EFFECT OF FOLIAR APPLICATION OF POTASH ON GROWTH AND YIELD OF SOYBEAN UNDER RAINFED CONDITION

THESIS

Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
in partial fulfilment of the requirements
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MASTER OF SCIENCE
IN
AGRICULTURE
(AGRONOMY)

BY

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Enrolment Number - KK/1731 **2018**

DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation in the thesis entitled **"EFFECT OF FOLIAR APPLICATION OF POTASH ON GROWTH AND YIELD OF SOYBEAN UNDER RAINFED CONDITION"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

Place : Akola **(Dhudase Atul Sainath)**

Date : / /2018 Enrolment No. KK/1731

CERTIFICATE

This is to certify that thesis entitled **"EFFECT OF FOLIAR APPLICATION OF POTASH ON GROWTH AND YIELD OF SOYBEAN UNDER RAINFED CONDITION"** submitted in partial fulfilment of the requirement for the degree of **"Master of Science in Agriculture (Agronomy)"** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **Dhudase Atul Sainath** under my guidance and supervision.

The subject of the thesis has been approved by the Student's Advisory Committee.

Place : Akola
Date : / /2018

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Date : / /2018 Enrollment No. KK/1731

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(D) Abbreviations

%	:	Per cent
@	:	At the rate of
^0C	:	Degree Celsius
$^{-1}$or /	:	Per
A	:	Actual
AGR	:	Absolute growth rate
B:C	:	Benefit to cost
BP	:	Bacterial postulates
CD	:	Critical Difference
Cm	:	Centimeter
DAS	:	Days after sowing
dm^2	:	Decimeter square
e.g.	:	For example
et al.	:	Et alia (and others)
Fig.	:	Figure
FYM	:	Farm yard manure
G	:	Gram
GM	:	General Mean
GMR	:	Gross monetary returns
Ha	:	Hectare
Hrs	:	Hours
i.e.	:	that is
K	:	Potash
K_2O	:	Potassium oxide
Kg	:	Kilogram
Kmph	:	Kilometer per hour
L. ha	:	Lakh hectares
LAI	:	Leaf area index
M	:	Meter
Max.	:	Maximum
Met	:	Meteorological
Min.	:	Minimum

ml	:	Milliliter
MLO	:	Mycoplasma like organism
Mm	:	Millimeter
MOP	:	Muriate of potash
MSL	:	Mean sea level
MT	:	Metric tones
MW	:	Meteorological week
N	:	Nitrogen
NAR	:	Net assimilation rate
NMR	:	Net monetary returns
No.	:	Number
NS	:	Non significant
P	:	Phosphorus
Ppm	:	Parts per million
Q/q	:	Quintal
RDF	:	Recommended Dose of Fertilizer
RH	:	Relative Humidity
Rs.	:	Rupees
SE (m)+	:	Standard Error of Mean
Sig.	:	Significant
SPAD METER	:	Soil Plant Analyses Development
T	:	Tonnes
Viz.	:	Namely
WS	:	Wind speed
Wt.	:	Weight

(F) Thesis Abstract

a) Title of the thesis	**:**	**"EFFECT OF FOLIAR APPLICATION OF POTASH ON GROWTH AND YIELD OF SOYBEAN UNDER RAINFED CONDITION"**
b) Full name of student	**:**	**Dhudase Atul Sainath**
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ABSTRACT

A field experiment entitled "Effect of foliar application of potash on growth and yield of soybean under rainfed condition" was conducted at Research Farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *Kharif* season of 2017-18.

The soil of experimental plot was clay in texture. Soil was slightly alkaline in reaction. As regards to fertility status, the soil was low in available Nitrogen (280 kg ha^{-1}), available Phosphorus (20.13 kg ha^{-1}),

high in available Potassium (353 kg ha^{-1}) and medium in organic carbon (0.53%).

The experiment was laid out in Randomized Block Design (RBD) with eight treatments and replicated thrice. The treatment comprised of control (No spray), Water Spray at 25-30 DAS and 60-65 DAS, 1% KNO_3 at 25-30 DAS, 2% KNO_3 at 25-30 DAS, 1% KNO_3 at 60-65 DAS, 2% KNO_3 at 60-65 DAS, 1 % KNO_3 at 25-30 and 60-65 DAS and 2% KNO_3 at 25-30 DAS and 60-65 DAS.

Growth parameters viz., plant height, number of branches, number of functional trifoliate leaves $plant^{-1}$, leaf area, dry matter, number of nodules, root length were improved with the foliar application of 1 % KNO_3 at 25-30 and 60-65 DAS. However, growth parameters were not significantly influenced due to stages of spraying of KNO_3.

Relative water content and chlorophyll content was also higher in treatment of 1% KNO_3 at 25-30 and 60-65 DAS and found at par with 2% KNO_3 at 25-30 DAS and 60-65 DAS

Whereas, the yield attributes such as number of pods $plant^{-1}$, seed weight $plant^{-1}$ and the seed yield (kg ha^{-1}) was significantly superior with foliar application of 1% KNO_3 at 25-30 and 60-65 DAS and at par with 2% foliar application of 2% KNO_3 at 25-30 DAS and 60-65 DAS.

However, significantly maximum GMR, NMR and B:C ratio was registered with foliar application of 1% KNO_3 at 25-30 and 60-65 DAS which was statistically similar to the application of 2% KNO_3 at 25-30 DAS and 60-65 DAS.

Nutrient (N, P and K) uptake were significantly influenced and found higher in foliar application of 1% KNO_3 at 25-30 and 60-65 DAS which was statistically similar to the application of 2% KNO_3 at 25-30 DAS and 60-65 DAS.

CHAPTER I

INTRODUCTION

1.1 Background information

Soybean is known as the “Golden Bean” of the twentieth century. Though soybean is a legume crop, yet it is widely used as oilseed. Due to very poor cook ability and digestibility on account of inherent presence of trypsin inhibitor, it cannot be utilized as a pulse. Soybean is also called as Chinese pea, Japan pea and Japanese fodder plant and it belongs to family leguminoceae. It requires rainfall about 700 to 1000 mm, average temperature range of 22-27°C and it is a short day photo sensitive plant. It is widely used for manufacturing of edible oil, vanaspati ghee, salad oil, butter, glycerin, oil for light, explosive, varnish paints, linoleum, soap, lubricating oil, printing ink, celluloid, plywood material, tape joint, typewriter ribbon, vitamins, antibodies, medicine and cosmetic material etc. It is widely used in different antibodies. It can be used as forage, hay, silage etc. Its forage and cake are excellent nutritive foods for livestock and poultry. Soybean builds up the soil fertility by fixing atmospheric nitrogen through the root nodules, and also through leaf fall on the ground on maturity. It also contains vitamin A, B, C, D, E, K and small amount of Ca, Mg and P. Soybean also contains 26.9 per cent carbohydrates, 4.6 per cent minerals and 2 per cent phospholipids, 0.69 per cent phosphorous, 0.0115% iron, 0.024 per cent calcium.

The area covered under soybean in India was 109.714 lakh ha which produced 114.907 lakh MT with productivity of 1047 kg ha^{-1}, whereas in Maharashtra the area under cultivation was 35.809 lakh ha which produced 39.456 lakh MT of soybean grains with productivity of 1102 kg ha^{-1}. In Vidarbha, area under soybean was 19.32 lakh ha with production of 14.77 lakh MT and productivity of 776 kg ha^{-1} (Anonymous, 2017).

Soybean is the second largest oilseed in India after groundnut. It grows in varied agro-climatic conditions. It has emerged as an important commercial crop in many countries and international trade of soybean is spread globally. Several countries such as Japan, China, Indonesia, Philippines, and European countries are importing soybean to supplement their domestic requirement for human consumption and cattle feed. It is preferred especially by vegetarians on account of its richness in protein, fat, carbohydrates, mineral salts and vitamins. A large number of Indian and western dishes such as bread, *kachori*, pastries, high-protein food for children, food for diabetic, milk, biscuits, sweets, fermented food, khoa, paneer, rabadi, powdered food material, chocolate, ice cream`, green pods as vegetable, canned seed vegetable, salad, dry seed-roasted, boiled, cooked, soya sauce, soya soup etc. can be prepared from its seed/flour. It is the cheapest and richest source of high quality protein. It supplies most of the nutritional constituents essential for human health. Hence, soybean is called “Wonder Bean” or “Miracle Bean”.

Soybean occupies an intermediate position between legumes and oilseeds. It is also known as “Gold of Soil” due to its various qualities such as ease in cultivation, less requirement of fertilizer and labor. It builds up the soil fertility by fixing atmospheric nitrogen through nodules. Symbiotically soybean fixes 125-150 kg N ha^{-1} and leaves about 30-40 kg N ha^{-1} for succeeding crop.

Soybean is gaining popularity on account of its unique characteristics and adaptability to varied agro-climatic conditions. It has unmatched composition of 40 per cent protein and 20 per cent oil and nutritional superiority on account of containing essential amino acids, unsaturated fatty acids, carbohydrates, vitamins and minerals.

Soybean is predominantly grown in Vertisols and associated soils of central India, which are generally rich in potassium. Soybean generally responds favorably to potassium application resulting in increased yield. Other yield associated characters viz., number of nodules per plant, grain weight, grain per plant etc. also increase on potassium application. Increased oil and protein content in seed have also been observed.

Potassium application has also been found to increase chlorophyll content and nitrate reeducates activity. Application of potassium in soybean also results in enhanced uptake of major and some of the micronutrients. Several of these beneficial effects transcend the soybean crop and are carried along to other crops succeeding soybean. In addition to above response, resistance of soybean plants against major insect-pests of soybean viz. girdle beetle, semilooper and aphids has also been realized.

1.2 Importance of study

Foliar applied potassium is a readily available form of potassium fertilizer that can provide much needed nutrition at a critical time of soybean development. Applying foliar potassium during pod filling improves the overall health of the plant, leading to improved yields. Despite the use of soil-applied potassium fertilizers, soybeans typically have in sufficient potassium to maintain high yields, due to their high requirement for this nutrient during pod -filling. The need for potassium in the developing pods and seeds is so great that potassium starts to be pulled out of the leaves, leaving them potassium deficit and unable to adequately photosynthesize. Only a portion of the potassium needed for pod -filling is available in the leaves and the stem of the plant. The roots must take up the rest, which requires an actively growing root system. However, root growth slows down during the reproductive stage of soybean development, severely limiting the amount of potassium that is taken up from the soil.

Potassium is one of the three major essential nutrient elements required by plants. Unlike nitrogen and phosphorus, potassium does not form bonds with carbon or oxygen, so it never becomes a part of protein and other organic compounds (Hoeft *et al.*, 2000). Although K is not a constituent of any plant structures or compounds, it is involved in nearly all processes needed to sustain the plant life. Potassium in cell sap is involved in enzyme activation, photosynthesis, transport of sugars, protein and starch synthesis. It is known to help crop to perform better under water stress through the regulation of the rate at which plant stomata open and close. It is also known for its role to provide lodging resistance and insect/disease resistance to plants. Since potassium is involved in many metabolic pathways that affect crop quality, it is often called as “the quality element”.

Foliar spray of nutrients is the fastest way to boost up crop growth because the nutrients application is uniform and crop reacts to nutrient application immediately. Under rainfed condition when the availability of moisture becomes scarce, the application of fertilizers as foliar spray resulted in efficient absorption and usage which are economical in respect the other methods of fertilization. Flower senescence and filling of pods are the major drawbacks in soybean, which can be managed through foliar application of nutrient. Adequate information on the effect of foliar application of potassium on soybean not available, keeping this in view, it has been proposed to investigate the effect of foliar application of potassium, on growth and yield of soybean.

Objectives

1. To study the effect of foliar application of potassium on growth and yield of soybean under rainfed condition.
2. To study the nutrient uptake by soybean.
3. To work out the economics.

1.3 Scope and limitation

The main reason for low productivity of soybean is its cultivation in marginal and sub marginal lands under poor management and input starved rainfed conditions. Further lack of proper nutrient management is one of the major causes of low yield. Yield is the manifestation of various physiological processes occurring in plants and these are usually modified by management practices in an environment. Among the management practices, planting methods and fertilization are the most important factors in determining yield of soybean. During the soybean growing period, one or two dry spell occurs in Vidarbha region therefore the crop growth suffers due to the lack of soil moisture and productivity is reduced.

Soybean is cultivated with traditional package of practices and inadequate use of inputs. Particularly the inadequate use of nutrients is an important factor which limiting the full expressions of soybean yield potential. Intensive crop cultivation requires use of chemical fertilizer but fertilizers are not only in short supply but also expensive. Therefore, current trend is to explore the possibility of supplementing foliar application of nutrients with the soil application of fertilizers which may enhance or maintain productivity of the crop. Soybean crop is taken in the study area, the knowledge of cost, returns and its profitability will be useful for the farmers who want to substitute this crop for the traditional crop grown in the area. The findings of study would be helpful to economic management of soybean. It will also provide the probable combinations of chemical fertilizer applied through soil and through foliar application. However, the findings may become applicable in the area where similar condition exists.

1.4 Hypothesis

The study will be helpful to see the effect of foliar application of potash on growth and yield of soybean. It will be beneficial to farmer and also to research worker to carryout research on soybean. The hypothesis is that, foliar application of potassium on soybean crop to enhance the productivity in term of seed yield under adverse climatic condition. i.e. dry spell during flowering and grain filling stage of the soybean crop. it is also helpful to improve soybean quality. It corrects nutrient deficiency, increase pest and disease resistance, maintain osmatic regulation during drought period, promote well balanced fruit and/or plant growth and development with decrease physiological disorders.

CHAPTER II

REVIEW OF LITERATURE

In this chapter an attempt has been made to present a brief review of important research work carried out in past by different researchers in respect of foliar application of potash on growth and yield of soybean under rainfed condition.

The available literature on foliar application of potash was reviewed and presented under appropriate heads.

Foliar application of potassium on soybean crop to enhance the productivity in term of seed yield under adverse climatic condition. i.e. dry spell during flowering and grain filling stage of the soybean crop. It is also helpful to improve soybean quality. It prevents the occurrence of nutrient deficiency before deficiency symptoms appear. It corrects nutrient deficiency, increase pest and disease resistance; maintain osmatic regulation during stress period.

2.1 Effect of foliar application of potash on growth attributes and growth

Rai *et al*. (1988) found that the variation in nitrate reductase activity by applying various sources of nitrogen in sugarcane during earlier growth stages. They stated that both KNO_3 and urea @ 10 mm of nitrogen increased dry matter production in sugarcane.

Shinde *et al.* (1991) reported that the foliar application of NAA @ 5 ppm and KNO_3 @ 100 ppm increased leaf weight in cowpea.

Upadhyay (1994) revealed that spraying of KNO_3 @ 100 ppm increased plant height at harvest in chickpea.

Patra *et al*. (1995) reported that the spraying of urea @ 2% and KNO_3 @ 0.5% at 70 DAS increased leaf area by 41.1% and 31.2% respectively over control under rainfed conditions in groundnut.

According to Das (1999) the maximum plant height, branches/plant were recorded for 40 kg K_2O ha^{-1} which was statistically at par with the 30 kg K_2O ha^{-1} and foliar sprays of KNO_3 once at flowering and twice at flowering and 15 days thereafter.

Govindan and Thirumurugan (2000) reported that LAI in green gram were significantly higher with the foliar spray of 1% KNO_3 or 1% KCL and their combination.

Jayaramireddy *et al.* (2000) observed that leaf area was more with foliar spray of KNO_3 @ 1% when compared with NAA @ 15 ppm in blackgram.

Jayaramireddy *et al.* (2004) reported that dry matter production was more with foliar application of KNO_3 @ 1% followed by urea @ 2% in black gram.

Moinuddin and Goswami (2004) reported that the foliar spray of urea @ 3% significantly increased dry matter production when compared with potassium sulphate in wheat plants under water deficit conditions.

Reddy *et al.* (2004) reported that the significant increase in number of branches $plant^{-1}$ in red gram due to application of potassium nitrate (1%) and NAA (100 ppm).

Abdullahil *et al.* (2006) conducted an experiment on effect of potassium fertilizer on growth, yield and nutrient uptake under water stress condition in wheat. They stated that water stress significantly reduced the dry matter accumulation in stem and root. However, high levels of potassium improved the dry matter production in stem and root.

Bardhan *et al.* (2007) conducted an experiment to evaluate the potentiality of exogenous osmoprotectants to mitigate water stress in chickpea and stated that spraying of KNO_3 @ 200 ppm attained significant increase in dry weight of all plant parts.

Adkine *et al*. (2011) reported that higher number of branches, number of leaves, dry matter accumulation and leaf area plant^{-1} was observed with the application of RDF + 1 % KNO_3 + 0.5 % Boron + 0.2 % Molybdenum foliar spray.

