number of pods $plant^{-1}$ and 1000-seed weight. The highest yield (2962.5 kg ha^{-1}) and 1000-seed weight (146.6 g) were obtained with 225 kg K ha^{-1}.

Yin and Vyn (2002) conducted a field experiment to evaluate the effects of potassium application rates (0, 42 and 84 kg ha^{-1}) on soybean. They found that average soybean yield significantly increased with the application of 84 kg K ha^{-1}.

Prakash *et al*. (2002) a field experiment in India were evaluated during 2000 to assess the yield response of soybean cv. Bragg. The average yield data for 27 years should that significant response to applied K resulting in 69.9% increased in the yield of soybean.

Wang *et al*. (2002) conducted an experiment to determine the effects of K humate (2000 and 1250 mg kg^{-1}) foliar application on soybean crop yield, the average yield increased by 14.06% (3699.9 kg ha^{-1}) compared to the control.

Mondal *et al.* (2001) conducted field trails of soybean with 3 K rates (0, 33 and 66 kg ha^{-1}) in west Bangle, India during the rainy and summer seasons. They observed that yield of soybean was high with 66 kg ha^{-1} application.

Bansal *et al.* (2001) conducted a field experiment from 1993 to 1996 in 10 fields Sesore, Madhya Pradesh, India to study the effect of K fertilizer on the yield of soybean. Five treatments were tested, consisting of 3 levels of KCl (0, 50 and 100 kg ha^{-1}). They found that K fertilizer rate at 50 kg K ha^{-1} resulted in the highest yield of soybean (25.9 q ha^{-1}).

Gurkirpal and Singh (2001) conducted a field experiment during the Kharif season in Punjab, India, to evaluate the response of soybean to the application of K (30 and 60 kg K ha^{-1}). The growth attributes and grain yield of soybean significantly increased with the application of the fertilizers. The highest number of pods $plant^{-1}$, seed yield and 100-seed weight were obtained at 60 kg K_2O.

Novo and Tanaka *et al.* (2001) studied the effect of K on crop yield of soybean were evaluated in 1991 to 1993 at experimental stations in Mococa, Ribeirao Preto and Botuporanga. Soybeans cv. IAC-8 and IAC-14 were given 0, 30 and 60 kg ha^{-1} and potassium chloride. Potassium application increased the yield of soybean.

Prassad *et al*. (2000) conducted a pot experiment to study the effect of potassium on yield, water used efficiency and K-uptake by summer soybean. They observed that total biomass production, grain yield, water use efficiency and K-uptake significantly increased with 20 and 30 kg K ha^{-1} as compared to other level of potassium.

Chawdhury and Mohamood (1999) laid out a field experiment to study the effect of optimum potassium levels on yield and quality of soybean and reported that 50 kg K_2O gave the highest seed yield (832 kg ha^{-1}) and the optimum level of K_2O was between 50 to 100 kg ha^{-1}.

Costa and Akanda *et al.* (1999) conducted a field experiment in Bangladesh to evaluate the response of 3 cultivars of soybean (Bragg, Davis, Sohag) to 3 levels of K (0, 20 and 40 kg K_2O ha^{-1}), during the rabi season. Application of K_2O up to 40 kg ha^{-1} significantly increased the yield of soybean.

Abd-el-lateef *et al.* (1998) carried out a field experiment with 0 or 24 kg K_2O $feddan^{-1}$ (0.42 ha^{-1}) and observed that seed yield increased by the application of K.

Asghar *et al.* (1996) conducted a field experiment to study the influence of various doses of potassium on yield and quality of soybean. They reported that the number of pods $plant^{-1}$, number of seeds pod^{-1}, seed yield ha^{-1} and seed protein contents were influence significantly by potassium application and the highest seed yield (1.67 t ha^{-1}) was obtained with application of 75 kg K_2O ha^{-1}.

Singh *et al.* (1993) conducted a field experiment to study the response of potassium. The reported that application of potassium improved plant productivity and enhanced the grain yields of green gram significantly. They also reported that response to K_2O was recorded up to 40 kg ha^{-1}.

Dinata *et al*. (1992) studied the effect of 0, 12.5, 25, 37.5, 50 and 75 kg K_2O ha^{-1} and reported that application of potassium significantly increased the entire yield contributing characters, grain yield and dry matter with increasing levels of potassium.

Sangakkara (1990) carried out a field experiment to study the effects of 0-120 kg K_2Oha^{-1} on growth, yield parameters and seed quality of soybean and reported that K application increased plant growth rate, flowers $plant^{-1}$, percentage pod set, seeds pod^{-1}, 100-seed weight and yield $plant^{-1}$.

Sardana and Verma (1987) made a field trial in Delhi. India, with application of potassium fertilizers and reported that plant height, leaf surface area, number and length of pods, 100-grain weight and yield of green gram were significantly increased.

Jones *et al.* (1977) investigated an experiment about effects of Phosphorus and Potassium on Soybean Seed Yield. The purpose of this investigation was to determine under field conditions the effects of P and K fertilization on number and weight of soybean nodules; the chemical composition of leaves, nodules, and seed; the number of pods per plant; and seed yield. Annual P rates of 0, 15, 30, and 60 kg/ha were applied with 0 and 112 kg K/ha in one field experiment. In another, annual K rates of 0, 28, 56, and 112 kg/ha were applied with 0 and 60 kg P/ha. Applied K increased the number of pods per plant more than P, but increases were largest when both P and K were applied. These experiment showed that application of both P and K individually increased pod formation with more response from K than P.

Chapter III

Materials & Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from December, 2019 to April 2020 to study the effect of potassium on the growth, nodulation yield and quality of soybean. This chapter includes materials and methods that were used in conducting the experiment are presented below under the following headings:

3.1 Experimental site

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experimental site is situated between $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude (Anon., 1989).

3.2 Soil

The soil of the experimental site belongs to Tejgaon series under the Agro-ecological zone, Madhupur Tract (AEZ-28), which falls into Deep Red Brown Terrace Soils. Soil samples were collected from the experimental plots to a depth of 0-15 cm from the surface before initiation of the experiment and analyzed in the laboratory. The soil was having a texture of silty clay with pH 5.8. The morphological characteristics of the experimental field and physical and chemical properties of initial soil are given in Appendix II (Khatun, 2014).

3.3 Climate

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix I.

3.4 Planting material

The variety BARI soybean 5 was used as the test crops. The seeds were collected from the Agronomy Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. BARI collected some lines from Taiwan and among the variety 'RANSOM' produced the highest yield in regional trial. In 2002, this line is released as variety BARI soybean 5, which was recommended by the national seed board. The life cycle of this variety ranges from 90-100 days. Maximum seed yield is 1.6-2.0 t ha^{-1}.

3.5 Land preparation

The land was irrigated before ploughing. After having 'zoe' condition the land was first opened with the tractor drawn disc plough. Ploughed soil was brought into desirable fine tilth by 3 ploughing and cross-ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 2th and 3thDecember, 2019, respectively. Experimental land was divided into unit plots following the design of experiment.

3.6 Treatments of the experiment

The experiment was followed just seven levels of potassium. The treatments were as follows-

i) T_0: 0 kg K ha^{-1} (control)

ii) T_1: 20 kg K ha^{-1}

iii) T_2 : 40 kg K ha^{-1}

iv) T_3 : 60 kg K ha^{-1}

v) T_4 : 80 kg K ha^{-1}

vi) T_5 : 100 kg K ha^{-1}

vii) T_6 : 120 kg K ha^{-1}

3.7 Fertilizer application

Urea, Triple super phosphate (TSP), Muriate of potash (MoP), gypsum and boric acid were used as a source of nitrogen, phosphorous, potassium, sulphur and boron respectively. The fertilizers urea, TSP, sulphur and boric acid were applied following the basal doses of nutrients as N- 25 kg/ha, P- 35 kg/ha, S- 15 kg/ha, Zn- 2 kg/ha, B- 1.0 kg/ha based on low fertility status. All of the fertilizers were applied in broadcast during final land preparation.

3.8 Experimental design and layout

The one factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. An area of 24 m × 8 m was divided into blocks. The size of the each unit plot was 2.5 m × 2 m. The space between two blocks and two plots were 0.5 m and 0.75 m, respectively. The layout of the experiment is shown in Figure 1.

3.9 Sowing of seeds in the field

The seeds of soybean were sown on December 4, 2019 in solid rows in the furrows having a depth of 2-3 cm and row to row distance was 30 cm and plant to plant 5-6 cm.

3.10 Intercultural operations

3.10.1 Thinning

Seeds started germination within four days after sowing (DAS). Thinning was at 25 DAS to maintain optimum plant population in each plot.

3.10.2 Irrigation and weeding

Irrigation was provided two times at 25 DAS and 55 DAS for all experimental plots equally. The crop field was weeded at 25 DAS and 55 DAS.