Besma *et al.* (2011) conducted an experiment on effect of foliar potassium fertilization and its effects on growth, yield and quality of potato grown on loam sandy soil under semi arid conditions. They concluded that increasing potassium nitrate rates (0 to 2 g L^{-1}) resulted in a significant increase in plant height and leaf number when sprayed at 75 DAS.

Yadav and Chaudhary (2012) reported that the significant increase in number of branches and flowering in cowpea due to application of water spray, 2 per cent urea, 2 per cent DAP and 2 per cent KCL.

Jabeen and Ahmad (2013) revealed that foliar application of KNO_3 had recorded significantly higher leaf area index, leaves fresh weight, and leaves dry weight in sunflower and safflower crop.

The highest plant height, number of branches plant^{-1} was observed due to application RDF + 2 % potassium nitrate in cotton crop (Channakeshava *et al.,* 2013).

Ganga *et al*. (2014) conducted a field experiment on sandy clay loam soil at Agricultural Research Farm, Banaras Hindu University, Varanasi during *rabi* 2006-07 to study the effect of potassium level and foliar application of nutrient on growth and yield of late sown chick pea. The results revealed that combined spray of 2% urea and 0.25% multiplex increased plant height, number of branches and dry matter per plant.

Goud *et al*. (2014) conducted an experiment at Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during *rabi* season 2008-09 to 2010-11 in clayey soil to study the response of chickpea to potassium fertilization on yield, quality, soil fertility and economic in vertisols and stated that the statistical competent plant height and number of branches were recorded due to application of 30 kg K_2O ha^{-1} and foliar spray of KNO_3 (2%) at flowering and 15 days thereafter.

Gowthami and Rao (2014) observed that foliar application of potassium nitrate @ 2 per cent + boric acid @ 50 ppm + zinc sulphate @ 1 per cent at 30 and 60 DAS recorded higher plant height (40 cm).

Hosmath *et al*. (2014) conducted experiment during rainy (*kharif*) seasons of 2007 and 2008 in vertisols on nutrient requirement of Bt cotton and stated that the higher number of sympodial branches was observed due to the foliar application of KNO_3 @ 2 % (three times).

Hiwale (2015) revealed that the application of two foliar sprays of KNO_3 @ 1.0% at 45 and 60 DAS improved all growth parameter viz., plant height (cm), number of branches $plant^{-1}$, nodules $plant^{-1}$ and total dry matter $plant^{-1}$ in soybean crop.

Kumar and Srivastava (2015) conducted an experiment at Oil Seed Farm, Kalyanpur of C.S. Azad University of Agriculture and Technology, Kanpur during *kharif* season from 2007 to 2009 to study the growth and yield attributes, yield, fibre quality and economics of *hirsutum* cotton as influenced by foliar application of KNO_3 and observed that foliar spray of KNO_3 improved all the growth characters compared to control.

2.2 Effect of foliar application of potash on relative water content (RWC)

Sharma *et al.* (1993) observed that the application of potassium significantly increased the leaf RWC in all Brassica genotypes under water stress conditions.

Reddy and Reddy (2003) reported that membrane stability index or percentage injury was significantly increased in moisture stressed plants compared to control groundnut plants.

Rosale *et al*. (2004) observed that the application of potassium significantly increased Relative Water Content is an integrative indicator used successfully to identify drought resistant crops.

2.3 Effect of foliar application of potash on chlorophyll

Rai *et al*. (1988) reported that both urea and KNO_3 @ 10 ppm of nitrogen increased chlorophyll a, chlorophyll b and total chlorophyll contents in sugarcane.

Makbul *et al*. (2011) observed that the increasing potassium nitrate (0 to 2 g L^{-1}) rates resulted in significant increase in chlorophyll a content when sprayed at 75 DAS in loam sandy soil under semi arid conditions in soybean.

2.4 Effect of foliar application of potash on nodulation

Goud *et al*. (2014) reported that the higher no. of nodules $plant^{-1}$ due to application of RDF with 2 per cent spray of KNO_3 at flowering and 15 days thereafter.

Hiwale (2015) observed that application of two foliar sprays of KNO_3 @ 1.0 per cent at 45 and 60 DAS improved no. of nodules $plant^{-1}$.

2.5 Effect of foliar application of potash on yield attributes and yield

Das (1999) reported that the maximum 100 seed weight were recorded for 40 kg K_2O ha^{-1} which was statistically at par with the 30 kg K_2O ha^{-1} and foliar sprays of KNO_3 once at flowering and twice at flowering and 15 days thereafter.

Basole *et al.* (2003) reported that the response of soybean cv. JS 335 to hormone and nutrients with respect to biochemical characters and yield. The result revealed that higher yield plant^{-1} was observed with the treatment of 1/2 RDF + NAA (50ppm) + 0.5 per cent KNO_3.

Narasimharao *et al.* (2005) revealed that the mepiquat chloride @ 50 ppm + triacontanol @ 1.25 ppm + borax @ 0.2% + KNO_3 @ 1% increased 100 seed weight and seed yield, whereas triacontanol @ 1.25 ppm + KNO_3 @ 0.2% increased harvest index in chickpea.

Sharma and Singh (2007) reported that application of 2 % K_2O @ 5 kg ha^{-1} at initiation of boll formation + peak boll formation significantly increased seed cotton yield, number of open bolls per plant and boll weight.

Adkine *et al.* (2011) studied that the combine application of RDF + potassium nitrate 1.0 % foliar spray at 30-35 DAS increased no. of pods per plant due to foliar application of boron, molybdenum and potassium nitrate which due to balancing of all nutrient.

Waraich *et al.* (2011) reported that the maximum number of bolls, yield plant^{-1} and GOT % was obtained with the application of 2 % of potassium.

Galavi *et al.* (2012) reported that the micronutrient foliar application had a significant effect on seed and biological yield in safflower.

Channakeshava *et al*. (2013) reported that the application of RDF + 2 % Potassium Nitrate foliar spray to cotton crop had significantly increased boll weight and kapas yield (2160 kg ha^{-1}) which was significantly superior (T_7).

Sekhon and Singh (2013) revealed that 4 sprays of KNO_3, NPK, MOP and MOP + urea recorded increase in seed cotton yield of 22.8 %, 22.4%, 18.5 % and 24.5 %, respectively over unsprayed control.

Vekaria *et al*. (2013) reported that the 0.4% spray of KNO_3 resulted in significantly increased grain yield by 18.4% as compare to water spray only. and also gave higher economic Benefit.

Goud *et al*. (2014) reported that the yield attributing character viz., yield, protein, 100 seed weight in chickpea were much better in the treatment due to foliar application of RDF + 2% KNO_3 at flowering and 15 days thereafter.

Gowthami and Rama Rao (2014) reported that foliar application of potassium nitrate @ 2 per cent+ boric acid @ 50 ppm + zinc sulphate @ 1 per cent (T_7) at 30 and 60 DAS was found to be superior at test weight by potassium nitrate @ 2 per cent + boric acid @ 50ppm at 30 and 60 DAS (T4), boric acid @ 50 ppm at @ 50 ppm + zinc sulphate @ 1 per cent at 30 and 60 DAS (T_6) and potassium nitrate @ 2 per cent + zinc sulphate @ 1 per cent at 30 and 60 DAS in soybean crop.

2.6 Effect of foliar application of potash on economics

Vekaria *et al*. (2013) reported that the 0.4% spray of KNO_3 resulted in higher economic benefit.

Goud *et al*. (2014) reported that the higher gross and net monetary returns was obtained from chickpea crop with the foliar spray of 2 % KNO_3 at flowering and 15 days thereafter

Hosmath *et al.* (2014) reported that the application of 120 kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1} 10 % N, full P and K as basal and 90 % N in equal to 6 splits + foliar application of KNO_3 @ 2 % three times at an interval of 15 days from Oct. to IIFN was recorded higher net returns and benefit cost ratio.

Kumar and Srivastava (2015) conducted an experiment to study the growth and yield attributes, yield, fibre quality and economics of *hirsutum* cotton as influenced by foliar application of KNO_3 and the results showed that higher net return and benefit cost ratio was obtained due to foliar application of KNO_3 than control.

2.7 Effect of foliar application of potash on uptake of nutrients

Das (1999) reported that the foliar sprays of KNO_3 once at flowering and twice at flowering and 15 days thereafter has synergistic effect on nitrogen uptake, facilitates protein synthesis and activates of different enzymes.

Umar *et al*. (1999) reported that the effect of foliar fertilization of potassium on yield, quality, and nutrient uptake of groundnut and observed the K content in the leaves and K uptake by crop were also maintained at higher levels with 1 percent KCL as foliar and 50 kg ha^{-1} soil application.

Reddy *et al*. (2005) reported that the nitrogen uptake by seeds of uradbean increased significantly with 2 per cent urea spray at 30, 40 and 60 DAS over absolute control on clay loam soil of Warangal. .

Raman and Venkataramana (2006) reported that the foliar spray of DAP @ 2 per cent with NAA 30 ppm and penshipao @ 0.01 per cent at 20 and 45 DAS recorded higher NPK (69.01, 18.19 and 65.71 kg ha^{-1} respectively) uptake over control (58.66,12.97 and 53.68 kg ha^{-1} respectively).

Naga Jyothi *et al*. (2013) observed that the nutrient uptake of soybean was significantly influenced by foliar application of nutrients at different growth stages of crop. Higher uptake of Zn and N by soybean plants was recorded with the 2 per cent urea as foliar application at flowering and at early pod development.

Shashikumar *et al*. (2013) reported that the foliar application of 2 per cent DAP along with RDF which increased the uptake of P in black gram crop.

CHAPTER III

MATERIAL AND METHODS

The investigation entitled "Effect of foliar application of potash on growth and yield of soybean under rainfed condition" was conducted during *Kharif* season of 2017 at Farm of Agronomy Department, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Details of material used and methods adopted during the course of investigation are outlined in this chapter.

3.1 Basic Resource Information

3.1.1 Experimental site

The field experiment was conducted at Farm of Agronomy Department, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* season of 2017-18.

3.1.2 Cropping history of the experimental site

Cropping history of the experimental plot for previous five years is presented in Table 1.

Table 1. Cropping history of the experimental site

Years	Kharif	Rabi	Summer
2012-13	Soybean	Chickpea	-
2013-14	Soybean	Gram	Summer soybean
2014-15	Soybean – Cotton	Cotton	-
2016-17	Soybean	Gram	-

3.1.3 Soil

The soil of experimental plot was *vertisol* with uniform and leveled topography in order to know the chemical composition of soil. Soil sample were collected at 0-30 cm depth from randomly selected spots spread over the experimental area before sowing. A composite soil sample was analyzed for the fertility status of soil. The methods adopted and the analytical values obtained for different physico-chemical properties of soil are presented in Table 2.

The soil of experimental plot was clay in texture. Soil was slightly alkaline in reaction. As regards to fertility status, the soil was medium in available Nitrogen, low in available phosphorus, fairly high in available potassium, and moderate in organic carbon.

Table 2. Physico-chemical properties of experimental site

Sr. No.	Particulars	Results	Analytical Method Adopted
A. Mechanical analysis			
1)	Sand (%)	23.2	Bouyucous Hydrometer Method (Piper, 1966)
2)	Silt (%)	27.2	
3)	Clay (%)	49.6	
4)	Textural class	Clay	
B. Chemical analysis			
1)	Organic carbon (%)	0.53	Walkely and Black Rapid titration method (Jackson,1967)
2)	Available nitrogen (kg/ha)	280	Alkaline permanganate method (Subbiah and Asija,1956)
3)	Available P_2O_5 (kg/ha)	20.13	Olsen's method (Jackson, 1967)
4)	Available K_2O (kg/ha)	353	Flame emission photometer (Jackson,1967)

3.1.4 Climate and Weather Conditions

Akola is situated in sub-tropical zone about 307.4 m above mean sea level at the latitude of 22.42 degree North and the longitude of 77.02 degree East. The climate of the area is semi-arid characterized by three distinct seasons viz., summer, rainy and winter.

The details of the meteorological data as recorded at Agro-meteorological Observatory of Agronomy Department, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola are presented along with normal value in Table 3 and illustrated in Fig. 1(a), (b) & (c).

Table 3. Weekly weather data for the year 2017 recorded at Meteorological Observatory, Department of Agronomy, Dr. PDKV, Akola

N = Normal of 40 years (1971 to 2010)
A = Actual of 2017-18

MW	Date	T Max. (^0C)		T Min. (^0C)		BSH (hrs)		WS (km/hr)		RH I (%)		RH II (%)		Evap. (mm)		RF (mm)		Rainy Days	
		N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A
18	30-6 May	42.7	42.2	26.0	26.7	9.9	9.3	11.4	3.5	38	28	14	14	15.4	13.2	0.3	0.0	0.2	0.0
19	7-13	42.6	43.5	26.5	27.7	10.1	8.7	12.7	3.7	43	30	17	15	16.4	13.8	0.3	0.3	0.1	0.0
20	14-20	42.6	43.8	27.3	30.4	9.7	9.2	14.6	10.2	48	37	18	17	17.3	17.5	1.8	0.0	0.2	0.0
21	21-27	42.4	43.6	27.4	30.1	9.8	8.9	15.7	9.2	50	41	20	18	17.0	17.3	4.1	0.0	0.5	0.0
22	28-3 Jun	41.9	40.5	27.6	28.9	9.7	7.3	16.2	8.2	56	58	23	31	16.3	13.7	5.7	0.8	0.5	0.0
23	4-10	39.0	38.0	25.8	25.5	8.0	7.1	14.9	10.0	62	74	30	41	13.4	10.9	18.3	24.6	1.2	1.0
24	11-17	38.2	35.6	25.5	23.8	7.5	5.2	15.4	6.3	71	80	42	51	11.1	7.4	43.3	45.4	2.0	4.0
25	18-24	35.3	37.4	24.9	26.3	7.1	8.9	15.1	11.0	76	67	50	36	9.1	11.5	52.3	5.7	2.2	1.0
26	25-1Jul	34.1	34.8	24.2	25.0	5.3	5.1	13.4	7.7	80	75	55	48	7.3	8.6	38.2	10.5	2.3	2.0
27	2-8	33.5	33.2	24.4	24.3	5.2	3.8	12.9	11.3	81	79	58	51	6.8	7.5	34.7	37.6	2.4	1.0
28	9-15	32.3	33.9	23.7	24.9	3.8	3.7	12.0	12.6	84	77	62	51	5.5	9.3	52.2	10.8	2.8	2.0
29	16-22	32.0	29.8	23.9	23.8	3.3	0.6	11.2	6.9	84	88	65	72	5.6	4.2	58.6	101.1	2.6	4.0
30	23-29	31.7	30.5	23.3	23.0	4.3	2.3	11.9	8.2	85	88	64	65	5.3	4.1	44.2	35.8	2.6	4.0
31	30-5 Aug	31.1	31.9	23.1	23.6	3.6	6.8	11.7	6.3	88	85	66	58	4.6	6.9	49.3	10.0	2.5	2.0
32	6-12	30.2	30.7	22.9	24.1	3.5	2.9	11.6	6.0	87	80	69	63	4.2	5.8	59.9	4.4	2.9	1.0
33	13-19	30.5	32.9	22.8	23.8	4.4	5.4	11.7	7.1	86	83	66	58	4.5	6.2	40.6	18.9	2.2	1.0
34	20-26	30.5	29.1	22.6	23.4	4.3	2.0	11.0	5.9	88	92	66	76	4.3	2.8	46.7	25.3	2.0	4.0
35	27-2 Sep	30.4	30.5	22.7	23.3	4.4	3.8	10.6	2.5	86	88	64	68	4.2	3.7	47.1	70.2	2.4	4.0
36	3-9	31.1	32.3	22.5	23.8	5.7	6.5	9.1	2.7	85	89	61	62	4.7	5.0	28.5	9.7	1.5	1.0
37	10-16	32.2	31.8	22.4	23.8	7.1	2.6	9.0	0.8	85	93	56	69	5.1	3.5	18.9	27.9	1.1	3.0
38	17-23	33.4	30.8	22.3	23.0	7.2	2.5	8.5	2.5	83	92	53	69	5.3	3.2	24.6	12.5	1.4	2.0
39	24-30	33.7	33.8	21.9	22.8	7.6	8.4	5.4	1.6	83	89	50	50	4.9	5.1	24.4	4.1	1.5	1.0
40	1-7 Oct	33.9	35.6	20.2	21.1	8.1	8.0	7.5	1.2	81	81	45	42	5.5	6.5	21.8	0.0	1.1	0
41	8-14	34.1	31.9	18.7	20.0	4.2	4.3	4.1	0.7	76	91	40	64	5.3	4.2	16.0	57.5	0.9	4
42	15-21	33.9	33.7	18.1	20.5	8.4	6.9	4.4	0.8	74	83	36	43	5.5	5.7	3.1	0.0	0.4	0
43	22-28	33.1	33.9	18.5	16.6	8.4	8.5	4.1	0.6	73	77	36	29	5.3	5.8	10.0	4.5	0.6	1
44	29-4 Nov	33.0	32.7	15.8	14.4	8.7	8.5	4.7	0.6	72	82	31	26	5.3	5.9	2.3	0.0	0.3	0