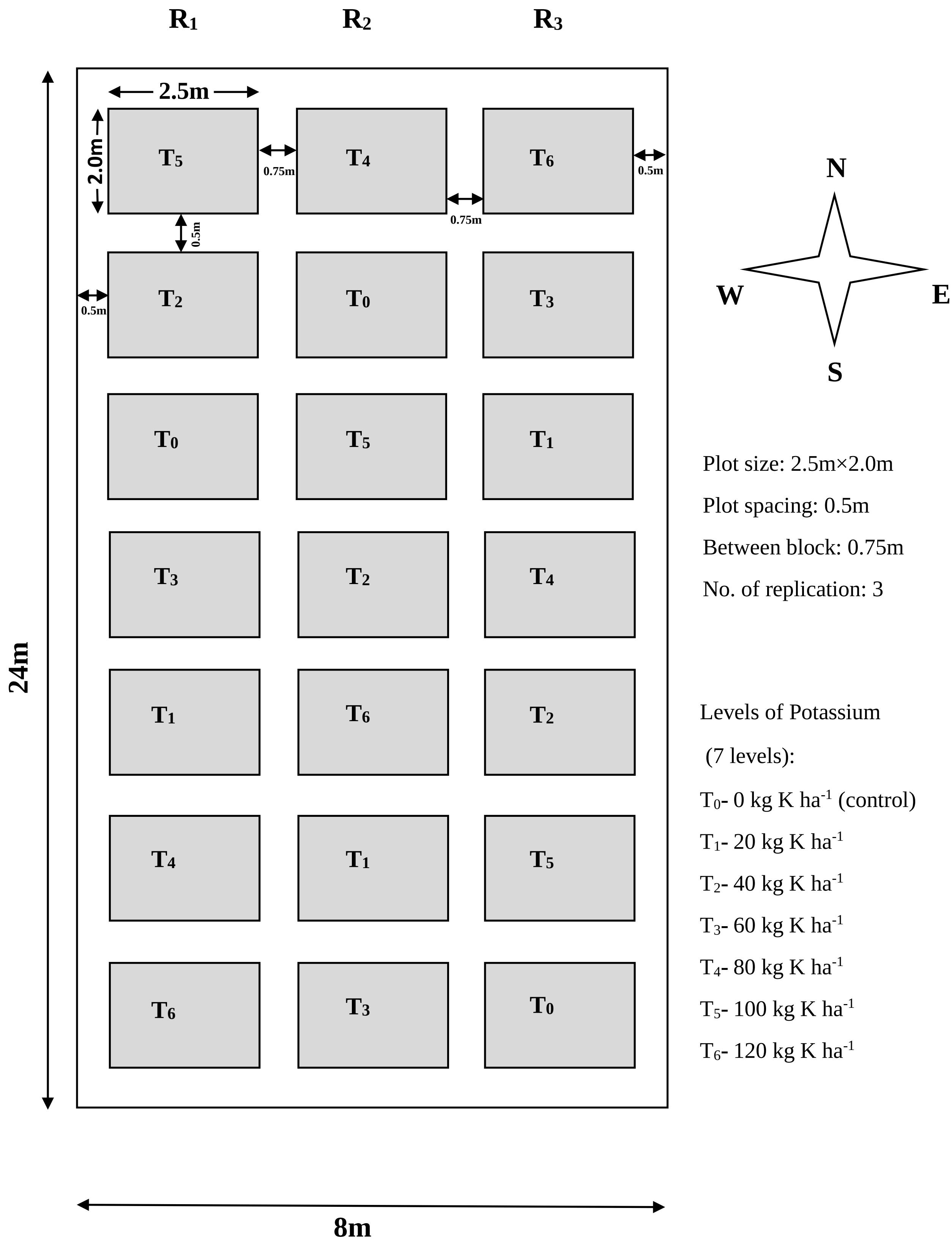

Figure 1. Layout of the experimental plot.

3.10.3 Protection against insect and pest

At early stage of growth few worms (*Agrotis ipsilon*) infested the young plants and at later stage of growth pod borer (*Maruca testulalis*) attacked the plant. Ripcord 10 EC was sprayed at the rate of 1 mm with 1 litre water for two times at 15 days interval after seedlings germination to control the insects.

3.11 Crop sampling and data collection

Five plants from each treatment were randomly selected and marked with sample card. Plant height and number of branches plant^{-1} were recorded from selected plants at an interval of 30 days started from 30 DAS to 60 DAS and at harvest.

3.12 Harvest and post-harvest operations

Harvesting was done when 90% of the pods became brown in color**.** The matured pods were collected by hand picking from the area of 4.2 m^2 of each plot.

3.13 Data collection

The following data were recorded

i. Plant height
ii. Number of leaves plant^{-1}
iii. Days required from sowing to harvest
iv. Number of nodules plant^{-1} at flowering stage
v. Pod length (cm)
vi. Number of pods plant^{-1}
vii. Number of seeds pod^{-1}
viii. Weight of 100 seeds (g)
ix. Seeds yield hectare^{-1}
x. Stover yield hectare^{-1}
xi. Harvest index

xii. pH, organic matter, exchangeable K , total N, available S in post-harvest soil

3.14 Procedure of data collection

3.14.1 Plant height

The plant height was measured at 30, 60 DAS and at harvest with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm.

3.14.2 Number of leaves plant^{-1}

The total number of leaves plant^{-1}was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at 30, 60 DAS and at harvest

3.14.3 Days required from sowing to harvest

Each plant of the experiment plot was kept under close observation to count days to harvest of soybean. Total number of days from the date of sowing to the harvest was recorded.

3.14.4 Number of nodules plant^{-1} at flowering stage

Regular observations were made to see the growth stages of the crop. Total effective nodules number per plant was counted at 60 DAS at flowering stage.

3.14.5 Pod length

Pod length was taken of randomly selected ten pods and the mean length was expressed on pod $^{-1}$ basis.

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

Numbers of total pods of selected plants from each plot were counted and the mean numbers were expressed as plant^{-1}basis. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot.

3.14.7 Number of seeds pod $^{-1}$

The number of seeds pods^{-1}was recorded from randomly selected 10 pods at the time of harvest. Data were recorded as the average of 10 pods from each plot.

3.14.8 Weight of 100 seeds

One hundred cleaned, dried seeds were counted from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g).

3.14.9 Seed yield hectare^{-1}

The seeds collected from 5.0 (2.5 m ×2.0 m) square meter of each plot was cleaned. The weight of seeds was taken and converted the yield in t ha^{-1}.

3.14.10 Stover yield hectare^{-1}

The stover collected from 5.0 (2.5 m ×2.0 m) square meter of each plot was sun dried properly. The weight of stover was taken and converted the yield in t ha^{-1}.

3.14.11 Harvest index

Harvest index (HI) (%) were calculated as the ratio of harvested grain dry mass to the total above ground plant dry mass.

HI (%) = (grain dry mass/total above ground plant dry mass) × 100

3.15 Post harvest soil sampling

After harvest of crop soil samples were collected from each plot at a depth of 0 to 15 cm. Soil samples of each plot was air-dried, crushed and passed through a two mm (20 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

3.16 Soil analysis

Soil samples were analyzed for both physical and chemical characteristics viz. pH, organic matter, exchangeable K, N, P and S contents. The soil samples were analyzed by the following standard methods as follows:

3.16.1 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 as described by Page *et al.*, 1982.

3.16.2 Organic matter

Organic carbon in soil sample was determined by wet oxidation method. The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_20_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_20_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter in soil sample was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results of organic matter content in post harvest soil expressed in percentage (Page *et al.*, 1982).

3.16.3 Exchangeable Potassium

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve (Page *et al.*, 1982).

3.16.4 Available Phosphorus

The choice of a colorimetric method for determining P depends on the concentration of P in solution and the concentration interfering substances in the solution to be analyzed and the particular acid system involved in the analytical procedure. The molybdenum blue methods were used for soil extracts containing small amounts of phosphorus. The intensity of the color was determined by spectrophotometer and calibrated with a standard curve (Page *et al.*, 1982).

3.16.5 Total Nitrogen

The Kjeldahl method were used for the available nitrogen to be precisely determined in the soil. The method of determination involved three successive phases which were,

1. Digestion of the soil sample to convert nitrogen into HNO_3: Digestion of the organic material is carried out by digesting the sample with Con. H_2SO_4 in the presence of $CuSO_4.H_2O$ as a catalyst and K_2SO_4 which raise the digestion temperature. In the organic matter, some nitrates are present, most of which are lost during the digestion. The loss may be disregarded for most soils. Since the amount of NO_3^- - N is far lesser than the Organic Nitrogen.

2. Distillation of the released Ammonia into an absorbing surface or medium: The Ammonia content of the digest is determined by distillation with excess NaOH and absorption of the evolved NH_3 is in standard HCl.