The soybean crop was sown on 1th July (26th MW) and harvested on 10th October (41st MW). The rainfall received during the season (June-October 2017) was 517.6 mm in 43 rainy days as against normal rainfall of 747.2 mm in 34.8 rainy days. The rainfall received

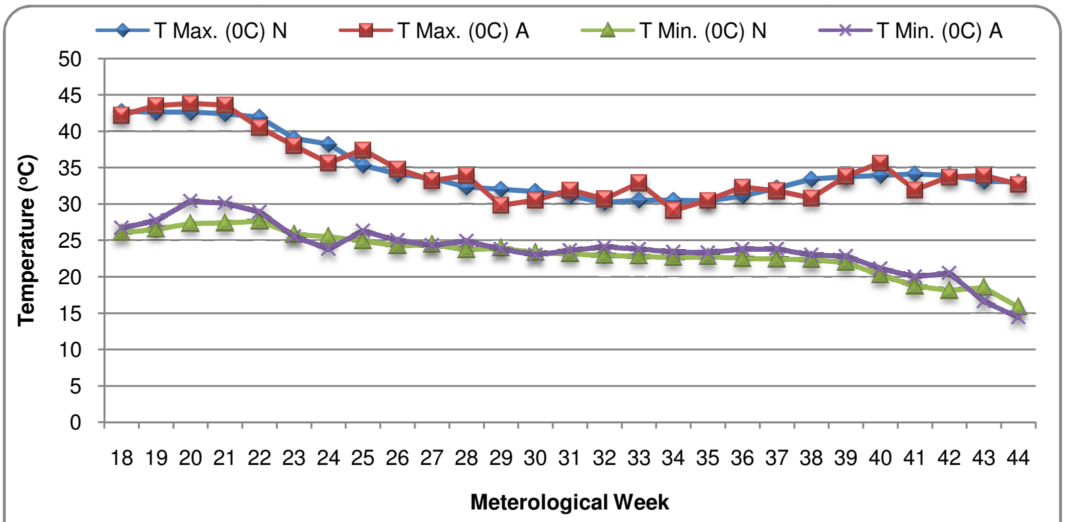


Fig. 1(a). Weekly meteorological data (Temperature °C) for Kharif 2017

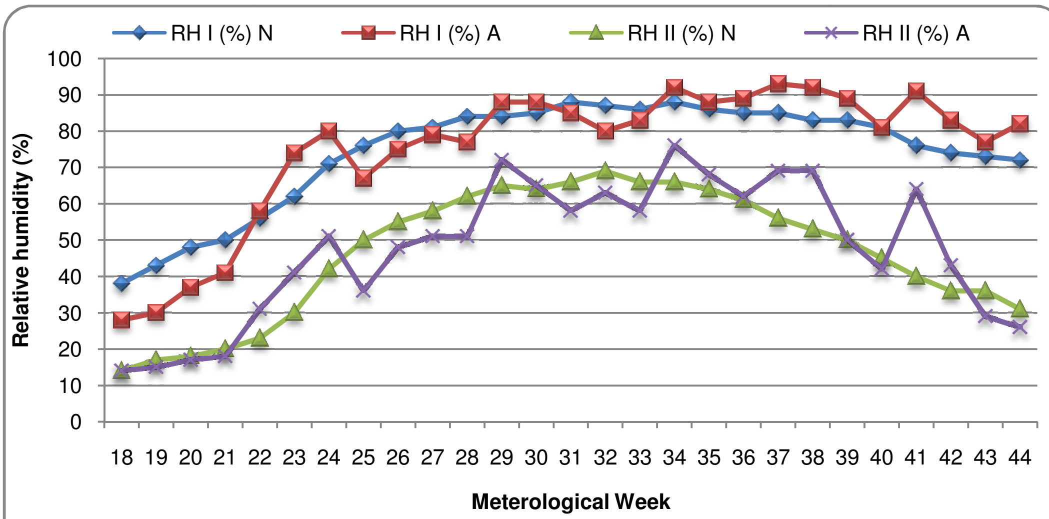


Fig. 1(b). Weekly meteorological data (Relative humidity %) for Kharif 2017

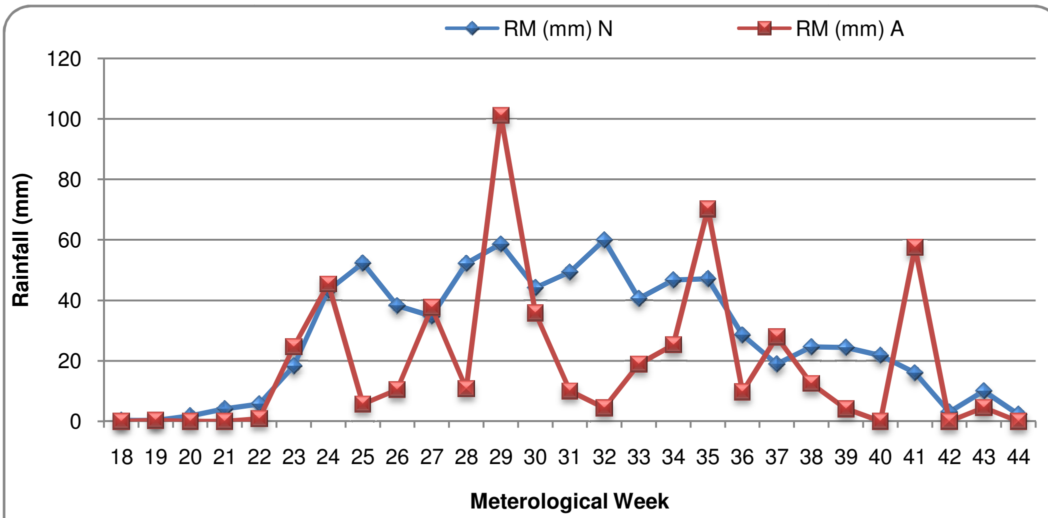


Fig. 1(c). Weekly meteorological data (Rainfall mm) for Kharif 2017

during the period of experimentation was 436.3 mm in 36 days which was 28 % lower than the normal rainfall of 605.7mm in 32.2 rainy days. The rainfall received was well distributed during the critical crop growth period which benefited the overall crop growth of soybean.

During the period of experimentation the maximum temperature ranged between 29.1 during 34th MW (1.4^{0}C higher than normal) to 33.8 during 39th MW (0.1^{o}C higher than normal). The minimum temperature varied from 20^{o}C during 41th MW (1.3^0 C higher than normal) to 24.9^{o}C during 28th MW (1.2^{0}C higher than normal).

Bright Sunshine hour was mostly lower than normal. However, during 29th MW it was lower (0.6 hrs.) than normal (3.3 hrs.) by 2.7 hours and lower (2.0 hrs.) during 34th MW than normal (4.3 hrs.) by 2.3 hours. The bright sunshine hours were lower than normal and helped the crop to utilize the available soil moisture for comparatively larger period of time.

Wind speed was lower than normal throughout the growing season which was helped to keep the rate of evaporation lower and remained favorable for the crop. However, maximum wind speed was observed as 12.6 km hr^{-1} in 28th MW as against normal 12 km hr^{-1}. While, the minimum wind speed of 0.7 km hr^{-1} was recorded in 41st MW than normal of 4.1km hr^{-1}.

Relative humidity of morning was higher during 37th MW (93%) and 38th MW (92%) than normal (85% and 83 % respectively). Also, the relative humidity of morning was found lower during 32nd MW (80%) than normal (87%). Evening relative humidity was intermittently higher than the normal value during 29th, 34th, 36th, 37th, 38th and 41th MW. It was lower in 26th, 27th, 28th, 31th, 32nd, 33th, 35th and 40th MW than the normal and it was found same in 39th MW.

Rate of evaporation was higher during 26th, 27th, 28th, 31st, 32nd, 33rd, 34th and 39th MW than normal. In other MW, it was found to be almost lower than normal.

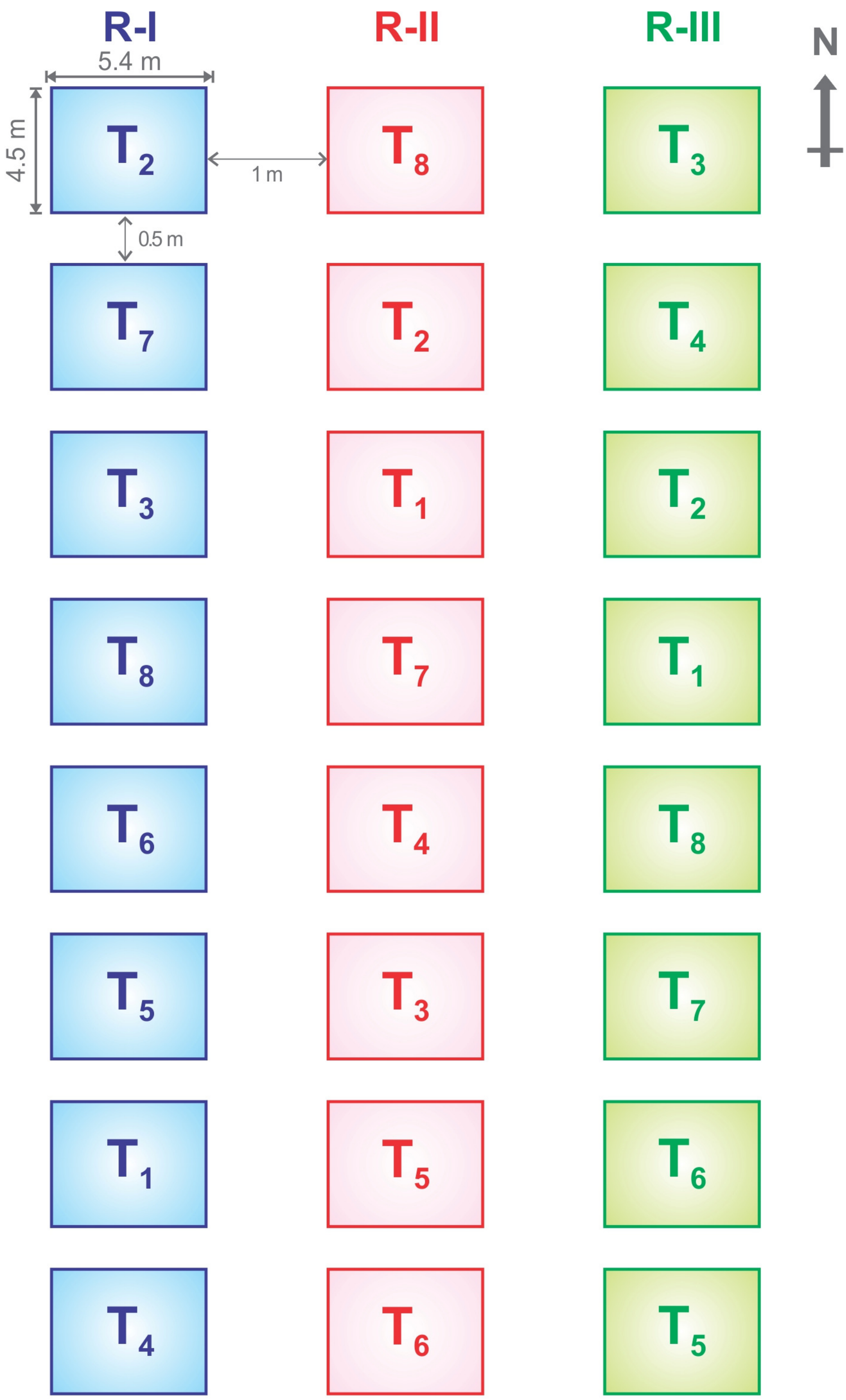
Overall the weather parameters were in favor of crop growth and thus positively reflected on yield.

3.1.5 Experimental details

1	Crop	:	Soybean (*Glycine max*)
2	Design	:	Randomized block design
3	Replications	:	3
4	Treatments	:	8
5	Total no. of plots	:	24
6	Plot size (Gross plot) (Net plot)	: :	4.5 x 5.4 m^2 3.6 X 5.0 m^2
7	Seed rate	:	75 kg/ha
8	Recommended Fertilizer dose	:	30: 75: 30 NPK kg/ha
9	Spacing	:	45 cm x 5 cm
10	Variety	:	JS-335

3.1.6 Treatment details

1	T_1	:	Control (No Spray)
2	T_2	:	Water Spray at 25-30 DAS and 60-65 DAS
3	T_3	:	1% KNO_3 at 25-30 DAS
4	T_4	:	2% KNO_3 at 25-30 DAS
5	T_5	:	1% KNO_3 at 60-65 DAS
6	T_6	:	2 % KNO_3 at 60-65 DAS
7	T_7	:	1 % KNO_3 at 25-30 and 60-65 DAS
8	T_8	:	2% KNO_3 at 25-30 and 60-65 DAS
	Note	:	Recommended dose of fertilizers 30:75:30 NPK kg ha^{-1} applied to all treatments



Design	: Randomized Block Design (RBD)
Treatment combinations	: 8 (Six)
Replications	: 3 (Four)
Plot Size	: 4.5 m x 5.4 m

Fig. 2. Plan of layout

Table 4. Important characters of Soybean (JS-335)

Sr. No.	Particulars	Characters
1	Parents	JS 78-77 x JS 71-05
2	Year of release	1993
3	Duration	100-110 days
4	100 seed weight	11-12 gm
5	Protein content	40%
6	Seed yield	22-25 q ha-1
7	Resistant to	Moderately resistant to leaf minor, stem fly girdle beetle, resistant to bacterial pustules and MLo, rust

3.1.7 Seed Treatments

The seeds of soybean (JS-335) were obtained from Department of Agronomy, Dr. P.D.K.V, Akola. The seed of soybean was inoculated with Rhizobium, PSB and Trichoderma. The culture was obtained from the Department of Plant Pathology, PGI, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

3.2 Details of cultural operations

The schedule of cultural operations carried out on experimental site is given in Table 5.

3.2.1 Preparatory tillage

The land was ploughed after the harvest of previous crop and subsequently harrowing was done for making the field ready for sowing.

3.2.2 Seed and Sowing

The sowing of soybean crop was carried out on 01-07-2017 Seed of soybean was inoculated with Rhizobium, PSB and Trichoderma. Seed inoculation was done @ 250 g of Rhizobium & PSB and 40 gm Trichoderma per 10 kg of seed.

Table 5. Schedule of cultural operations

Sr. No.	Field Operation	Frequency	Date of Operation
A.	**Pre-sowing operation**		
1	Ploughing	1	10.05.2017
2	Harrowing	2	
	a. First		26.05.2017
	b. Second		10.06.2017
3	Stubble picking	1	17.06.2017
4	Layout and marking of the field	1	25.06.2017
B.	**Sowing operation**		
1	Sowing and Seed inoculation with *Trichoderma*, *Rhizobium* and *PSB*	1	01.07.2017
2	Fertilizer application	1	01.07.2017
C.	**Post sowing operation**		
1	Thinning	1	11.07.2017
2	Hoeing	2	
	a. First		04.08.2017
	b. Second		15.08.2017
3	Weeding	1	19.08.2017
D.	**Spraying of potassium nitrate**		
1	1^{st} spraying	1	25.07.2017
2	2^{nd} spraying	1	30.08.2017
E.	**Spraying of insecticide**		
	Triazophos	1	02.09.2017
F.	**Harvesting of Soybean**		10.10.2017
G.	**Threshing of Soybean**		28.10.2017

The recommended dose of nitrogen @ 30 kg N ha^{-1} was applied through urea, phosphorous @ 75 kg ha^{-1} was applied through single super phosphate and potassium @ 30 kg ha^{-1} was applied through muriate of potash at the time of sowing.

3.2.4 Preparation of solution

The 100 and 200 gm KNO_3 was dissolved in 10 litre of water for the preparation of solution for foliar spray of 1 and 2 % respectively.

3.2.5 Gap filling and thinning

The optimum plant population of soybean was maintained by gap filing and subsequently by thinning, keeping one plant $hill^{-1}$.

3.2.6 Intercultural operations

The experimental field was kept weed free to avoid the crop weed competition. The intercultural operation like two hoeing and one hand weeding were given to the crop to keep the soil loose and porous for good aeration, moisture conservation and better establishment of root system. The schedule of intercultural operations undertaken is mentioned in Table 5.

3.2.7 Harvesting and threshing

Before harvesting the crop from net plots, five observation plants from each plot were taken out for recording post-harvest observations. From each plot, net plot rows were harvested, threshed winnowed and cleaned separately. The produce was sun dried and its weight was recorded.