3. Volumetric analysis of the Ammonia formed during the digestion process: The excess of standard HCl is titrated against standard NaOH using Methyl Red as an indicator. The decrease in the multi equivalence of acid as determined by acid-base titration, which gives a measure of the N content of the sample. The end point is determined by a change of color from pink to yellow (Amrita, 2013).

3.16.6 Available Sulphur

Abailable S was determined by $CaCl_2$ extraction methods and by using spectophotometer and calibrated with a standard curve (Page *et al*., 1982).

3.17 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different levels of potassium on soybean. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment means was estimated by the Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

Chapter IV

Results & Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted at the farm condition of Sher-e-Bangla Agricultural University, Dhaka to find out the effect of potassium on nodulation, growth and yield of soybean. Data on different growth parameter, nodulation, yield parameters and soil nutrients status of post-harvest soil was recorded. The analysis of variance (ANOVA) of the data on different recorded parameters are presented in Appendix III-VII. 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 Plant height

Plant height of soybean showed statistically significant variation due to different levels of potassium at 30, 60 days after sowing (DAS) and at harvest (Figure 2 & Appendix III). At 30, 60 DAS and at harvest, the tallest plant (35.36, 68.59 and 70.367 cm respectively) was recorded from T_4 (80 kg K ha^{-1}), whereas the shortest plant was found from T_1 (20 kg K ha^{-1}) treatment and statistical data showed on Table 1. It was revealed that as a necessary element of potassium for the growth and development of soybean and with the increase of potassium fertilizer, plant height increased upto a certain level then decreases. Potassium fertilizer application can rapidly help plants to recover from stress due to drought, high heat, pests and diseases. Potassium increased shoot growth and as a significant factor in overcoming soils moisture stress in tropical cropping systems (Sangakkara *et al.,* 2001) and plant height increased with increasing rates of potassium (Nita *et al.,* 2002).

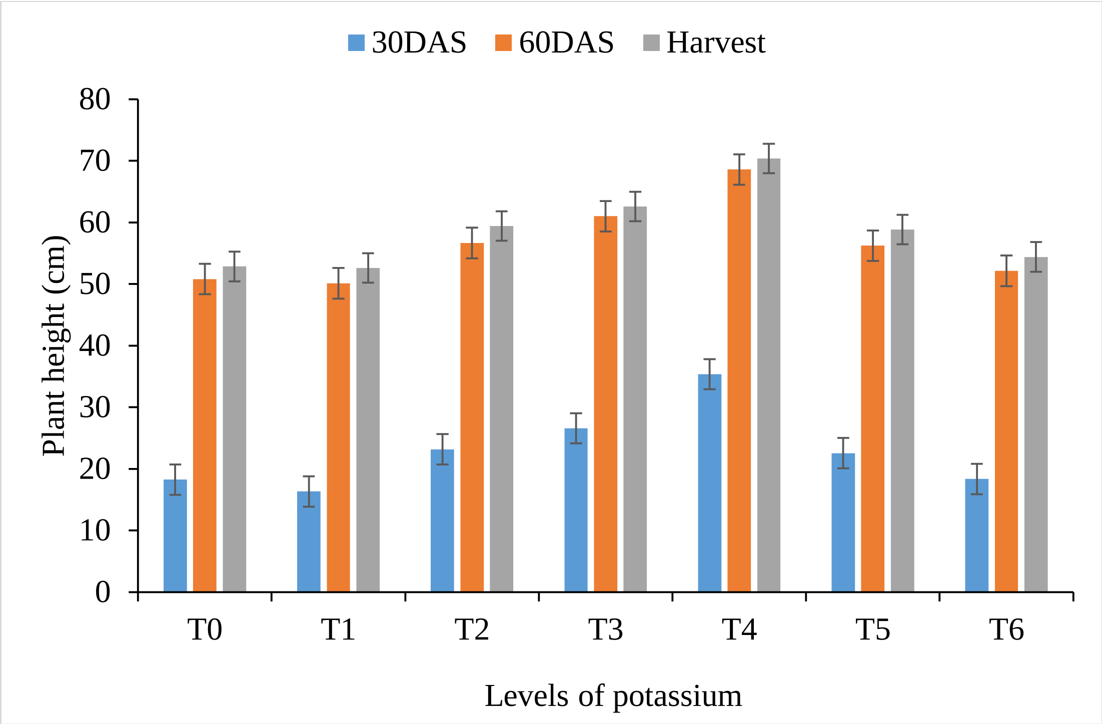

Figure 2. Effect of different levels of potassium on plant height of soybean.

Here,

T_0: 0 kg K ha^{-1} (control)

T_1: 20 kg K ha^{-1}

T_2 : 40 kg K ha-1

T_3 : 60 kg K ha^{-1}

T_4 : 80 kg K ha^{-1}

T_5 : 100 kg K ha^{-1}

T_6 : 120 kg K ha^{-1}

Table 1. Effect of potassium on plant height at different days after sowing (DAS) of soybean

Treatments	Plant Height (cm)		
	30DAS	60DAS	Harvest
T_0	18.240 de	50.803 e	52.840 d
T_1	16.327 e	50.103 e	52.593 d
T_2	23.153 c	56.660 bc	59.420 bc
T_3	26.573 b	61.003 b	62.567 b
T_4	35.360 a	68.590 a	70.367 a
T_5	22.540 c	56.217 cd	58.827 c
T_6	18.340 d	52.140 de	54.387 d
$LSD_{(0.05)}$	2.0131	3.1563	3.4805
Level of significance	0.05	0.01	0.05
CV (%)	4.93	3.14	3.33

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

Here,

T_0: 0 kg K ha^{-1} (control)

T_1: 20 kg K ha^{-1}

T_2 : 40 kg K ha-1

T_3 : 60 kg K ha^{-1}

T_4 : 80 kg K ha^{-1}

T_5 : 100 kg K ha^{-1}

T_6 : 120 kg K ha^{-1}

4.2 Number of leaves plant^{-1}

Statistically significant variation was recorded in terms of number of leaves plant^{-1} of soybean due to different levels of potassium at 30, 60 DAS and at harvest (Figure 3 & Appendix IV). At 30, 60 DAS and at harvest, the maximum number of leaves plant^{-1} (6.71, 24.73 and 29.00 respectively) was observed from T_4 (80 kg K ha^{-1}), while the minimum number of leaves plant^{-1} (4.02, 19.00 and 24.33 respectively) was recorded from T_0 (0 kg K ha^{-1}) treatment. These results showed that application of K fertilizer increased leaves plant^{-1} of soybean. Gurkirpal and Singh (2001) reported that the growth attributes of soybean significantly increased with the application of the fertilizers.

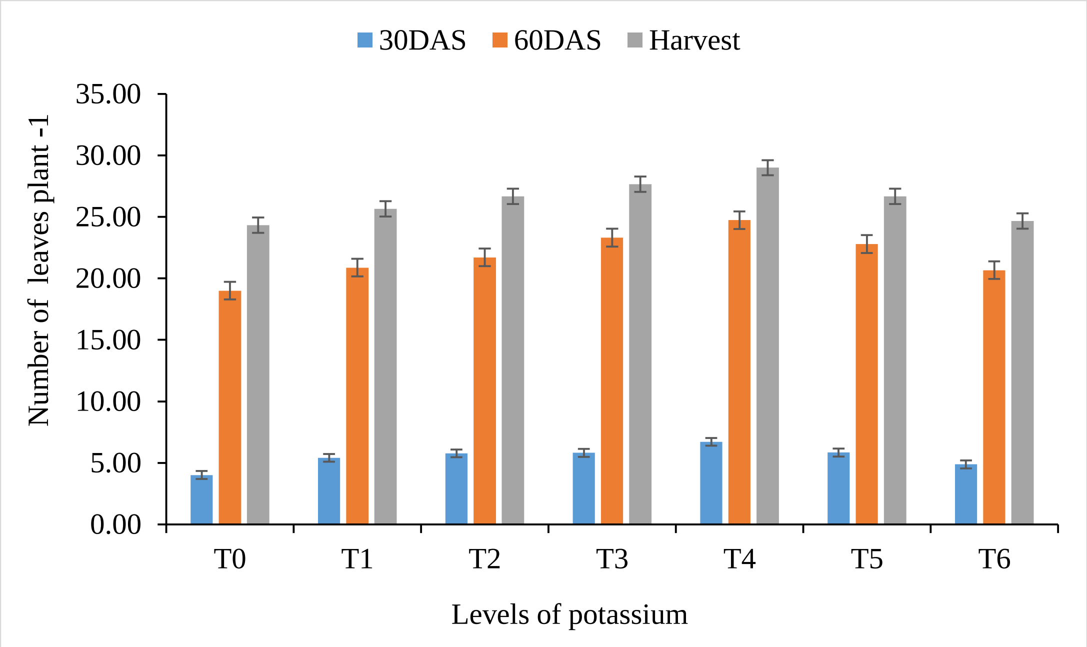

Figure 3. Effect of different levels of potassium on number of leaves plant^{-1} of soybean.