3.3 Biometric observations

The various biometric observations were recorded treatment wise on randomly selected five soybean plants and labeled from each net plot during the course of investigation. The details of observation recorded and their frequency is presented in Table 6. The techniques followed for recording each observation are described separately wherever necessary

3.3.1 Plant stand

3.3.1.1 Initial and final plant stand

The plant population was recorded by actually counting the number of plants in the net plot after complete emergence and thinning as well as at harvest of the crops during the years of experimentation. The net plot population was converted into plant population ha^{-1}.

3.4 Growth studies

3.4.1 Plant height (cm)

Height of five plants selected at random was measured from the base of the plant to the tip of main shoot. Observations were recorded at 20, 40, 60, 80 DAS and at harvest and average height was calculated.

Table 6. Details of Biometric observations

Sr. No.	Particulars	Frequency	Days After Sowing (DAS)
A	Pre Harvest studies		
1	Initial plant stand	1	At emergence
2	Final plant stand	1	At harvest
3	Plant height $plant^{-1}$ (cm.)	5	20, 40, 60, 80 and at harvest
4	No of branches $plant^{-1}$	5	40, 60 and 80 DAS
5	No. of the trifoliate functional leaves $plant^{-1}$	4	20, 40, 60 and 80 DAS
6	Leaf area	4	20,40,60 and 80 DAS
7	Total dry matter accumulation $plant^{-1}$ (g)	5	20, 40, 60, 80 and at harvest
8	RWC	3	40, 60 and 80 DAS
9	Chlorophyll content	4	Before and after spraying

B	**Root studies**		
1	Root length plant^{-1} (cm)	4	20, 40, 60 and 80 DAS
2	No. of nodule plant^{-1}	3	40, 60 and 80 DAS
C	**Post harvest studies**		
1	No of pods plant^{-1}	1	At harvest
2	Seed yield plant^{-1} (g)	1	At harvest
3	No. of grain plant^{-1}	1	At harvest
4	100 seed weight (gm)	1	After harvest
5	Seed yield (kg ha^{-1})	1	At harvest
6	Straw yield (kg ha^{-1})	1	At harvest
7	Biological yield (kg ha^{-1})	1	At harvest
8	Harvest index (%)	1	At harvest
D	**Economic observation**		
1	GMR (Rs/ha^{-1})	1	At harvest
2	NMR (Rs ha^{-1})	1	At harvest
3	Benefit :cost ratio	1	At harvest
E	**Nutrient studies**		
1	Available N, P and K content in the soil	1	Initial
2	Nutrient uptake by plant	1	After harvest
3	Water use efficiency	1	At harvest

3.4.2 Number of branches plant^{-1}

The numbers of branches arising from the main stem were counted at 40, 60 and 80 DAS from selected plants and the mean was worked out.

3.4.3 Number of functional trifoliate leaves plant^{-1}

The total numbers of trifoliate functional leaves on the selected plants were counted at 20, 40, 60 and 80 DAS. The mean was worked out.

3.4.4 Leaf area plant^{-1} (dm^2)

The leaves from the sampled for dry matter study were used for estimating the leaf area. The leaf area (dm^2) was estimated at 20, 40, 60 and 80 DAS with leaf area meter.

3.4.5 Dry matter weight plant^{-1}

The dry matter was recorded by taking five plants from each net plot at 20, 40, 60 80 DAS and at harvest. Sample plants were cut from the ground level. The aerial portion of the plant was sun dried and then put in oven at 65^0 C until constant weights were attained. The oven dried samples were weight on electronic balance. The final weight was recorded as total dry matter weight in gram plant^{-1}.

3.4.6 Relative water content (RWC)

The relative water content was recorded by taking five plants from each net plot at 40, 60 and 80 DAS. it is estimates the current water content of the sampled leaf tissue relative the maximal water content it can hold at full turgidity. The RWC was calculated by using following formula 40, 60 and 80 DAS.

$$\text{RWC (\%)} = \frac{\text{Fresh weight of sample - dry weight of sample}}{\text{Turgid weight of sample - dry weight of sample}} \times 100$$

s

3.4.7 Chlorophyll content

The chlorophyll SPAD meter is used to estimate nitrogen status of the crop. It was recorded taking five plants from each plot before and after spraying.

3.5 Root studies

3.5.1 Root length plant $^{-1}$ (cm)

The Root length was measured by taking five plants from each net plot at 20, 40, 60 and 80 DAS.

3.5.2 No. of root nodule

The Root nodule was calculated by taking five plants from each net plot at 40, 60 and 80 DAS.

3.6 Post Harvest Observations

3.6.1 Number of pods plant^{-1}

The numbers of pods were counted from randomly selected plants and average numbers of pods per plant were worked out.

3.6.2 Number of seeds pod^{-1}

The numbers of seeds were counted from randomly selected five plants and average numbers of seeds per pod were worked out after harvest.

3.6.3 Seed yield plant^{-1} (g)

The numbers of pods per plant were threshed out and weighed the seed wt. (g) per plant.

3.6.4 Seed yield (kg ha^{-1})

After harvesting, the produce was threshed and seed produced from each net plot was weighed to record seed yield per plot and was expressed per hectare by multiplying with hectare factor.

3.6.5 Straw Yield (kg ha^{-1})

The weight of straw after separating the seeds was recorded and the yield of straw per net plot was worked out and was expressed per hectare by multiplying with hectare factor.

3.6.6 Biological yield (kg ha^{-1})

The biological yield per hectare was worked out by adding the yield of seed yield kg ha^{-1} and dry weight of straw yield kg ha^{-1}.

3.6.7 Test Weight (g)

Random sample of 100 seeds was taken from net plot yield. It was weighed on electronic balance and their weight (g) was recorded.

3.6.8 Harvest Index (%)

Harvest Index indicated the yielding efficiency of a crop to produce seed yield per unit of total biological yield. Harvest Index in different treatments was worked out by the following formula given by Donald (1962).

$$\text{Harvest index (\%)} = \frac{\text{Economical Yield}}{\text{Biological yield}} \times 100$$

3.7 Chemical Studies

3.7.1 Initial Soil Status

Soil samples (0-30 cm depth) from experimental area were collected and composite soil sample was prepared by air drying in shade, powdered and analyzed for determination of physic-chemical properties of soil. The samples were air dried, powdered and analyzed for estimation of available nitrogen, phosphorus and potassium content.

3.7.2 Available Nitrogen (kg ha^{-1})

The available nitrogen from soil was estimated by alkaline permanganate method (Subbiah and Asija, 1956). The easily oxidizable organic nitrogen present in soil was oxidized by potassium permanganate in the presence of NaOH by distillation. During oxidation, the released ammonia was absorbed in boric acid. To convert the ammonia to ammonium borate this was titrated with the standard sulphuric acid. Available nitrogen expressed in kg ha^{-1}.

3.7.3 Available phosphorus (kg ha^{-1})

The Olsen's method (Jackson, 1967) was used for determining available phosphorus in soil in which phosphorus was extracted from the soil using 0.5 M sodium bicarbonate ($NaHCO_3$), pH 8.5 as an extractant. Phosphorus was estimated calorimetrically by adding ammonium molybdate to aliquot and reducing the molybdenum phosphate complex in acidic medium. The intensity of blue colour on reduction as a measure for concentration of phosphorus in extract was read on colorimeter using 730 nm red filters. Available phosphorus expressed in kg ha^{-1}.

3.7.4 Available Potassium (kg ha^{-1})

Available potassium was determined by extracting soil with neutral (1N) ammonium acetate (pH 7) solution and readings were recorded using Flame photometer (Jackson, 1967).

Nutrient uptake Studies

Chemical analysis of plant was done after harvest for determining the nutrient uptake (N, P and K) by plant and seed. The total nutrient uptake was calculated in kg ha^{-1} by using following formula.

$$\text{Uptake by seed (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) x Seed yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Uptake by straw (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) x Straw yield (kg ha}^{-1}\text{)}}{100}$$

3.7.5 Total Nitrogen (kg ha^{-1})

Total nitrogen in the seed and stalk samples was estimated by Kjeldhal’s method as describe by Jackson (1967). Complex nitrogenous compounds in plant samples were converted into ammonia and then to ammonium sulphate. The ammonia in ammonium sulphate was released with sodium hydroxide during distillation and absorbed in known volume of standard sulphuric acid. The unutilized excess of standard sulphuric acid was determined by a back titration with sodium hydroxide. Total nitrogen was then calculated from the amount of the standard sulphuric acid neutralized by absorbed ammonia during distillation.

Digestion of Sample

For the nutrients other than nitrogen, the plant material was digested in a di-acid containing 9:4 ratio HNO_3:$HClO_4$.The samples were predigested with 25 mlHNO_3 g^{-1} sample to avoid explosion. Volume was made up with deionized water and the aliquots of this solution were used for determination of P and K.

3.7.6 Total Potassium (kg ha^{-1})

Total potassium in seed and stalk samples was estimated by using Flame photometer method as described by Jackson (1967). The extract was diluted to appropriate concentration and was directly atomize to the flame photometer at 548 nm wavelength.

3.8 Soil moisture studies

3.8.1 Water use efficiency

Water use efficiency (WUE) is a measure of a crop's capacity to convert water into plant biomass or grain. It includes the use of water stored in the soil and rainfall during the growing season. It is expressed in kg ha^{-1} mm^{-1}

$$\text{WUE (kg ha/mm)} = \frac{\text{Yield}}{\text{Evapotranspiration}}$$

3.9 Economics

3.9.1 Gross monetary returns (Rs ha^{-1})

The total value of produce i.e. seed and straw was estimated treatment wise as per prevailing market rates and gross monetary returns were computed.

3.9.2 Net monetary returns (Rs ha^{-1})

Net monetary returns were calculated treatment wise by subtracting the costs of cultivation from gross monetary returns. This represents the actual income to the farmers.

3.9.3 B:C ratio

The benefit cost ratio was worked out by dividing the gross return with total cost of cultivation using the following formula.

$$\text{Benefit cost ratio} = \frac{\text{Gross monetary returns (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

3.10 Statistical Analysis and Interpretation of Data

The experimental data collected during the course of investigation were analyzed with Randomized Block Design programme on computer by adopting standard statistical techniques of analysis of variance (Gomez and Gomez, 1984). Whatever, the results were significant, critical difference at p=0.05 level was calculated for comparison of treatment means. The treatment effects are presented suitably in appropriate tables and illustrated in graphs and charts.

Plate 1. General view of plot

CHAPTER IV

RESULTS AND DISCUSSION

A field experiment entitled "Effect of foliar application of potash on growth and yield of soybean under rainfed condition'' was conducted during *Kharif* Season of 2017-18 at Agronomy Farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The results obtained are interpreted and discussed in this Chapter to have a clear understanding about effect of foliar application of potash on growth and yield of soybean. The attempts have been made to provide logical reasoning for results obtained during the investigation.

4.1 Pre-harvest studies

4.1.1. Initial plant count and final plant stand

Data pertaining to initial plant stand and final plant stand as affected by various treatments are presented in Table 7.

Table 7. Initial and final plants stand as influenced by different treatments

Treatments	Initial plant stand		Final plant stand	
	Per Plot	Per Ha	Per Plot	Per Ha
T_1 - Control (No Spray)	799	766	443871	425441
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	795	751	441919	417218
T_3 - 1% KNO_3 at 25-30 DAS	794	761	441374	422931
T_4 - 2% KNO_3 at 25-30 DAS	798	761	443182	422980
T_5 - 1% KNO_3 at 60-65 DAS	791	760	439394	422348
T_6 - 2% KNO_3 at 60-65 DAS	793	764	440657	424242
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DAS	791	756	439394	419847
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	795	767	441925	426117
SE (m)±	42	36	23382	19741
CD at 5%	NS	NS	NS	NS
GM	795	761	441464	422641

Data obtained on initial plant count and final plant stand did not show any significant differences due to various treatments tried under study. It suggests that, the treatment differences obtained under various parameters are only due to the treatments imposed and not due to the variation in plant population.

4.1.2. Plant height plant $^{-1}$ (cm)

The observation of plant height plant^{-1} (cm) recorded at 20, 40, 60, 80 DAS and at harvest as influence by foliar application of potassium is given in Table 8 and graphically depicted in Fig 3.

Table 8. Plant height (cm) of soybean as influenced periodically by different treatments

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	At Harvest
T_1 - Control (No Spray)	10.77	29.97	37.45	40.24	40.30
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	10.87	33.84	38.21	40.92	40.97
T_3 - 1% KNO_3 at 25-30 DAS	10.93	38.96	45.39	47.68	47.80
T_4 - 2% KNO_3 at 25-30 DAS	10.90	36.50	43.05	46.37	46.45
T_5 - 1% KNO_3 at 60-65 DAS	11.00	32.72	38.92	42.80	42.88
T_6 - 2% KNO_3 at 60-65 DAS	10.78	31.05	38.50	41.35	41.49
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DAS	11.13	39.48	46.62	52.25	52.43
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	10.83	36.77	43.72	48.93	49.11
SE (m)±	0.38	1.20	1.35	1.50	1.51
CD at 5%	NS	3.61	4.06	4.54	4.56
GM	10.9	34.91	41.48	45.07	45.18

The observation of plant height plant^{-1}(cm) recorded at 20,40,60,80 DAS and at harvest as influenced by foliar application of potassium is presented in Table 8 and depicted in Fig. 3. Plant height increased as the crop advanced in age attaining the mean height of

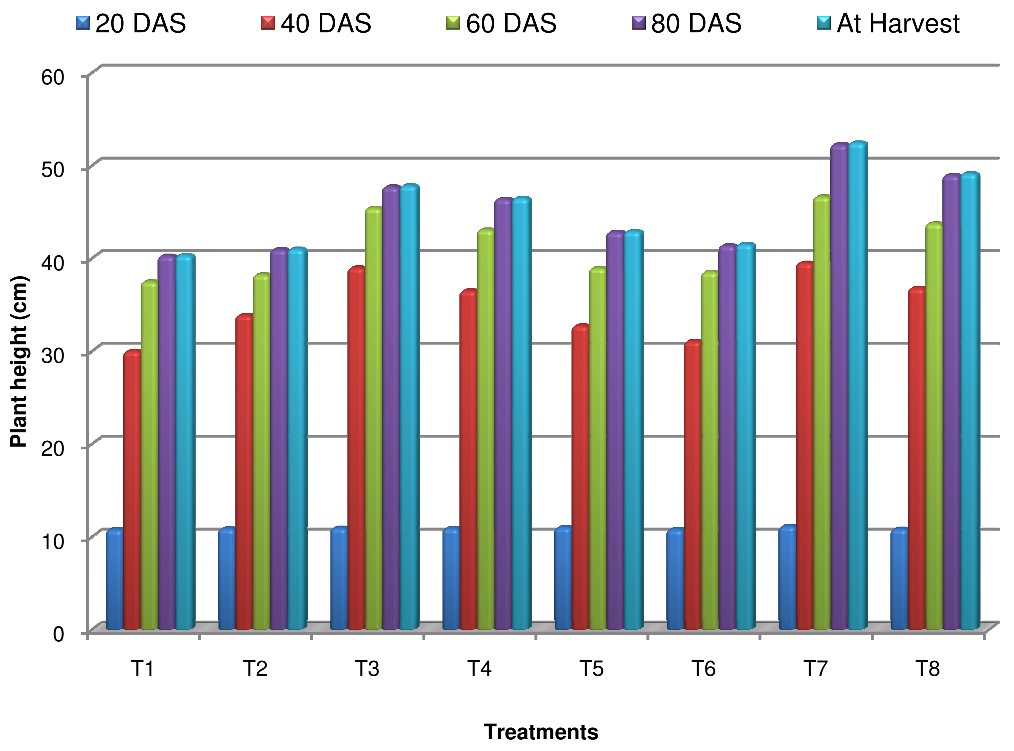


Fig. 3. Plant height (cm) of soybean as influenced periodically by different treatments

10.9 cm at 20 DAS, 34.91cm at 40 DAS, 41.48cm at 60 DAS, 45.07cm at 80 DAS and 45.18 cm at harvest. The growth rate was higher during the 20 DAS to 40 DAS and thereafter the growth slowed down.

There was non significant difference in plant height plant $^{-1}$ at 20 DAS among treatment but the plant height at 40 DAS was influenced significantly. The foliar application of 1 % KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher plant height (39.48 cm) and found at par with application of 1 % KNO_3 at 25-30 DAS (T_3) which recorded plant height (38.96 cm), 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) and 2% KNO_3 at 25-30 DAS (T_4) respectively to each other and followed by treatment of water spray at 25-30 DAS and 60- 65 DAS (T_2), 2% KNO_3 at 60-65 DAS(T_6), 1% KNO_3 at 60-65 DAS (T_5). The lowest plant height of 29.97cm was observed in T_1 (control).

At 60 DAS, application of 1 % KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher plant height (46.62 cm) and found at par with application of 1 % KNO_3 at 25-30 DAS (T_3), 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) and 2% KNO_3 at 25-30 DAS (T_4) to each other respectively and followed by 1% KNO_3 at 60-65 DAS (T_5), 2% KNO_3 at 60-65 DAS(T_6), Water Spray at 25-30 DAS and 60-65 DAS (T_2). The lowest plant height (37.45 cm) was observed in T_1 (control).

At 80 DAS, application of 1 % KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher plant height (52.25 cm) and found at par with application of 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) which recorded plant height (48.93 cm). Treatment of foliar spraying 2% KNO_3 at 25-30 DAS and 60-65 DAS was found at par with 1% KNO_3 at 25-30 DAS (T_3) and 2% KNO_3 at 25-30 DAS (T_4). The lowest plant height of 40.24 cm was observed in T_1 (control).

At harvest, application of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher plant height of 52.43cm and found at par with application of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) which recorded plant height of 49.11cm. Treatment of 2% KNO3 at 25-30

DAS and 60-65 DAS was found on par with 1% KNO_3 at 25-30 DAS (T_3) and 2% KNO_3 at 25-30 DAS (T_4). and followed by 1% KNO_3 at 60-65 DAS (T_5), 2% KNO_3 at 60-65 DAS(T_6) and water spray at 25-30 DAS and 60- 65 DAS (T_2). The lowest plant height of (40.30) was observed in T_1 (control).

Significant increase in plant height might be due to potassium enhances plant vigour and strengthens the stalk, further it has synergistic effect with nitrogen and potassium resulted in better plant growth. Similar finding were obtained by Das (1999) and Upaddhyay (1994) who reported that spraying of KNO_3 @ 100 ppm increased plant height at harvest in chickpea crop.

4.1.3 Number of branches

Data regarding number of branches $plant^{-1}$ recorded at 40, 60 and 80 DAS as influence by foliar application of potassium is given in Table 9.

Table 9. Number of branches $plant^{-1}$ of soybean as influenced periodically by different treatments

Treatments	40 DAS	60 DAS	80 DAS
T_1 - Control (No Spray)	2.35	3.20	3.35
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	2.65	3.60	3.71
T_3 - 1% KNO_3 at 25-30 DAS	3.05	4.21	4.29
T_4 - 2% KNO_3 at 25-30 DAS	3.00	4.09	4.15
T_5 - 1% KNO_3 at 60-65 DAS	2.46	3.37	4.11
T_6 - 2% KNO_3 at 60-65 DAS	2.38	3.22	4.01
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DAS	3.07	4.30	4.45
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	3.02	4.14	4.30
SE (m)±	0.12	0.18	0.21
CD at 5%	0.38	0.55	0.63
GM	2.75	3.77	4.05

The number of branches at 40 DAS was found significant due to influence of different treatments. Application of 1% KNO_3 at 25-30 and DAS 60-65 DAS (T_7) recorded significantly higher number of branches plant $^{-1}$ (3.07) and found on par with application of 1% KNO_3 at 25-30 DAS (T_3) which recorded number of branches plant $^{-1}$ (3.05), 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) and 2% KNO_3 at 25-30 DAS (T_4) to each other respectively and followed by water spray at 25-30 DAS and 60-65 DAS (T_2). The lowest number of branches plant $^{-1}$ (2.35) was observed in T_1 (control).

At 60 DAS, application of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher number of branches plant $^{-1}$ (4.30) and found at par with application of 1% KNO_3 at 25-30 DAS (T_3), 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) and 2% KNO_3 at 25-30 DAS (T_4) to each other and followed by water spray at 25-30 DAS and 60-65 DAS (T_2). The lowest number of branches plant $^{-1}$ (3.20) was observed in T_1 (control).

At 80 DAS, application of 1% KNO_3 at 25-30 and DAS 60-65 DAS (T_7) recorded significantly maximum number of branches plant^{-1}(4.45) and found at par with application of 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8), 1% KNO_3 at 25-30 DAS (T_3), 2% KNO_3 at 25-30 DAS (T_4), 1% KNO_3 at 60-65 DAS (T_5) and 2 % KNO_3 at 60-65 DAS(T_6) to each other respectively and followed by water spray at 25-30 DAS and 60- 65 DAS (T_2). The lowest number of branches plant $^{-1}$ of (3.35) was observed in T_1 (control).

The increase in number of branches might be due to increase in plant height and better uptake and translocation of plant nutrients to growing plants which boosted the plant for producing more number of branches. Similar observations were recorded by Reddy *et al.* (2004), Channakeshava *et al.* (2013). They observed that foliar application of potassium nitrate increased the number of branches plant^{-1} in cotton crop. Similar results also observed by Hosmath *et al.* (2014).

4.1.4 Number of trifoliate functional leaves plant $^{-1}$

The observations of number of trifoliate functional leaves plant^{-1} recorded at 20,40, 60 and 80 DAS and as influenced by foliar application of potassium is given Table 10. The number of functional trifoliate leaves was increased up to 60 DAS and thereafter it was reduced due to the leaf senescence.

Table10. Number of trifoliate functional leaves plant^{-1} of soybean as influenced periodically by different treatments

Treatments	20 DAS	40 DAS	60 DAS	80 DAS
T_1 - Control (No Spray)	2.13	7.83	10.77	6.51
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	1.93	8.41	11.23	7.63
T_3 - 1% KNO_3 at 25-30 DAS	2.39	10.50	15.15	8.83
T_4 - 2% KNO_3 at 25-30 DAS	2.15	9.48	14.05	8.76
T_5 - 1% KNO_3 at 60-65 DAS	2.36	8.03	10.96	8.73
T_6 - 2% KNO_3 at 60-65 DAS	2.15	7.89	10.81	8.70
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DAS	2.94	10.67	15.21	11.09
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	2.40	9.72	14.11	10.26
SE (m)±	0.24	0.32	0.50	0.33
CD at 5%	NS	0.97	1.51	1.02
GM	2.31	9.07	12.79	8.81

There was non significant difference in number of leaves plant $^{-1}$ at 20 DAS among treatments. The number of leaves plant^{-1} at 40 DAS was found significant due to influence of different treatments. The treatment, application of 1 % KNO_3 at 25-30 and 60-65 DAS (T_7) recorded significantly maximum number of leaves plant $^{-1}$ (10.67) and found at par with application of 1% KNO_3 at 25-30 DAS (T_3) and 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8). Treatment of 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) on par with 2% KNO_3 at 25-30 DAS (T_4) and followed by water spray at 25-30 DAS and 60-65 DAS (T_2), 1% KNO_3 at 60-65 DAS (T_5), 2 % KNO_3 at 60-65 DAS (T_6). The lowest number of leaves plant $^{-1}$ (7.83) was observed in T_1 (control).

At 60 DAS, application of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) was recorded significantly maximum number of functional trifoliate leaves plant^{-1} (15.21) and found at par with application of 1% KNO_3 at 25-30 DAS (T_3) which recorded number of leaves plant $^{-1}$ of (15.15) , 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) and 2% KNO_3 at 25-30 DAS (T_4) to each other respectively and followed by Water Spray at 25-30 DAS and 60- 65 DAS (T_2), 1% KNO_3 at 60-65 DAS (T_5), 2% KNO_3 at 60-65 DAS(T_6). The lowest number of functional trifoliate leaves plant^{-1} of 10.77 was observed in T_1 (control).

At 80 DAS, treatment of application of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher number of leaves plant $^{-1}$ (11.09) and found at par with application of 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) and followed by 1 % KNO_3 at 25-30 DAS (T_3), 2% KNO_3 at 25-30 DAS (T_4), 1% KNO_3 at 60-65 DAS (T_5) and 2 % KNO_3 at 60-65 DAS (T_6) which was at par with each other. The lowest number of leaves plant $^{-1}$ of 6.51 was observed in T_1 (control).

This might be due to foliar spray of nutrients is the fastest way to boost up crop growth because the nutrients application is uniform and crop reacts to nutrient application immediately. Similar kind of observations was recorded by Ashour *et al*. (1983).

4.1.5 Leaf area (dm^{-2})

The observation of leaf area recorded at 20, 40, 60 and at 80 DAS as influence by foliar application of potassium is presented in Table 11. The leaf area increased with the age in progress up to 60 DAS and thereafter the reduction of leaf area observed due to the leaf senescence. The rate of increase in leaf area was higher from 20 DAS to 60 DAs and thereafter rate of increase was less.

Table 11. Leaf area plant^{-1} (dm^2) of soybean as influenced periodically by different treatments

Treatments	20 DAS	40 DAS	60 DAS	80 DAS
T_1 - Control (No Spray)	2.98	8.30	11.25	7.27
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	2.78	8.88	11.83	8.39
T_3 - 1% KNO_3 at 25-30 DAS	3.24	10.97	15.75	9.59
T_4 - 2% KNO_3 at 25-30 DAS	3.00	9.95	14.65	9.52
T_5 - 1% KNO_3 at 60-65 DAS	3.21	8.50	11.56	9.49
T_6 - 2% KNO_3 at 60-65 DAS	3.00	8.36	11.41	9.46
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DAS	3.59	11.14	15.81	11.85
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	3.25	10.19	14.71	11.02
SE (m)±	0.22	0.34	0.59	0.35
CD at 5%	NS	1.01	1.79	1.07
GM	3.13	9.54	13.37	9.57

The non significant difference in respect of leaf area was found at 20 DAS. The leaf area per plant was found significant at 40 DAS. The application of 1% KNO_3 at 25-30 and DAS 60-65 DAS (T_7) recorded significantly higher leaf area (11.14 dm^2) and found at par with application of 1% KNO_3 at 25-30 DAS (T_3) and 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) to each other respectively. Similarly, treatment of 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) was found at par with 2% KNO_3 at 25-30 DAS (T_4). The lowest of leaf area of (8.30) was observed in T_1 (control).

At 60 DAS, application of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) was found significantly higher leaf area plant^{-1} (15.81dm^2) and at par with application of 1% KNO_3 at 25-30 DAS (T_3), 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) and 2% KNO_3 at 25-30 DAS (T_4) to each other respectively and followed by Water Spray at 25-30 DAS and 60- 65 DAS

(T_2), 1% KNO_3 at 60-65 DAS (T_5), 2 % KNO_3 at 60-65 DAS(T_6). The lowest leaf area plant^{-1} of (11.25) was observed in T_1 (control).

At 80 DAS, application of 1 % KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly maximum leaf area plant^{-1} (11.85 dm^2) and found at par with application of 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) which recorded of leaf area of (11.02) to each other respectively and followed by 1% KNO_3 at 25-30 DAS (T_3), 2 % KNO_3 at 25-30 DAS (T_4), 1% KNO_3 at 60-65 DAS (T_5) and 2% KNO_3 at 60-65 DAS (T_6) which were at par with each other. The lowest leaf area of 7.27 dm^2 was observed in T_1 (control).

This might be due to foliar application of potassium nitrate which influence the growth and nitrate reducatse activity and therefore increase in leaf area. Similar kind of observations was recorded by Jabeen and Ahmad (2013) reported that significantly higher leaf area, leaves freash weight and leaves dry weight due to foliar application of KNO_3 in sunflower and safflower crops. The results was in line with the findings of Jayaramiraddy *et al.*, (2000) they reported that leaf area was more with the foliar spray of KNO_3 @1% when compared with NAA @ 15 ppm in blackgram.

4.1.6 Total dry matter accumulation plant $^{-1}$ (g)

Data pertaining total dry matter plant $^{-1}$ (g) recorded at 20, 40, 60, 80 DAS and at harvest as influenced by foliar application of potassium are given in Table 12 and depicted in Fig. 4.

The treatments of potassium application not reach to the significance levels at 20 DAS in respect of total dry matter plant^{-1}. The total dry matter plant $^{-1}$ at 40 DAS influenced significantly due to the foliar application of potassium. The treatment, application of 1 % KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher total dry matter plant $^{-1}$ (8.61gm) and found at par with application of 1 % KNO_3 at 25-30 DAS (T_3), 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) and 2% KNO_3 at

25-30 DAS (T_4) to each other respectively and followed by Water Spray at 25-30 DAS and 60- 65 DAS (T_2). The lowest total dry matter plant $^{-1}$ of (5.09 g) was observed in T_1 (control).

Table 12. Total dry matter production plant^{-1} (g) of soybean as influenced periodically by different treatments

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	At Harvest
T_1 - Control (No Spray)	0.93	5.09	10.72	20.36	21.13
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	0.93	6.05	12.27	23.51	24.48
T_3 - 1% KNO_3 at 25-30 DAS	0.95	8.45	15.75	27.53	28.03
T_4 - 2% KNO_3 at 25-30 DAS	0.99	7.74	14.84	26.63	27.71
T_5 - 1% KNO_3 at 60-65 DAS	1.03	5.13	11.81	29.62	31.01
T_6 - 2% KNO_3 at 60-65 DAS	0.93	5.1	11.72	28.83	29.25
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DAS	1.04	8.61	15.89	34.51	35.88
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	1.02	7.82	14.95	32.77	34.19
SE (m)±	0.04	0.31	0.47	0.99	1.02
CD at 5%	NS	0.95	1.43	3.05	3.13
GM	0.98	6.75	13.49	27.97	28.96

At 60 DAS, application of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher total dry matter plant $^{-1}$ (15.89 g) and found at par with application of 1 % KNO_3 at 25-30 DAS (T_3), 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) and 2% KNO_3 at 25-30 DAS (T_4) to each other respectively and followed by Water Spray at 25-30 DAS and 60-65 DAS (T_2), 1% KNO_3 at 60-65 DAS (T_5), 2% KNO_3 at 60-65 DAS(T_6). The lowest of total dry matter plant $^{-1}$ of (10.72 g) was observed in T_1 (control).

At 80 DAS, application of 1 % KNO_3 at 25-30 and DAS 60-65 DAS (T_7) recorded significantly higher of total dry matter plant^{-1}

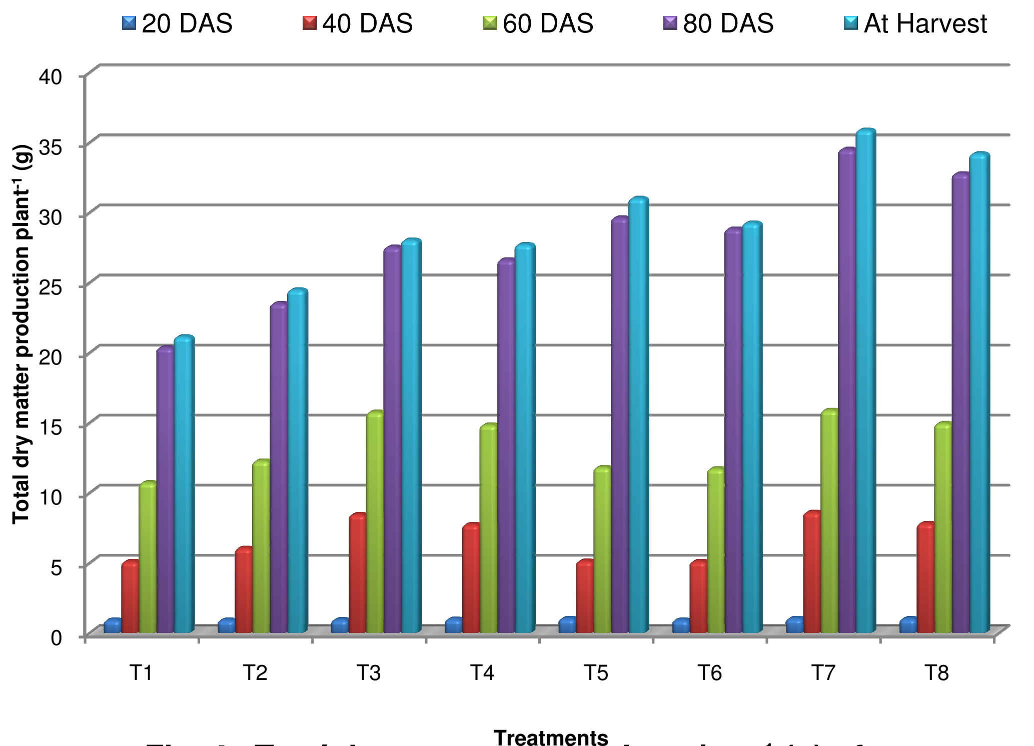


Fig. 4. Total dry matter production plant^{-1} (g) of soybean as influenced periodically by different treatments

(34.51g) and found at par with application of 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) and followed by 1% KNO_3 at 60-65 DAS (T_5) , 2% KNO_3 at 60-65 DAS (T_6), 1% KNO_3 at 25-30 DAS (T_3) and 2% KNO_3 at 25-30 DAS (T_4) which was at par with each other. The lowest of total dry matter plant $^{-1}$ of (20.36 g) was observed in T_1 (control).