Here,

T_0: 0 kg K ha^{-1} (control)

T_1: 20 kg K ha^{-1}

T_2 : 40 kg K ha-1

T_3 : 60 kg K ha^{-1}

T_4 : 80 kg K ha^{-1}

T_5 : 100 kg K ha^{-1}

T_6 : 120 kg K ha^{-1}

4.3 Days required for sowing to harvest

Days required for sowing to harvest of soybean showed statistically significant variation due to different levels of potassium (Figure 4 & Appendix V). The minimum days required for sowing to harvest (91.20) was found from T_4 (80 kg K ha^{-1}), which was closely followed (95.35) with T_5 (100 kg K ha^{-1}), while the maximum days required for sowing to harvest (104.71) was observed from T_0 (0 kg K ha^{-1}) treatment.

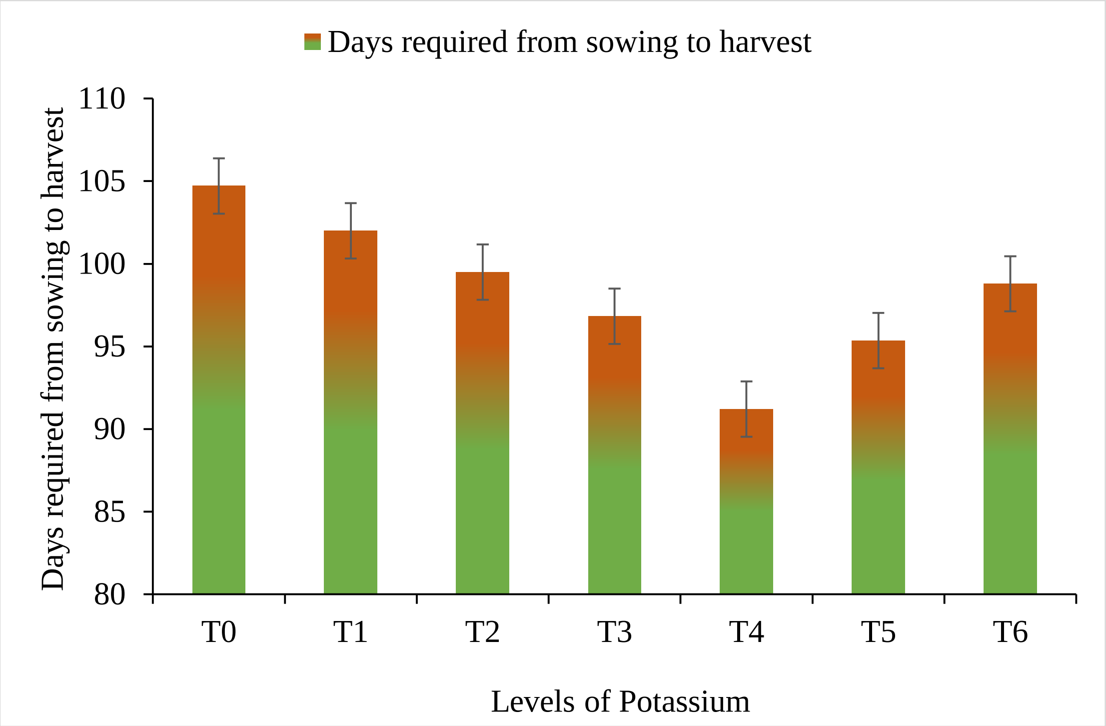

Figure 4. Effect of different levels of potassium on days required from sowing to harvest of soybean.

Here,

T_0: 0 kg K ha^{-1} (control)

T_1: 20 kg K ha^{-1}

T_2 : 40 kg K ha-1

T_3 : 60 kg K ha^{-1}

T_4 : 80 kg K ha^{-1}

T_5 : 100 kg K ha^{-1}

T_6 : 120 kg K ha^{-1}

4.4 Number of nodules plant^{-1} at flowering stage

Statistically significant variation was recorded due to different levels of potassium in terms of nodule plant^{-1} at flowering stage of soybean (Figure 5 & Appendix V). The effective nodule numbers plant^{-1} of soybean varied significantly due to the different levels of K application. The treatment T_4 (80 kg K ha^{-1}) gave the maximum number of nodules (8.00) at the sampling dates of 60 DAS than the other potassium levels, while the minimum nodules number (2.00) was found from T_0 (0 kg K ha^{-1}) treatment (Table 2). These results showed that application of K fertilizer individually increased nodulation. Jones *et al.*, (1977) also reported that K applied alone increased the number of nodules per plant and per unit volume of soil. Applied K increased the number of nodules, total and individual weight of nodules per plant.

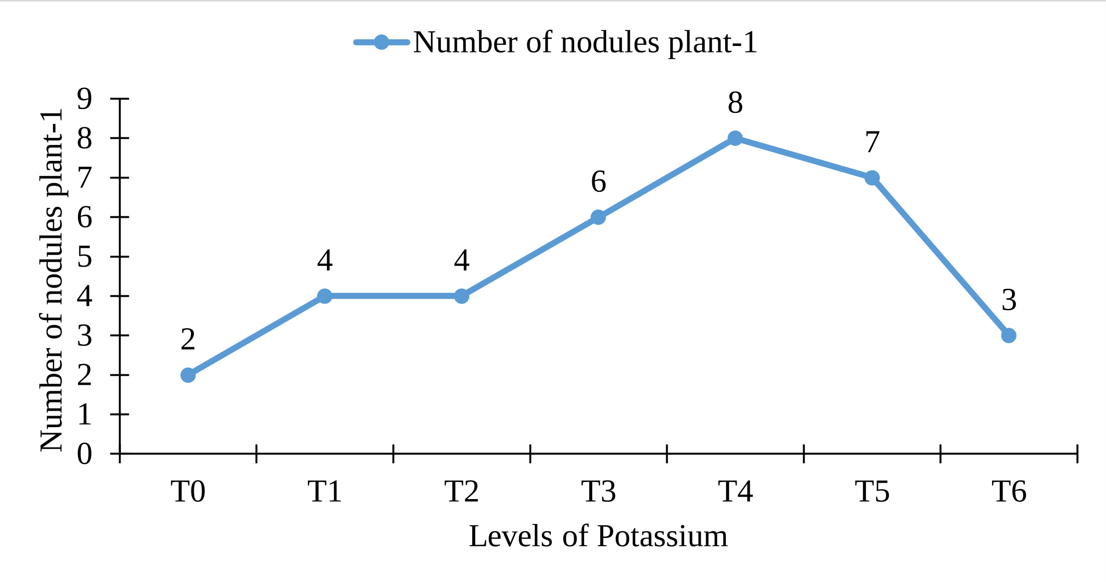

Figure 5. Effect of different levels of potassium on number of effective nodules plant^{-1} at flowering stage of soybean.

Here,

T_0: 0 kg K ha^{-1} (control)	T_4 : 80 kg K ha^{-1}
T_1: 20 kg K ha^{-1}	T_5 : 100 kg K ha^{-1}
T_2 : 40 kg K ha-1	T_6 : 120 kg K ha^{-1}
T_3 : 60 kg K ha^{-1}	

4.5 Pod length

Statistically significant variation was recorded due to different levels of potassium in terms of pod length of soybean (Figure 6 & Appendix V). The longest pod (5.85 cm) was observed from T_4 (80 kg K ha^{-1}), which were statistically identical (5.45 cm) with T_3 (60 kg K ha^{-1}) closely followed (5.17 cm and 5.03 cm) by T_5 (100 kg K ha^{-1}) and T_2 (40 kg K ha^{-1}), while the shortest pod (3.83 cm) was found from T_0 (0 kg K ha^{-1}) treatment (Table 2). Menaria *et al.* (2004) reported that application of 80 kg K ha^{-1} significantly increased all yield attributes and both seed and stover yields of soybean.