At harvest, application of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher of total dry matter plant $^{-1}$ (35.88 g) and found at par with application of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) and followed by 1% KNO_3 at 60-65 DAS (T_5), 2% KNO_3 at 60-65 DAS (T_6), 1% KNO_3 at 25-30 DAS (T_3), 2% KNO_3 at 25-30 DAS (T_4) which were at par with each other. The lowest total dry matter plant $^{-1}$ of (21.13 g) was observed in T_1 (control).

This might be due to increase in physiological processes of plant and helped in increasing the biomass production by improving the growth i.e. plant height, no. of trifoliate leaves and leaf area which increase the photosynthesis and ultimately the dry matter. Similar observations were recorded by Hiwale (2015) who observed that application of foliar sprays of KNO_3 @1.0 per cent at 45 and 60 DAS improved in total dry matter.

4.1.7 Relative water content (%)

Data on Relative water content as influenced by different treatments recorded periodically are presented in Table 13 and depicted in Fig. 5.

The significant difference was observed in different treatments regarding relative water content (RWC) at 40 DAS. The application of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher relative water content (87.15) and found at par with application of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) which recorded Relative water content of (84.91) to each other respectively and followed by 1% KNO_3 at 25-30 DAS (T_3), 2% KNO_3 at 25-30 DAS (T_4), 1%

KNO_3 at 60-65 DAS (T_5), 2% KNO_3 at 60-65 DAS(T_6), Water Spray at 25-30 DAS and 60- 65 DAS (T_2). The lowest Relative water content of (74.70) was observed in T_1 (control).

Table 13. Relative water content (%) of soybean as influenced periodically by different treatments

Treatment	Relative Water Content (%)		
	40 DAS	**60 DAS**	**80 DAS**
T_1 - Control (No Spray)	74.70	75.17	72.14
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	74.94	75.67	73.53
T_3 - 1% KNO_3 at 25-30 DAS	84.05	84.34	75.98
T_4 - 2% KNO_3 at 25-30 DAS	82.66	83.06	74.08
T_5 - 1% KNO_3 at 60-65 DAS	79.32	79.84	75.85
T_6 - 2% KNO_3 at 60-65 DAS	82.39	83.60	76.35
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DAS	87.15	87.15	78.98
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	84.91	84.81	78.01
SE (m)±	0.62	0.52	0.37
CD at 5%	1.90	1.61	1.13
GM	81.27	81.70	75.61

At 60 DAS, significantly highest relative water content (87.15) was recorded in treatment of foliar application 1% KNO_3 at 25-30 and DAS 60-65 DAS (T_7). Similarly, treatment of 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) recorded relative water content of (84.81), followed by 1 % KNO_3 at 25-30 DAS (T_3) and 2% KNO_3 at 60-65 DAS(T_6) which were on par with each other. The lowest Relative water content of (75.17) was observed in T_1 (control).

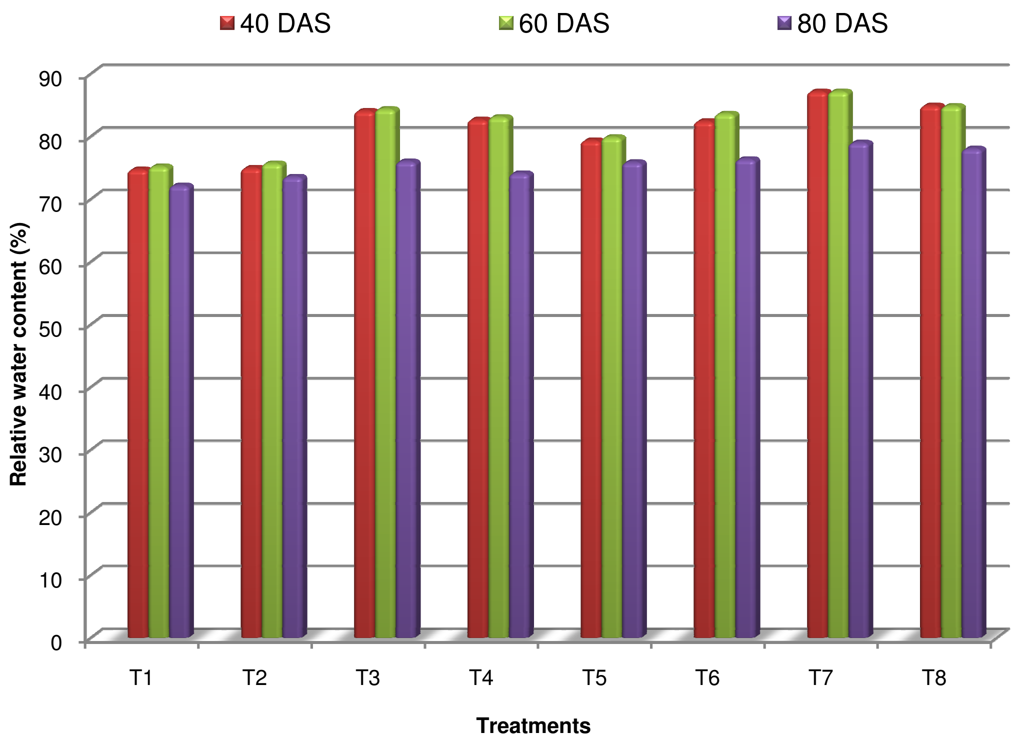


Fig. 5. Relative water content (%) of soybean as influenced periodically by different treatments

At 80 DAS, application of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher relative water content (78.98) and found at par with application 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) which recorded Relative water content of (78.01). Similarly, treatment of 2% KNO_3 at 60-65 DAS (T_6), 1% KNO_3 at 60-65 DAS (T_5) and 1% KNO_3 at 25-30 DAS (T_3) found at par with each other and followed by 2% KNO_3 at 25-30 DAS (T_4). The lowest relative water content of (72.14) was observed in T_1 (control).

This might be due to foliar application of potassium nitrate which provides nitrogen and potassium to the plants. Potassium plays an important role for maintaining the turgidity of the stomata and transpiration and stomatal behavior of the plants. These results were supported by Vekaria *et al.* (2013).

4.1.8. Chlorophyll content

The relevant data pertaining to chlorophyll content recorded at before and after spraying as influence by foliar application of potassium are given in Table 14 and depicted in Fig. 6.

There was non significant difference in chlorophyll content at 25-30 DAS among treatment before foliar application of potassium. But after foliar application of potassium nitrate on 25-30 DAS, it was found significant difference among the treatments. Foliar application of 1 % KNO_3 at 25-30 and DAS 60-65 DAS (T_7) recorded significantly higher chlorophyll content (41.33) and found at par with application of 1% KNO_3 at 25-30 DAS (T_3), 2% KNO_3 at 25-30 and DAS 60-65 DAS (T_8) and 2% KNO_3 at 25-30 DAS (T_4) to each other. Similarly, the treatment of Water Spray at 25-30 DAS and 60-65 DAS (T_2), 1% KNO_3 at 60-65 DAS (T_5), 2% KNO_3 at 60-65 DAS(T_6) and T_1 (control) found at par with each other.

Before foliar application at 60-65 DAS, 1 % KNO_3 at 25-30 and DAS 60-65 DAS (T_7) recorded significantly higher chlorophyll content (42.27) and found at par with application of 1 % KNO_3 at 25-30 DAS (T_3), 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) and 2% KNO_3 at 25-30 DAS

(T_4) and followed by Water Spray at 25-30 DAS and 60-65 DAS (T_2), 1% KNO_3 at 60-65 DAS (T_5), 2% KNO_3 at 60-65 DAS (T_6). The lowest chlorophyll content (38.00) was observed in T_1 (control).

Table 14. Chlorophyll content of soybean as influenced periodically by different treatments

Treatment	Before spraying	After spraying	Before spraying	After spraying
	25-30 DAS		60-65 DAS	
T_1 - Control (No Spray)	36.51	37.57	38.00	38.35
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	36.10	38.60	39.17	40.11
T_3 - 1% KNO_3 at 25-30 DAS	36.75	41.10	42.05	43.70
T_4 - 2% KNO_3 at 25-30 DAS	35.96	40.33	41.31	42.90
T_5 - 1% KNO_3 at 60-65 DAS	36.20	37.92	38.60	42.67
T_6 - 2% KNO_3 at 60-65 DAS	36.44	37.07	38.31	43.05
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DAS	36.62	41.33	42.27	46.00
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	36.01	40.97	41.30	45.23
SE (m)±	0.28	0.35	0.37	0.50
CD at 5%	NS	1.05	1.12	1.59
GM	36.32	39.36	40.12	42.75

After foliar application at 60-65 DAS, 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher chlorophyll content (46.00) and found at par with application of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8). Similarly, treatment of 1 % KNO_3 at 25-30 DAS (T_3), 2 % KNO_3 at 60-65 DAS (T_6), 2% KNO_3 at 25-30 DAS (T_4), 1% KNO_3 at 60-65 DAS (T_5) and Water Spray at 25-30 DAS were at par with each other. The lowest chlorophyll content (38.35) was observed in T_1 (control).

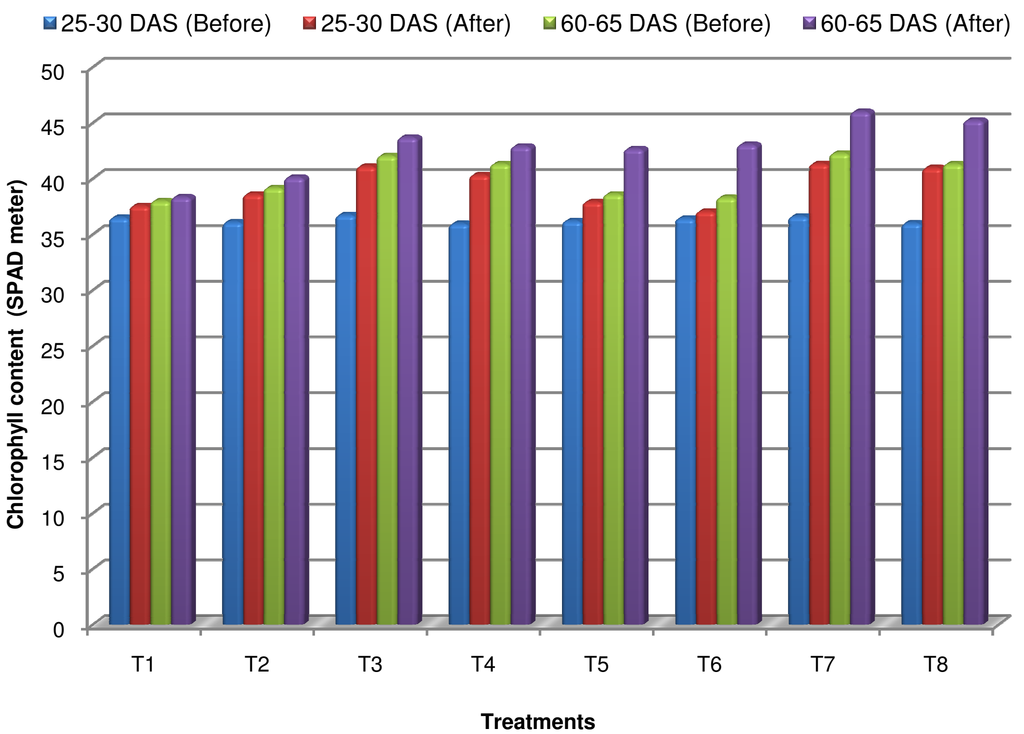


Fig. 6. Chlorophyll content of soybean as influenced periodically by different treatments

This might be due to delay the synthesis of abscisic acid and promoted cytokinin activity, causing higher chlorophyll retention. Similar kind of observations was recorded by Mengal (1976) and Makbul *et al*. (2011).

4.2 Root studies

4.2.1. Root length plant $^{-1}$ (cm)

Data pertaining on root length plant $^{-1}$ (cm) recorded periodically as influenced by foliar application of potassium are given in Table 15.

Table 15. Root length plant^{-1} (cm) of soybean as influenced periodically by different treatments

Treatment	20 DAS	40 DAS	60 DAS	80 DAS
T_1 - Control (No Spray)	3.99	14.40	17.16	17.49
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	4.11	16.69	19.43	18.81
T_3 - 1% KNO_3 at 25-30 DAS	4.36	18.27	21.44	20.34
T_4 - 2% KNO_3 at 25-30 DAS	4.22	17.19	21.27	19.84
T_5 - 1% KNO_3 at 60-65 DAS	4.19	14.84	17.40	20.79
T_6 - 2% KNO_3 at 60-65 DAS	4.27	14.63	17.24	20.54
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DAS	4.50	18.35	21.91	23.14
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	4.53	17.40	21.65	23.01
SE (m)±	0.20	0.58	0.66	1.68
CD at 5%	NS	1.75	1.97	2.05
GM	4.27	16.47	19.68	20.49

The root length of the plants was found non significant among the treatment difference at 20 DAS. The root length of the plant at 40 DAS was found significant. Application of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher root length (18.35cm) and found at par with application of 1% KNO_3 at 25-30 DAS (T_3), 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8), 2% KNO_3 at 25-30 DAS (T_4) and Water Spray at 25-30 DAS and 60-65 DAS (T_2) to each other respectively. The lowest root length of (14.40 cm) was observed in T_1 (control).

At 60 DAS, application of 1% KNO_3 at 25-30 and DAS 60-65 DAS (T_7) recorded significantly higher root length (21.91 cm) and found at par with application of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8), 1% KNO_3 at 25-30 DAS (T_3), 2% KNO_3 at 25-30 DAS (T_4) to each other respectively and followed by Water Spray at 25-30 DAS and 60-65 DAS (T_2). The lowest root length of (17.16 cm) was observed in T_1 (control).

At 80 DAS, significantly higher root length of (23.14 cm) recorded in application of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) and found at par with application of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8). Similarly, foliar application of 1% KNO_3 at 60-65 DAS (T_5), 2% KNO_3 at 60-65 DAS (T_6), 1% KNO_3 at 25-30 DAS (T_3), 2% KNO_3 at 25-30 DAS (T_4) and Water Spray at 25-30 DAS and 60-65 DAS (T_2) found at par with each other. The lowest root length of (17.49cm) was observed in T_1 (control). Similar kind of observations was recorded Abdullahil *et al.* (2006).

4.2.2. Number of root nodule plant $^{-1}$

The observation on root nodules plant $^{-1}$ recorded at 40, 60 and 80 DAS as influenced by foliar application of potassium are presented in Table 16.

At 40 DAS, number of root nodules plant^{-1} was recorded significantly maximum in application of 1 % KNO_3 at 25-30 and DAS 60-65 DAS (T_7) (21.33) and found at par with application of 1% KNO_3 at 25-30 DAS (T_3) which recorded root nodules plant $^{-1}$ of (21.00), 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) and 2% KNO_3 at 25-30 DAS (T_4). Similarly, treatment of 2% KNO_3 at 25-30 DAS (T_4) at par with water spray at 25-30 DAS and 60- 65 DAS (T_2). The lowest root nodules plant $^{-1}$ of (16.36) was observed in T_1 (control).

Table 16. Number of root nodule plant^{-1} of soybean as influenced periodically by different treatments

Treatment	40 DAS	60 DAS	80 DAS
T_1 - Control (No Spray)	16.36	21.00	23.31
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	19.00	24.21	28.67
T_3 - 1% KNO_3 at 25-30 DAS	21.00	29.33	30.00
T_4 - 2% KNO_3 at 25-30 DAS	19.51	28.04	29.15
T_5 - 1% KNO_3 at 60-65 DAS	16.61	21.57	28.00
T_6 - 2% KNO_3 at 60-65 DAS	16.40	21.63	27.83
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DAS	21.33	29.67	34.72
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	19.67	28.21	32.48
SE (m)±	0.62	0.69	1.88
CD at 5%	1.86	2.06	2.23
GM	19.54	25.96	25.50

At 60 DAS, application of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher number of root nodules plant^{-1} (29.67) and found at par with application of 1% KNO_3 at 25-30 DAS (T_3), 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) and 2% KNO_3 at 25-30 DAS (T_4) each other and followed by Water Spray at 25-30 DAS and 60-65 DAS (T_2). The lowest root nodules plant^{-1} of (21.00) was observed in T_1 (control).

At 80 DAS, significantly highest number of root nodules plant^{-1} (34.72) recorded in treatment of application 1% KNO_3 at 25-30 DAS and 60 -65 DAS (T_7) and followed by application of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8). Similarly, foliar application of 1% KNO_3 at 25-30 DAS (T_3), 2% KNO_3 at 25-30 DAS (T_4), Water Spray at 25-30 DAS and 60-65 DAS (T_2), 1% KNO_3 at 60-65 DAS (T_5), 2 % KNO_3 at 60-65

DAS (T_6) were at par with each other. The lowest root nodules plant^{-1} of (23.31) was observed in T_1 (control).

Similar results were observed by Goud *et al.*, (2014) and Hiwale (2015). They reported that higher no. of nodule plant^{-1} due to application of RDF with 2 per cent spray of KNO_3 at flowering and 15 days thereafter. Potassium contributes to good root growth and has been shown to improve the number and size of nodules on roots. The application of K to responsive soils can increase both nodule size and number. This results in improved nodule activity and conversion of atmospheric N into organic forms of N.

4.3 Post harvest studies

4.3.1 Number of pods plant^{-1}

Data pertaining of number of pods plant^{-1}, number of seeds pod^{-1}, seed yield plant^{-1} and 100 seed weight (g) of soybean as influenced by different treatments are presented in Table 17 and depicted in Fig. 7 & Fig. 8

Different treatments of potassium application had significant influence on number of pods plant^{-1}. Application of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher number of pods plant^{-1} (67.25) and found at par with application of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) which recorded number of pods plant^{-1} of (62.58). Similarly, treatment of 1% KNO_3 at 60-65 DAS (T_5), 2% KNO_3 at 60-65 DAS(T_6), 1% KNO_3 at 25-30 DAS (T_3) and 2% KNO_3 at 25-30 DAS (T_4) found at par with each other and followed by treatment of Water Spray at 25-30 DAS and 60-65 DAS (T_2). The lowest number of pods plant^{-1} of (36.95) was observed in T_1 (control).

This might be due to, the application of potassium nitrate supplied N and K which are absorbed as anion and cation by plants, and might have delayed the synthesis of abscisic acid and promoted cytokinin activity causing higher chlorophyll retention which in turn promoted more leaf area. This may secure higher phosynthetic activity in effective leaves and supplied to developing pods with current photosynthates for proper filling, resulting in higher yield. Thalooth *et al.* (2006), Venkaria (2013), Gowda *et al.* (2014) and Kumar *et al.* (2017) also reported similar results.

Table 17. Number of pods plant^{-1}, number of seeds pod^{-1}, seed yield plant^{-1} and 100 seed weight of soybean as influenced by different treatments

Treatment		Yield attributes per plant			
	No. of pods/ plant	Seeds/ pod	Seed wt/plant	Seed pod wt/plant	Test wt
T_1 - Control (No Spray)	36.95	2.68	7.57	12.2	12.02
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	43.51	2.71	9.09	14.12	12.11
T_3 - 1% KNO_3 at 25-30 DAS	51.32	2.82	10.24	16.31	12.20
T_4 - 2% KNO_3 at 25-30 DAS	49.75	2.79	10.15	16.05	12.17
T_5 - 1% KNO_3 at 60-65 DAS	55.11	2.88	11.02	17.77	12.94
T_6 - 2% KNO_3 at 60-65 DAS	52.43	2.85	10.54	16.93	12.42
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DAS	67.25	2.97	13.02	21.25	13.02
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	62.58	2.90	12.23	19.76	13.00
SE (m)±	2.48	0.15	0.35	0.61	0.45
CD at 5%	5.64	NS	1.05	1.89	NS
GM	52.36	2.83	10.48	16.80	12.49

4.3.2 Number of seed pod^{-1}

The relevant data on number of seeds per pod as influenced by different treatments are presented in Table 17. Mean seeds per plant was 2.83.

The treatment difference was not reach to the significance levels. as it is a genetically controlled parameter. Hence no significant

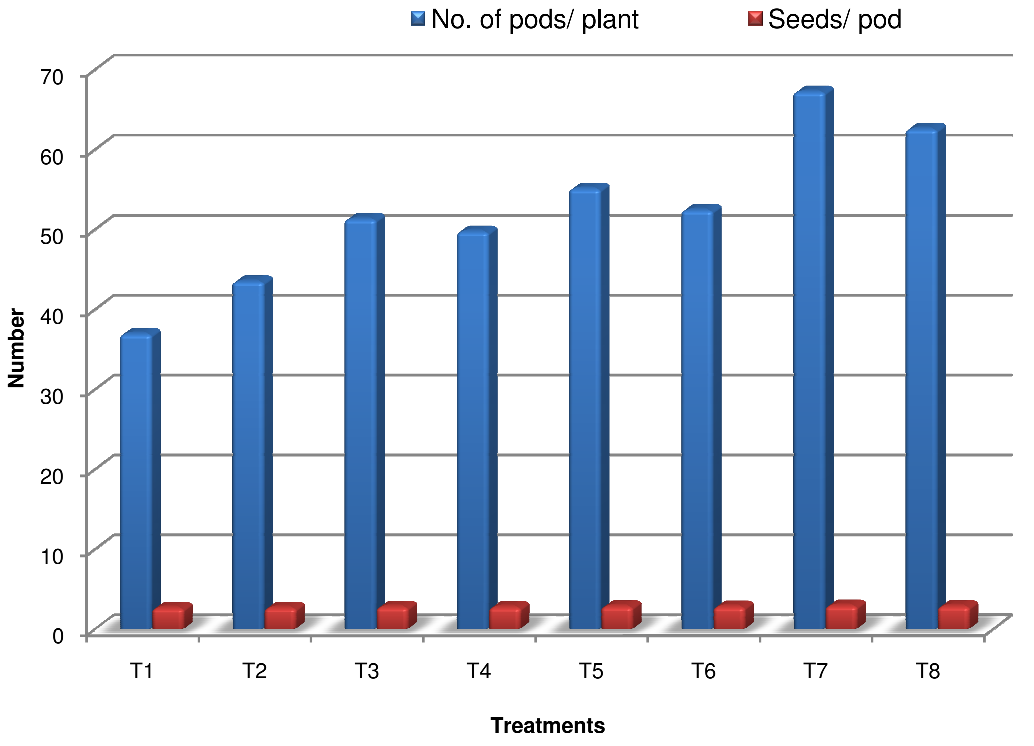


Fig. 7. Number of pods plant^{-1} and number of seeds pod^{-1} of soybean as influenced by different treatments

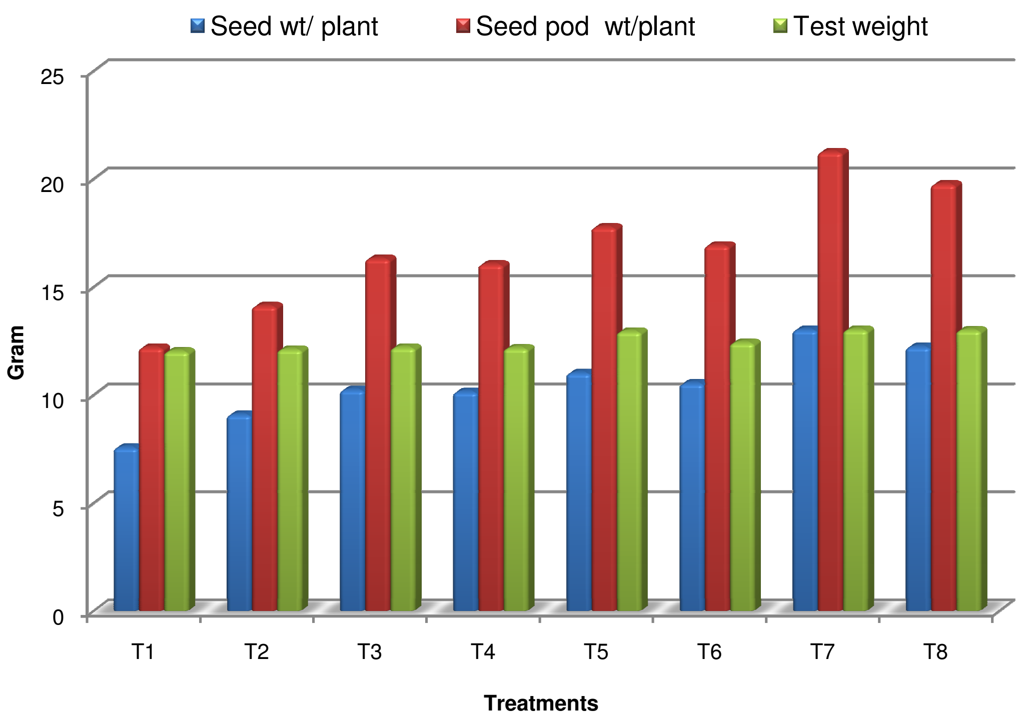


Fig. 8. Seed yield plant^{-1}, 100 seed weight and test weight of soybean as influenced by different treatments

differences were observed among treatments for the number of seeds per pod. Similar result was supported by Sanbagavalli *et al.* (2017).

4.3.3 Weight of seeds plant^{-1} (g)

Data on number of seeds per pod as influenced by different treatments are presented in Table 17.

The seed weight plant^{-1} was significantly influenced by various treatments. The seed weight plant^{-1} was significantly superior in treatment of application of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) and found at par with application of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8). Similarly, treatment of 1% KNO_3 at 60-65 DAS (T_5), 2% KNO_3 at 60-65 DAS (T_6), 1% KNO_3 at 25-30 DAS (T_3) and 2% KNO_3 at 25-30 DAS (T_4) was found at par with each other and followed by Water Spray at 25-30 DAS and 60-65 DAS (T_2). The lowest weight of seeds plant $^{-1}$ of (7.57g) was observed in T_1 (control)

This might be due to increases assimilate production and transportation from source to sink thereby increasing yield components. Similar kind of observations was recorded in grasspea crop by Sarkar and Malik (2001).

4.3.4 Seed pod weight plant^{-1} (g)

Data regarding on seed pod weight plant^{-1} of soybean are presented in Table 17.

The differences among the treatments were found significant. Application of 1% KNO_3 at 25-30 DAS and 60-65DAS (T_7) recorded significantly higher seed pod weight plant^{-1} (21.25g) and found on par with application of 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8). Similarly, treatment of 1% KNO_3 at 60-65 DAS (T_5), 2% KNO_3 at 60-65 DAS (T_6), 1%KNO_3 at 25-30 DAS (T_3) and 2% KNO_3 at 25-30 DAS (T_4) found at par with each other and followed by Water Spray at 25-30 DAS and 60-65 DAS (T_2). The lowest seed pod weight of (12.2g) was observed in T_1 (control).

This might be due to, the application of potassium nitrate supplied N and K which are absorbed as anion and cation by plants, and might have delayed the synthesis of abscisic acid and promoted cytokinin activity causing higher chlorophyll retention which in turn promoted more leaf area. This may secure higher phosynthetic activity in effective leaves and supplied to developing pods with current photosynthates for proper filling, resulting in higher yield. Thalooth *et al.* (2006), Venkaria (2013), Gowda *et al.* (2014) and Kumar *et al.* (2017) also reported similar results.

4.3.5 Test weight (g)

The data pertaining to test weight (g) are presented in Table 17.

The difference among the treatments regarding test weight (g) was not reach to significance levels while numerically 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded higher test weight (13.02g) and followed by the treatment of application of 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8). The lowest test weight of (12.02 g) was observed in T_1 (control).

4.3.6 Seed yield (kg ha^{-1})

Data on seed yield (kg ha^{-1}), straw yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%) of soybean as influenced by different treatments are presented in Table 18 and depicted in Fig. 9.

Seed yield was significantly influenced by various treatments. Treatment of application 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher grain yield (2135 kg ha^{-1}) and found at par with application of 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) which recorded of grain yield (2055 kg ha^{-1}). Similarly, treatment of 1% KNO_3 at 60-65 DAS (T_5), 2% KNO_3 at 60-65 DAS (T_6), 1% KNO_3 at 25-30 DAS (T_3), 2% KNO_3 at 25-30 DAS (T_4) were found at par with each other. The lowest grain yield of (1590kg ha^{-1}) was observed in T_1 (control).

Table 18. Seed yield (kg ha^{-1}), straw yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%) in soybean seed as influenced by different treatments

Treatment	Seed yield	Straw yield	Biological yield	HI
T_1 - Control (No Spray)	1590	2103	3693	43.05
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	1651	2140	3791	43.55
T_3 - 1% KNO_3 at 25-30 DAS	1852	2391	4243	43.65
T_4 - 2% KNO_3 at 25-30 DAS	1820	2356	4176	43.58
T_5 - 1% KNO_3 at 60-65 DAS	1905	2445	4350	43.79
T_6 - 2% KNO_3 at 60-65 DAS	1880	2422	4302	43.70
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DAS	2135	2677	4812	44.37
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	2055	2610	4665	44.05
SE (m)±	47	71	103	.
CD at 5%	145	213	310	.
GM	1861	2393	4254	43.71

The application of potassium nitrate supplied N and K which are absorbed as anion and cation by plants, and might have delayed the synthesis of abscisic acid and promoted cytokinin activity causing higher chlorophyll retention which in turn promoted more leaf area. This may secure higher phosynthetic activity in effective leaves and supplied to developing pods with current photosynthates for proper filling, resulting in higher yield. Vekaria *et al*. (2013)) and Kumar *et al.* (2017) also found similar results.

4.3.7 Straw yield (kg ha^{-1})

Data on straw yield (kg ha^{-1}) is presented in Table 18. The mean of straw yield was 2393 kg ha^{-1}.

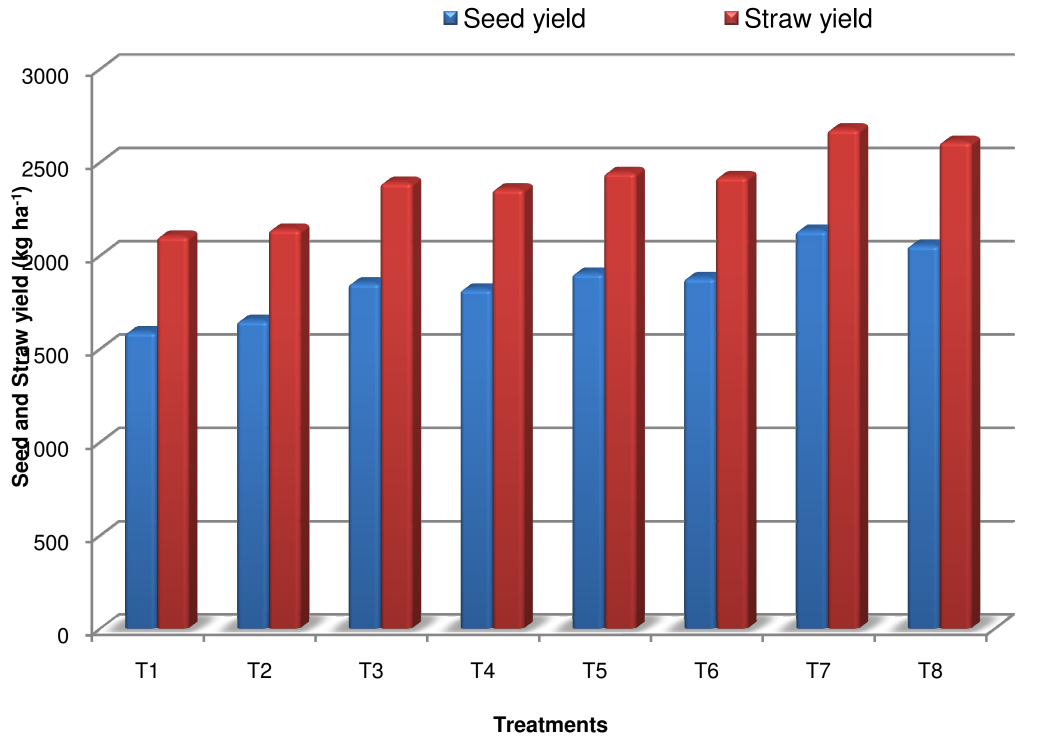


Fig. 9. Seed yield and straw yield (kg ha^{-1}) in soybean seed as influenced by different treatments

The straw yield (kg ha^{-1}) was significantly influenced due to the treatment difference. Treatment of 1 % KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher straw yield (2677 kg ha^{-1}) and found at par with application of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) which recorded of straw yield (2610 kg ha^{-1}) to each other respectively. The treatment of 1% KNO_3 at 60-65 DAS (T_5), 2% KNO_3 at 60-65 DAS (T_6), 1 % KNO_3 at 25-30 DAS (T_3) and 2% KNO_3 at 25-30 DAS (T_4) were found at par with each other. The lowest straw yield of (2103 kg ha^{-1}) was observed in treatment T_1 (control).

This might be due to increase in plant height, number of branches, number of functional leaves and dry matter accumulation which ultimately convert in the physiological and reproductive growth. The results were supported by Babalad (1999).

4.3.8 Biological yield (kg ha^{-1})

Biological yield manifest the overall status of plant dry matter including the economic yield and quantity of straw, stalk or stover obtained from the plant on hectare basis. It highlights the plant response to various treatments under investigation and makes the treatment effect more magnified. The data on biological yield are presented in Table 18.

The treatment of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher biological yield (4812kg ha^{-1}) and found at par with application of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) which recorded of biological yield (4665 kg ha^{-1}) to each other respectively. Similarly, treatment of 1% KNO_3 at 60-65 DAS (T_5), 2% KNO_3 at 60-65 DAS (T_6), 1 % KNO_3 at 25-30 DAS (T_3) and 2% KNO_3 at 25-30 DAS (T_4) were found at par with each other. The lowest biological yield of (3693 kg ha^{-1}) was observed in T_1 (control). The results were supported by Moinuddin and Goswami (2004) in wheat.