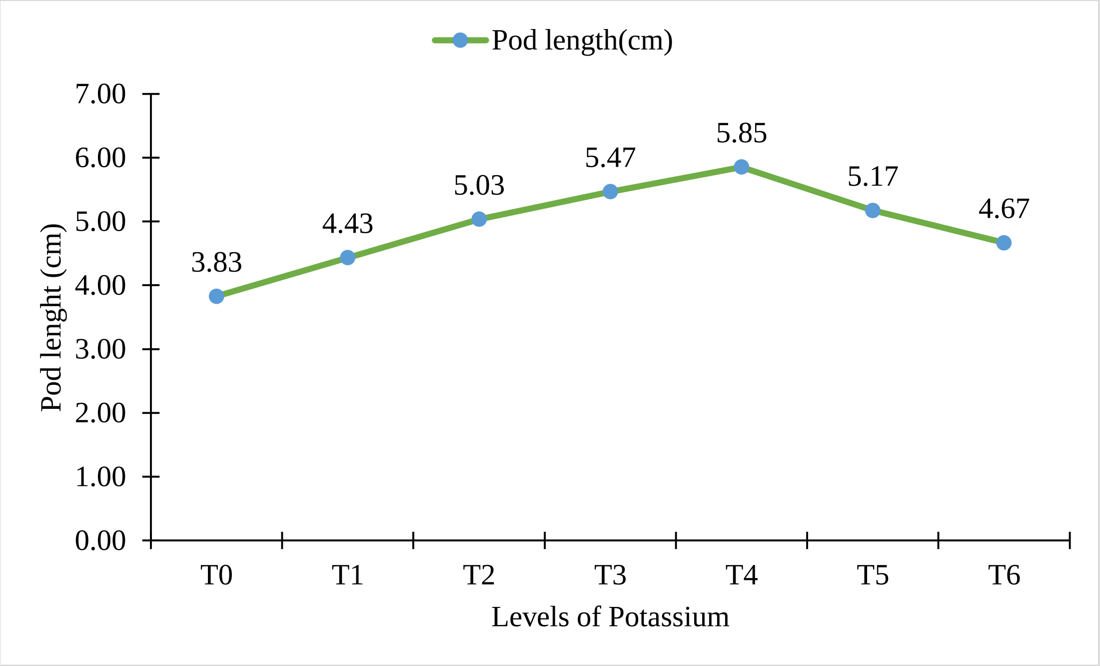

Figure 6. Effect of different levels of potassium on pod length of soybean.

Here,

T_0: 0 kg K ha^{-1} (control)

T_1: 20 kg K ha^{-1}

T_2 : 40 kg K ha-1

T_3 : 60 kg K ha^{-1}

T_4 : 80 kg K ha^{-1}

T_5 : 100 kg K ha^{-1}

T_6 : 120 kg K ha^{-1}

4.6 Number of pods plant^{-1}

Different levels of potassium showed statistically significant variation on number of pods plant^{-1} of soybean (Figure 7 & Appendix V). The maximum number of pods plant^{-1} (33.87) was recorded from T_4 (80 kg K ha^{-1}), which were statistically identical (31.74) with T_3 (60 kg K ha^{-1}), whereas the minimum number (23.23) from T_0 (0 kg K ha^{-1}) treatment (Table 2). Nita et al. (2002) reported that pods plant-1 increased with increasing rates of potassium. Gurkirpal and Singh (2001) reported that the growth attributes and grain yield of soybean significantly increased with the application of the fertilizers and the highest number of pods plant^{-1} were obtained at 80 kg K ha^{-1}.

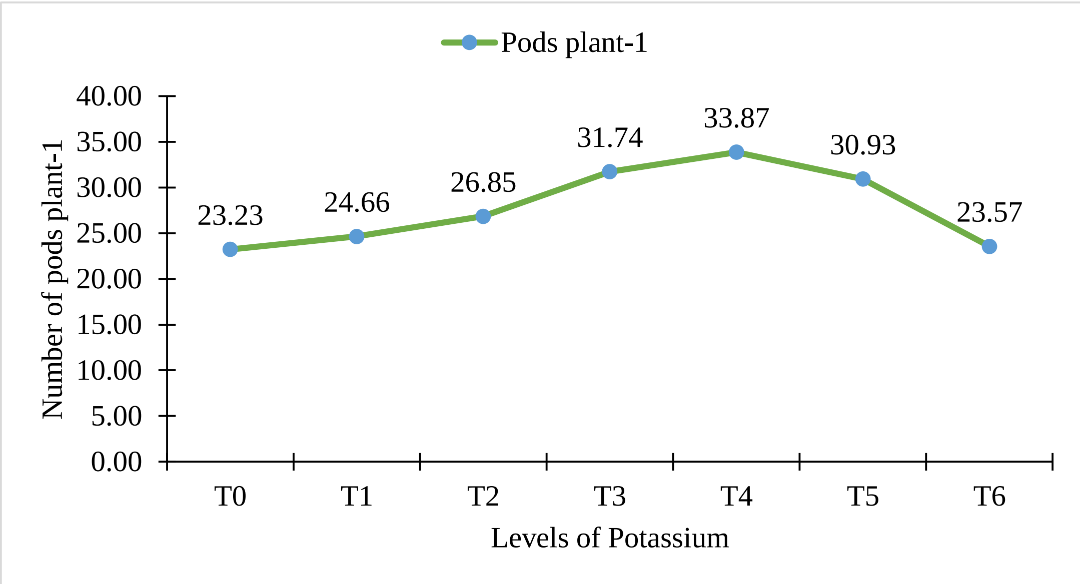

Figure 7. Effect of different levels of potassium on number of pods plant^{-1} of soybean.

Here,

T_0: 0 kg K ha^{-1} (control)

T_1: 20 kg K ha^{-1}

T_2 : 40 kg K ha-1

T_3 : 60 kg K ha^{-1}

T_4 : 80 kg K ha^{-1}

T_5 : 100 kg K ha^{-1}

T_6 : 120 kg K ha^{-1}

4.7 Number of seeds pod^{-1}

Different levels of potassium showed statistically significant variation on number of seeds pod^{-1} soybean (Figure 8 & Appendix V). The maximum number of seeds pod^{-1} (5.15) was found from T_4 (80 kg K ha^{-1}) (Figure 8), while the minimum number (2.41) was recorded from T_0 (0 kg K ha^{-1}) treatment (Table 2). Menaria *et al.* (2004) reported that application of 80 kg K ha^{-1} significantly increased all yield attributes of soybean.

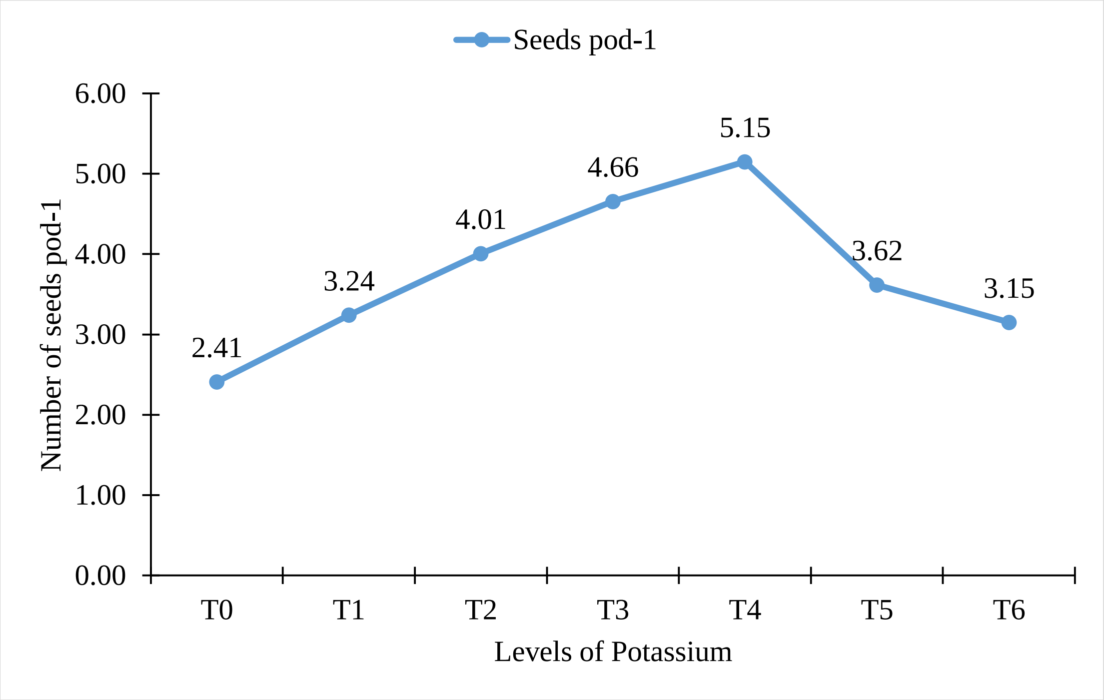

Figure 8. Effect of different levels of potassium on number of seeds pod^{-1} of soybean.

Here,

T_0: 0 kg K ha^{-1} (control)	T_4 : 80 kg K ha^{-1}
T_1: 20 kg K ha^{-1}	T_5 : 100 kg K ha^{-1}
T_2 : 40 kg K ha-1	T_6 : 120 kg K ha^{-1}
T_3 : 60 kg K ha^{-1}	

4.8 Weight of 100 seeds

Weight of 100 seeds of soybean varied significantly due to different levels of potassium under the present trial (Figure 9 & Appendix V). The highest weight of 100 seeds (14.90 g) was observed from T_4 (80 kg K ha^{-1}), which were statistically identical (14.14 g) with T_3 (60 kg K ha^{-1}) and closely followed (13.97 g) by T_5 (100 kg K ha^{-1}), while the lowest weight (10.91 g) was attained from T_0 (0 kg K ha^{-1}) treatment (Table 2). Gurkirpal and Singh (2001) reported that the growth attributes and grain yield of soybean significantly increased with the application of the fertilizers and the highest 100-seed weight were obtained at 80 kg K ha^{-1}.

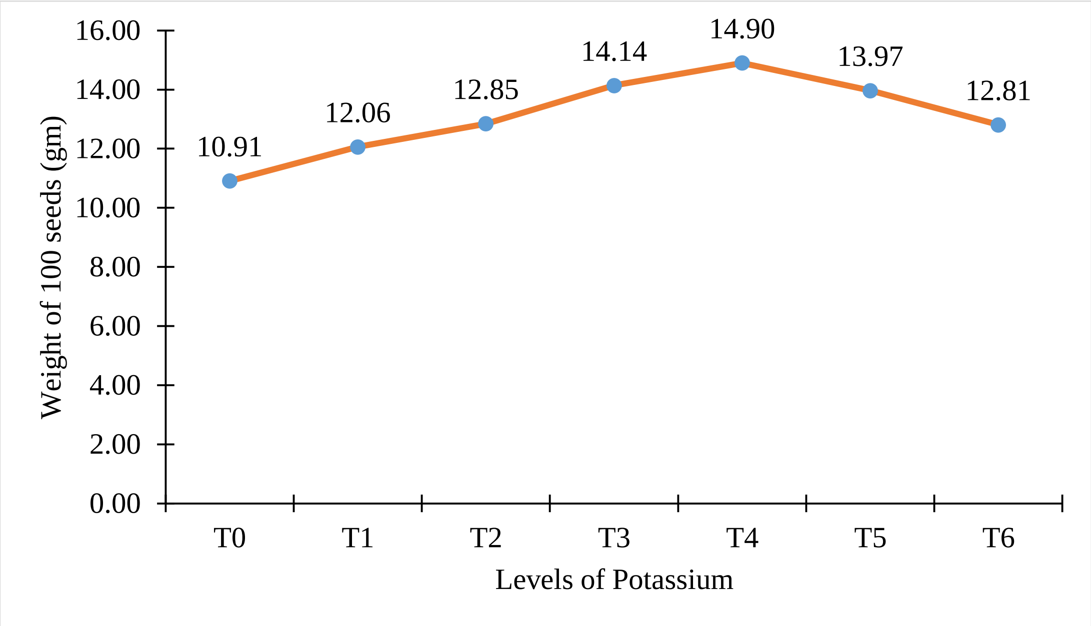

Figure 9. Effect of different levels of potassium on weight of 100 seeds of soybean.

Here,

T_0: 0 kg K ha^{-1} (control)

T_1: 20 kg K ha^{-1}

T_2 : 40 kg K ha-1

T_3 : 60 kg K ha^{-1}

T_4 : 80 kg K ha^{-1}

T_5 : 100 kg K ha^{-1}

T_6 : 120 kg K ha^{-1}

Table 2. Effect of potassium on effective nodule and yield contributing characters of soybean

Treatments	Number of nodules plant^{-1}	Pod length (cm)	Pods plant^{-1}	Seeds pod^{-1}	Weight of 100 seeds (gm)
T_0	2 d	3.83 c	23.23 d	2.41 f	10.91 d
T_1	4 c	4.43 cd	24.66 cd	3.24 de	12.06 cd
T_2	4 c	5.03 abc	26.85 c	4.01 c	12.85 bc
T_3	6 b	5.47 ab	31.74 ab	4.66 b	14.14 ab
T_4	8 a	5.85 a	33.87 a	5.15 a	14.90 a
T_5	7 ab	5.17 abc	30.93 b	3.62 cd	13.97 ab
T_6	3 cd	4.67 bcd	23.57 d	3.15 e	12.81 bc
$LSD_{(0.05)}$	1.76	0.8727	2.366	0.444	0.993
Level of significance	0.05	0.05	0.05	0.05	0.01
CV (%)	20.34	9.97	4.78	6.66	4.26

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

Here,

T_0: 0 kg K ha^{-1} (control)

T_1: 20 kg K ha^{-1}

T_2 : 40 kg K ha-1

T_3 : 60 kg K ha^{-1}

T_4 : 80 kg K ha^{-1}

T_5 : 100 kg K ha^{-1}

T_6 : 120 kg K ha^{-1}

4.9 Seed yield hectare^{-1}

Seed yield hectare^{-1} of soybean varied significantly due to different levels of potassium (Figure 10 & Appendix VI). The highest seed yield (2.63 t ha^{-1}) was observed from T_4 (80 kg K ha^{-1}), which was statistically highest (2.17 t ha^{-1}) over T_5 (100 kg K ha^{-1}) and followed (2.13 t ha^{-1}) by T_3 (60 kg K ha^{-1}). On the other hand, the lowest seed yield (0.9 t ha^{-1}) was observed from T_0 (0 kg K ha^{-1}) treatment (Table 3). Menaria *et al.* (2004) reported that application of 80 kg K ha^{-1} significantly increased all yield attributes and seed yields of soybean. Nita *et al.* (2002) reported that seed yield value increased with increasing rates of potassium. Yin and Vyn (2002) found that average soybean yield significantly increased with the application of 84 kg K ha^{-1}. Gurkirpal and Singh (2001) reported that the growth attributes and grain yield of soybean significantly increased with the application of the fertilizers and the highest seed yield were obtained at 60 kg K ha^{-1}.

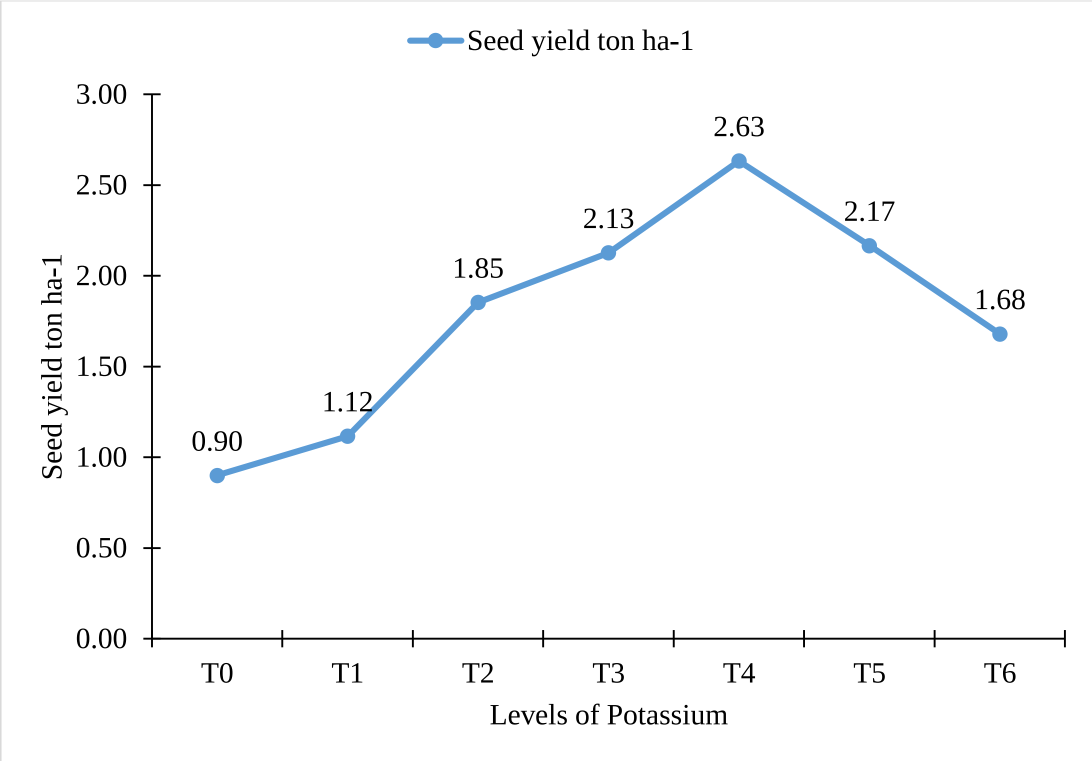

Figure 10. Effect of different levels of potassium on seed yield ha^{-1} of soybean.

Here,

T_0: 0 kg K ha^{-1} (control)

T_1: 20 kg K ha^{-1}

T_2 : 40 kg K ha-1

T_3 : 60 kg K ha^{-1}

T_4 : 80 kg K ha^{-1}

T_5 : 100 kg K ha^{-1}

T_6 : 120 kg K ha^{-1}

4.10 Stover yield hectare^{-1}

Different levels of potassium varied significantly on stover yield hectare^{-1} of soybean (Figure 11 & Appendix VI). The highest stover yield (4.00 t ha^{-1}) was found from T_5 (100 kg K ha^{-1}), which were statistically identical (3.72 t ha^{-1}, 3.65 t ha^{-1} and 3.55 t ha^{-1}) with T_3 (60 kg K ha^{-1}), T_4 (80 kg K ha^{-1}) and T6 (120 kg K ha^{-1}), whereas the lowest stover yield (2.06 t ha^{-1}) from T_0 (0 kg K ha^{-1}) treatment (Table 3). Menaria *et al.* (2004) reported that application of 80 kg K ha^{-1} significantly increased all yield attributes and stover yields of soybean.

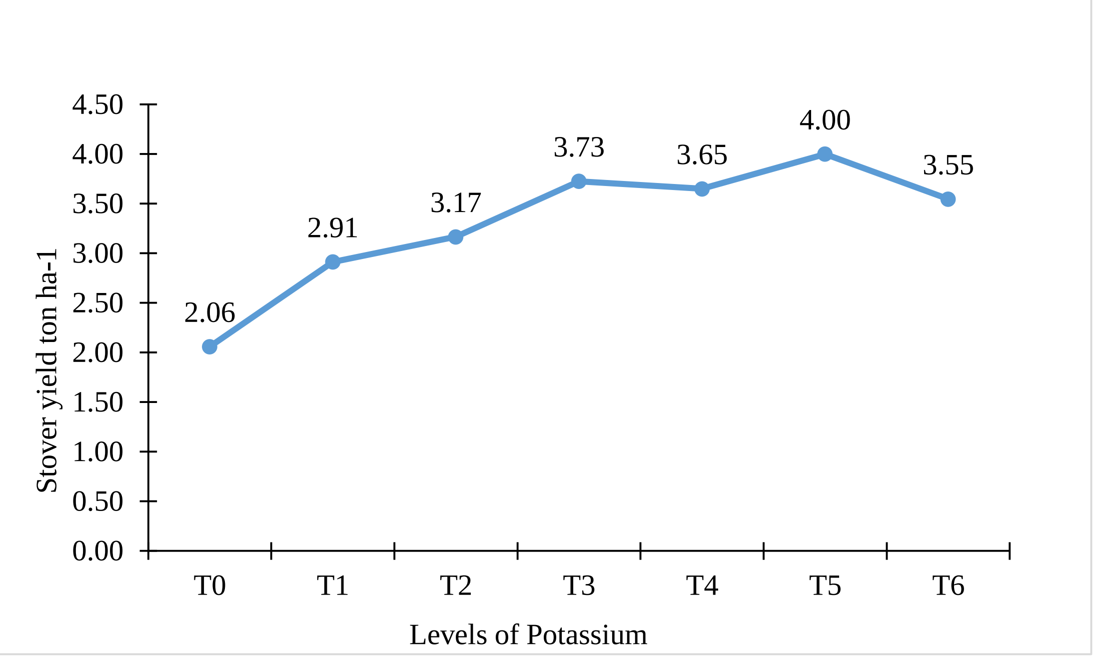

Figure 11. Effect of different levels of potassium on stover yield ha^{-1} of soybean.

Here,

T_0: 0 kg K ha^{-1} (control)

T_1: 20 kg K ha^{-1}

T_2 : 40 kg K ha-1

T_3 : 60 kg K ha^{-1}

T_4 : 80 kg K ha^{-1}

T_5 : 100 kg K ha^{-1}

T_6 : 120 kg K ha^{-1}

4.11 Harvest index (%)

Harvest index of soybean varied non-significant with different level of K application (Appendix VI). The maximum HI of soybean (46.26%) was recorded from T_4 (80 kg of K ha^{-1}) and minimum HI (43.18%) was recorded from T_6 (120 kg of K ha^{-1}) (Table 3). The present result is consistent with the findings of Malik *et al*. (2006) who found that HI varied non-significant due to different levels of potassium.

Table 3. Effect of potassium on seed yield, stover yield and harvest index (HI) of soybean

Treatments	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest Index (%)
T_0	0.90 d	2.06 d	44.49 bcd
T_1	1.12 d	2.91 c	44.80 abc
T_2	1.85 bc	3.17 bc	45.46 ab
T_3	2.13 b	3.73 ab	45.00 abc
T_4	2.63 a	3.65 abc	46.26 a
T_5	2.17 b	4.00 a	43.54 cd
T_6	1.68 c	3.55 abc	43.18 d
$LSD_{(0.05)}$	0.369	0.808	1.158
Level of significance	0.05	0.05	0.01
CV (%)	11.66	13.79	1.46

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

Here,

T_0: 0 kg K ha^{-1} (control)

T_1: 20 kg K ha^{-1}

T_2 : 40 kg K ha-1

T_3 : 60 kg K ha^{-1}

T_4 : 80 kg K ha^{-1}

T_5 : 100 kg K ha^{-1}

T_6 : 120 kg K ha^{-1}

4.12 pH, organic matter, exchangeable K, N, S in post-harvest soil

4.12.1 pH

Different levels of potassium showed statistically no significant variation in terms of pH in post-harvest soil (Appendix VII). The highest pH in post-harvest soil (5.9) was observed from T_4 (80 kg K ha^{-1}), while the lowest pH (5.65) was found from T_1 (20 kg K ha^{-1}) treatment (Table 4). The study of soil pH is very important in agriculture due to the fact that soil pH regulates plant nutrient availability by controlling the chemical forms of the different nutrients and also influences their chemical reactions. The pH influences the availability of essential nutrients. Most agricultural crops perform optimally around soil pH 7.0 (neutral) grow satisfactorily in soils having a pH between 6 (slightly acid) and 7.5 (slightly alkaline) (Suarau, 2018)

4.12.2 Organic matter

Organic matter in post-harvest soil showed statistically no significant variation due to different levels of potassium (Appendix VII). The highest organic matter in post-harvest soil (1.57%) was recorded from T_4 (80 kg K ha^{-1}), whereas the lowest organic matter (1.25%) was observed from T_0 (0 kg K ha^{-1}) treatment (Table 4). Based on the nutrient availability on soil the treatments were selected. Organic matter (OM) 2–10% in most soil's mass has an important role in the physical, chemical and biological function of agricultural soils. However, even in small amounts, organic matter is very important. (Alexandra *et al.*, 2005)

4.12.3 Exchangeable Potassium

Different levels of potassium showed statistically significant variation in terms of exchangeable potassium in post-harvest soil (Appendix VII). The highest exchangeable potassium in post-harvest soil (0.418 meq/100g) was found from T_4 (80 kg K ha^{-1}), which was followed (0.373 meq/100g) by T_5 (100 kg K ha^{-1}), while the lowest exchangeable potassium (0.160 meq/100g) was found from T_0 (0 kg K ha^{-1}) treatment (Table 4). To reduce potassium leaching and well growth of Soybeans, the cation exchange capacities (CECs) less than or equal to 5 meq/100g of K (Michael *et al.*, 2021).

Table 4. Interaction effect of potassium on pH, organic matter, exchangeable K, total N and available S of post-harvest soil of soybean

Treatments	pH	Organic matter (%)	Exchangeable K (meq/100g)	Total N (%)	Available S (ppm)
T_0	5.70	1.25	0.160 f	0.057 d	13.720 c
T_1	5.65	1.41	0.224 e	0.061 cd	14.667 c
T_2	5.70	1.40	0.331 c	0.064 cd	16.287 b
T_3	5.80	1.52	0.293 d	0.065 c	17.567 b
T_4	5.90	1.57	0.418 a	0.081 a	19.953 a
T_5	5.80	1.29	0.373 b	0.077 ab	19.627 a
T_6	5.86	1.34	0.340 bc	0.074 b	19.503 a
$LSD_{(0.05)}$	NS	NS	0.0349	6.613	1.503
CV (%)	2.95	1.87	6.24	5.41	3.48

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

Here,

T_0: 0 kg K ha^{-1} (control)

T_1: 20 kg K ha^{-1}

T_2 : 40 kg K ha-1

T_3 : 60 kg K ha^{-1}

T_4 : 80 kg K ha^{-1}

T_5 : 100 kg K ha^{-1}

T_6 : 120 kg K ha^{-1}

4.12.4 Total Nitrogen

Nitrogen concentration in post-harvest soil showed statistically significant variation due to different levels of potassium (Appendix VII). The highest nitrogen in post-harvest soil (0.08 %) was recorded from T_4 (80 kg K ha^{-1}), which was closely followed (0.07 %) with T_5 (100 kg K ha^{-1}), whereas the lowest nitrogen (0.06 %) was observed from T_0 (0 kg K ha^{-1}) treatment (Table 4). Compared to the initial soil status, this results showed that available N concentration increased. Soybeans increase the fertility strength of versatile soils. Soybeans increase nitrogen levels in the soil. It can add 250 to 277 kg nitrogen per hectare in each planting season. Which is about 80 to 85 percent of the required nitrogen of the crop. (Anon., 2019)

4.12.4 Available Sulphur

Sulphur concentration in post-harvest soil showed statistically significant variation due to different levels of potassium (Appendix VII). The highest sulphur in post-harvest soil (19.95 ppm) was recorded from T_4 (80 kg K ha^{-1}), which was closely followed (19.62 ppm) with T_5(100 kg K ha^{-1}) and T_6 (120 kg K ha^{-1}), whereas the lowest sulphur (13.72 ppm) was observed from T_0 (0 kg K ha^{-1}) treatment (Table 4).

Chapter V

Summary & Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from December, 2019 to March 2020 to study the effect of potassium on the growth, nodulation and yield of soybean. The variety BARI soybean 5 was used as the test crops. The experiment comprised of seven levels of potassium - T_0- 0 kg K ha^{-1} (control), T_1- 20 kg K ha^{-1}, T_2- 40 kg K ha^{-1}, T_3- 60 kg K ha^{-1}, T_4- 80 kg K ha^{-1}, T_5- 100 kg K ha^{-1}, T_6- 120 kg K ha^{-1}. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth parameter, nodule, yield in seed & straw, and soil nutrients status of post-harvest soil was recorded and significant variation was observed for different treatment.

In the experiment, at 30, 60 DAS and at harvest, the tallest plant (35.36, 68.59 and 70.36 cm, respectively) was recorded from T_4, whereas the shortest plant (16.32, 50.10 and 52.59 cm, respectively) was found from T_1. At 30, 60 DAS and at harvest, the maximum number of leaves $plant^{-1}$ (6.71, 24.73, 29.00 respectively) was observed from T_4, while the minimum (4.02, 19.00, 24.33 respectively) from T_0. The minimum days required for sowing to harvest (91.20) was found from T_4, while the maximum days required for sowing to harvest (104.71) was observed from T_0. The maximum number of nodules (8.00) was found from T_4, while the minimum number of nodules (2.00) was found from T_0. The longest pod (5.85 cm) was observed from T_4 (80 kg K ha^{-1}), while the shortest pod (3.83 cm) was found from T_0. The maximum number of pods plant^{-1} (33.87) was recorded from T_4, whereas the minimum number (23.23) was attained from T_0. The maximum number of seeds pod^{-1} (5.15) was found from T_4, while the minimum number (2.41) was recorded from T_0. The highest weight of 100 seeds (14.90 g) was observed from T_4, while the lowest weight (10.91 g) was attained from T_0. The highest seed yield (2.63 t ha-1) was observed from T_4 and the lowest seed yield (0.9 t ha-1) was observed from T_0. The highest straw yield (4.00 t ha^{-1}) was found from T_5, whereas the lowest straw yield (2.06 t ha-1) from T_0. The maximum harvest index (46.26%) was observed from T_4 (80 kg K ha^{-1}) and the minimum (43.18%) from T_6 (120 kg K ha^{-1}).

The highest pH in post-harvest soil (5.9) was observed from T_4, while the lowest pH (5.65) was found from T_1. The highest organic matter in post-harvest soil (1.57%) was recorded from T_4, whereas the lowest organic matter (1.25%) was observed from T_0. The highest exchangeable potassium in post-harvest soil (0.418 meq/100g) was found from T_4, while the lowest exchangeable potassium (0.160 meq/100g) was found from T_0. The highest total nitrogen in post-harvest soil (0.08 %) was recorded from T_4 and, the lowest total nitrogen (0.06 %) was recorded from T_0. The highest available sulphur in post-harvest soil (19.95 ppm) was recorded from T_4 and, the lowest available sulphur (13.72 ppm) was recorded from T_0.

Conclusion

From the results of this experiment it may be concluded that the application of K fertilizers influenced nodule formation, yield attributes and seed yield of soybean. Although K played an important role on the yield of soybean, the application of their excess amount however acted negatively. The application of 80 kg K ha^{-1} can be more beneficial for the farmers to get maximum yield from the cultivation of soybean.

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Appendices

APPENDICES

Appendix I. Monthly records of air temperature, relative humidity, rainfall and sunshine during the period from November 2019 to March 2020

Year	Month	Temperature (^{0}C) (mean)	Relative humidity (%)	Precipitation (mm)
2019	December	19.3	74	5.0
2020	January	18.5	76	21.0
2020	February	21.6	59	1.0
2020	March	26.4	57	30.0

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

Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	5.8
Organic matter (%)	1.32
Total N (%)	0.005
Available P (ppm)	7.40
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	22

Appendix III. Analysis of variance of the data on plant height of soybean at different days after sowing (DAS) as influenced by different levels of potassium

Source of variation	Degree of freedom	Mean square Plant height (cm)		
		30 DAS	60 DAS	Harvest
Replication	2	3.102	4.220	6.843
Levels of Potassium	6	127.320*	129.476*	120.926*
Error	12	1.284	3.154	3.828

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

NS – Non significant

Appendix IV. Analysis of variance of the data on number of leaves plant-1 of soybean at different days after sowing (DAS) as influenced by different levels of potassium

Source of variation	Degree of freedom	Mean square Leaves $plant^{-1}$		
		30 DAS	60 DAS	Harvest
Replication	2	0.380	4.952	0.904
Levels of Potassium	6	2.177*	10.910*	8.158*
Error	12	0.124	0.641	0.682

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

NS – Non significant

Appendix V. Analysis of variance of the data on nodules, yield contributing characters soybean as influenced by different levels of potassium

Source of variation	Degree of freedom	Mean square		
		Days required from sowing to harvest	Number of nodules $plant^{-1}$	Pod length (cm)
Replication	2	8.045	0.142	0.029
Levels of Potassium	6	58.828*	14.428*	1.371*
Error	12	9.338	0.976	0.240

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

NS – Non significant

Appendix V. Contd'

Source of variation	Degree of freedom	Mean square		
		Number of pods plant^{-1}	Number of seeds pod^{-1}	Weight of 100 seeds (gm)
Replication	2	4.330	1.064	0.253
Levels of Potassium	6	55.901*	2.640*	5.542**
Error	12	1.770	0.062	0.311

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

NS – Non significant

Appendix VI. Analysis of variance of the data on seed yield, stover yield and harvest index of soybean as influenced by different levels of potassium

Source of variation	Degree of freedom	Mean square		
		Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest Index (%)
Replication	2	0.025	0.692	0.445
Levels of Potassium	6	1.113*	1.280*	3.403^{NS}
Error	12	0.043	0.206	0.423

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

NS- Non significant

Appendix VII. Analysis of variance of the data on pH, organic matter, exchangeable K, total N and available S of post-harvest soil of soybean as influenced by different levels of potassium

Source of variation	Degree of freedom	Mean square				
		pH	Organic matter (%)	Exchangeable K (meq/100g)	Total N (%)	Available S (ppm)
Replication	2	1.32893	0.00069	0.00039	2.763	0.7926
Levels of Potassium	6	0.02547^{NS}	0.04077^{NS}	0.03229*	2.348*	19.0750**
Error	12	0.02893	0.00069	0.00039	1.382	0.3632

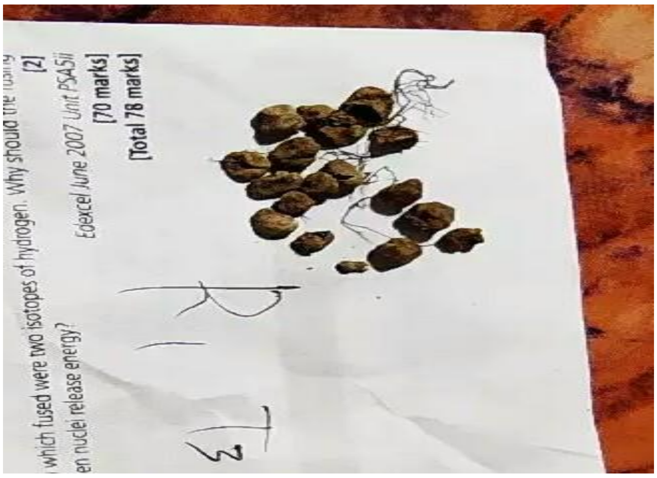
** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

NS – Non significant

Appendix Figure I. Layout and land preparation of the experiments

Appendix Figure II. Presentation of experimental field

Appendix Figure III. Vegetative growth and flowering of plants of the experimental field



Appendix Figure IV. Number of effective nodules per plant at flowering stage

Appendix Figure V. Green and ripe pods per plant of the experimental plots

Appendix Figure VI. Some pictures of doing soil test at Soil Science Laboratory in Sher-e-Bangla Agricultural University