4.3.9 Harvest index (%)

The data regarding seed yield as influenced by foliar application of potassium are resented in Table 18.

Among all the treatments, foliar application of 1% KNO_3 at 25-30 DAS and 60-65DAS (T_7) recorded maximum harvest index (44.37%) and followed by application of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) which recorded harvest index of (44.05%). The minimum harvest index of (43.05%) was observed in T_1 (control).

Harvest index (HI) represents the increased physiological capacity (sink capacity) to mobilize photosynthate and translocate to organs having economic value. It is a convenient index to express numerically what proportion of total dry matter of the plant was apportioned to grain.

Similar kind of observations was reported by Narasimharao *et al.* (2005).

4.4 Economics observation

4.4.1 Gross monetary return (Rs ha^{-1})

The data pertaining on Gross monetary return of soybean as influenced by foliar application of potassium are given in Table 19 and depicted in Fig. 10.

The gross monetary returns were significantly influenced among the treatment difference. The treatment of foliar application 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly maximum gross monetary returns (Rs. 80079 ha^{-1}) and found at par with application of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) which recorded of gross monetary returns of (Rs.77115 ha^{-1}) and followed by 1% KNO_3 at 60-65 DAS (T_5), and 2% KNO_3 at 60-65 DAS (T_6), 1% KNO_3 at 25-30 DAS (T_3), and 2% KNO_3 at 25-30 DAS (T_3) . The minimum gross monetary return of (Rs.59856 ha^{-1}) was observed in T_1 (control).

Table 19. Cost of cultivation, gross and net monetary returns and benefits cost ratio of soybean as influenced by different treatments

Treatment	COC	GMR	NMR	B:C
T_1 - Control (No Spray)	28073	59856	31783	2.13
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	28993	62065	33072	2.14
T_3 - 1% KNO_3 at 25-30 DAS	29890	69602	39712	2.33
T_4 - 2% KNO_3 at 25-30 DAS	30787	68412	37625	2.22
T_5 - 1% KNO_3 at 60-65 DAS	30020	71565	41545	2.38
T_6 - 2% KNO_3 at 60-65 DAS	30917	70644	39727	2.28
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DAS	31837	80079	48242	**2.52**
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	33631	77145	43514	2.29
SE (m)±	.	1845	1845	0.06
CD at 5%	.	5536	5536	0.19
GM	30519	69921	39402	2.28

This might be due to improvement in growth and yield attributes and ultimate increase in seed yield could be the reason for enhanced economic returns in the above treatments. Similar observation was recorded by Jayachandran *et al.* (2004).

4.4.2 Net monetary return (Rs ha^{-1})

Data on net monetary returns of soybean as influenced by the foliar application of potash in different treatments presented in Table 19 and depicted in Fig. 10.

The net monetary returns were significantly influenced among the treatments. Application of 1 % KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher NMR (Rs. 48242 ha^{-1}) and found at par with application of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) which recorded of NMR (Rs.43514 ha^{-1}) and followed by 1% KNO_3 at 60-65

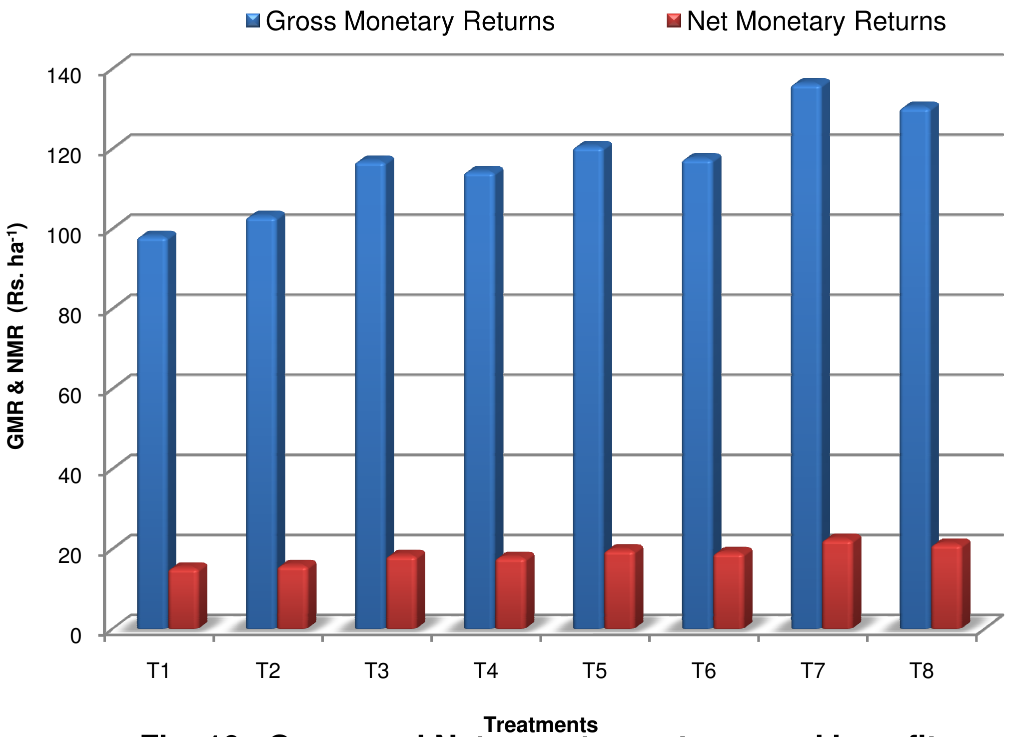


Fig. 10. Gross and Net monetary returns and benefits cost ratio of soybean as influenced by different treatments

DAS (T_5), and 2% KNO_3 at 60-65 DAS (T_6), 1% KNO_3 at 25-30 DAS (T_3) and 2% KNO_3 at 25-30 DAS (T_4) which were at par with each other. The lowest NMR of (Rs. 31783 ha^{-1}) was observed in T_1 (control).

This might be due to improvement in growth and yield attributes and ultimate increase in seed yield could be the reason for enhanced economic returns in the above treatments. Similar kind of observations was recorded by Jayachandran *et al.* (2004). The similar finding were revealed by Goud *et al.* (2014) in chickpea crop and Kumar and Shrivastava (2015) in cotton crop.

4.4.3 Benefit: Cost ratio

Data pertaining on B:C ratio of soybean as influenced by the foliar application of potash in different treatments presented in Table 19.

Maximum B:C ratio of 2.52 were recorded in treatment of application of 1% KNO_3 DAS at 25-30 and 60-65 DAS (T_7) and followed by treatment of 1 % KNO_3 at 60-65 DAS (T_5) and 1 % KNO_3 at 60-65 DAS (T_5). The lowest Benefit: Cost ratio of 2.13 was observed in T_1 (control).

Similar observation was recorded by Kumar and Srivastava (2015). They revealed that higher net returns and benefit cost ratio was obtained due to foliar application of KNO_3 than control in cotton crop

4.5 Nutrient studies

4.5.1 Nutrient content and uptake by Soybean

4.5.1.1 Nitrogen content in grain and straw (%)

The data presented in Table 20. revealed that, the values of nitrogen content. The mean N content was 5.77 % and 0.40 % in grain and straw respectively.

The treatment difference in respect of nitrogen content in seed and straw were not reach to the significance levels.

Table 20. Nitrogen content and uptake in seed and straw of soybean as influenced by different treatments

Treatment	N Concentration (%)		Uptake of Nitrogen (kg ha^{-1})		
	Seed	Straw	Seed	Straw	Total uptake
T_1 - Control (No Spray)	5.68	0.37	90.31	7.78	98.09
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	5.75	0.38	94.93	8.13	103.06
T_3 - 1% KNO_3 at 25-30 DAS	5.78	0.41	107.05	9.80	116.85
T_4 - 2% KNO_3 at 25-30 DAS	5.76	0.40	104.83	9.42	114.26
T_5 - 1% KNO_3 at 60-65 DAS	5.80	0.41	110.49	10.02	120.51
T_6 - 2% KNO_3 at 60-65 DAS	5.72	0.41	107.54	9.93	117.47
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DAS	5.84	0.43	124.68	11.51	136.20
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	5.81	0.42	119.40	10.96	130.36
SE (m)±	0.15	0.03	2.9	0.41	3.26
CD at 5%	NS	NS	8.72	1.25	9.80
GM	5.77	0.40	107.40	9.70	117.01

4.5.1.2 Nitrogen uptake (kg ha^{-1})

The data in respect to nitrogen uptake of nitrogen by seed and straw and total uptake are presented in Table 20 and depicted in Fig. 11.

Nitrogen uptake were found significant in seed and straw due to the treatment difference. Significantly superior uptake of nitrogen was found with treatment 1% KNO_3 at 25-30 and DAS 60-65 DAS (T_7) i.e. 124.68 kg ha^{-1} and 11.51 kg ha^{-1} by seed and straw respectively and at par with the treatment of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8).

Similarly treatment of T_5, T_6, T_3 and T_4 were found at par with each other in respect of nitrogen uptake by the seed and straw.

The total uptake of nitrogen was found significant due to the treatment difference. Treatment of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher uptake of nitrogen and at par with treatment of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) followed by treatment of 1% KNO_3 at 60-65 DAS (T_5), 2 % KNO_3 at 60-65 DAS (T_6) and 1% KNO_3 at 25-30 DAS (T_3) which were at par with each other. Total uptake of nitrogen was lowest in treatment of control (T_1). The results were supported by Das (1999).

4.1.5.2 Phosphorus uptake (kg ha^{-1})

4.1.5.2.1 Phosphorus content in grain and straw (%)

Data on phosphorus content in seed and straw are presented in Table 21. The data revealed that, mean values of phosphorus content were 0.57 % and 0.26 % in seed and straw.

The non significant difference was observed among the treatments for phosphorus content in seed and straw.

4.1.5.2.2 Phosphorus uptake (kg ha^{-1})

Data on phosphorus uptake by seed and straw as well as total uptake are presented in Table 21 and depicted in Fig 10. Mean uptake of phosphorus was 11.80 and 6.90 kg ha^{-1} by seed and straw respectively. The mean total uptake of phosphorus was 18.70 kg ha^{-1}.

Significant differences were observed in uptake of phosphorus in seed and straw. Significantly higher phosphorus uptake was found in treatment of 1 % KNO_3 at 25-30 DAS and 60-65 DAS (T_7) i.e. 14.09 kg ha^{-1} and at par with 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8). However, in straw phosphorus uptake was superior in 1 % KNO_3 at 25-30 DAS and 60-65 DAS (T_7) and at par with 2% KNO_3 at 25-30 DAS and 60- 65 DAS (T_8). The lowest uptake of phosphorus by seed and straw was observed in treatment of Control (T_1).

Table 21. Phosphorus content and uptake in seed and straw of soybean as influenced by different treatments

Treatment	P Concentration (%)		Uptake of Phosphorus (kg ha^{-1})		
	Seed	Straw	Seed	Straw	Total uptake
T_1 - Control (No Spray)	0.60	0.27	9.54	5.68	15.22
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	0.61	0.27	10.07	5.78	15.85
T_3 - 1% KNO_3 at 25-30 DAS	0.63	0.28	11.67	6.69	18.36
T_4 - 2% KNO_3 at 25-30 DAS	0.62	0.28	11.28	6.60	17.88
T_5 - 1% KNO_3 at 60-65 DAS	0.65	0.30	12.38	7.34	19.72
T_6 - 2% KNO_3 at 60-65 DAS	0.64	0.29	12.03	7.02	19.06
T_7 -1% KNO_3 at 25-30 DAS and 60-65 DAS	0.66	0.31	14.09	8.30	22.39
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	0.65	0.30	13.36	7.83	21.19
SE (m)±	0.03	0.02	0.3	0.15	0.45
CD at 5%	NS	NS	0.92	0.46	1.37
GM	0.57	0.26	11.80	6.90	18.70

The total uptake of phosphorus was found significant due to the treatment difference. Treatment of 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher uptake of phosphorus and at par with treatment of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) followed by treatment of 1% KNO_3 at 60-65 DAS (T_5), 2 % KNO_3 at 60-65 DAS (T_6) and 1% KNO_3 at 25-30 DAS (T_3) which were at par with each other. Total uptake of phosphorus was lowest in treatment of control (T_1). The results were supported by Shashikumar (2013).

4.1.5.3 Potassium uptake (kg ha^{-1})

4.1.5.3.1 Potassium content in seed and straw (%)

The data pertaining to potassium content in seed and straw are presented in Table 22. The data revealed that, mean values of potassium content was 0.52 % and 1.75 % in seed and straw respectively.

The difference among the treatment were found non significant in respect of potassium content in seed and straw.

Table 22. Potassium content and uptake in seed and straw of soybean as influenced by different treatments

Treatment	K concentration (%)		Uptake of Potassium (kg ha^{-1})		
	Seed	Straw	Seed	Straw	Total uptake
T_1 - Control (No Spray)	0.55	1.84	8.75	38.70	47.45
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	0.56	1.85	9.25	39.59	48.84
T_3 - 1% KNO_3 at 25-30 DAS	0.57	1.89	10.56	45.19	55.75
T_4 - 2% KNO_3 at 25-30 DAS	0.57	1.86	10.37	43.82	54.20
T_5 - 1% KNO_3 at 60-65 DAS	0.58	1.97	11.05	48.17	59.22
T_6 - 2% KNO_3 at 60-65 DAS	0.57	1.94	10.72	46.99	57.70
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DAS	0.63	2.16	13.45	57.82	71.27
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	0.61	2.09	12.54	54.55	67.08
SE (m)±	0.03	0.11	0.43	1.79	2.32
CD at 5%	NS	NS	1.31	5.38	6.96
GM	0.52	1.75	10.83	46.85	57.68

4.1.5.3.2 Potassium uptake by seed and straw (kg ha^{-1})

Data on uptake of potassium by seed and straw as well as total uptake are presented in Table 22 and depicted in Fig 10. The data

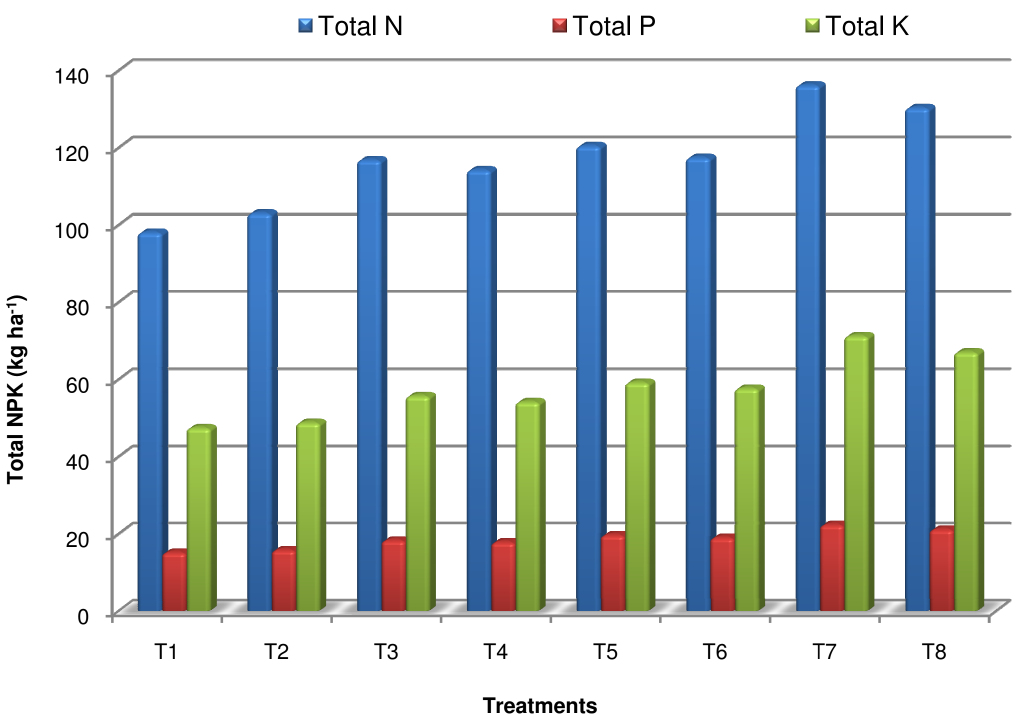


Fig. 11. Total Nitrogen, Phosphorus and Potassium uptake of soybean as influenced by different treatments

revealed that, mean values of potassium uptake were 10.83 and 46.85 kg ha^{-1} by seed and straw respectively. The total uptake of potassium was 57.68 kg ha^{-1}.

Significant difference was observed in uptake of potassium in seed and straw. Significantly maximum potassium uptake was found with treatment 1 % KNO_3 at 25-30 DAS and 60-65 DAS (T_7) i.e. 13.45 kg ha^{-1} in seed followed by 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8). However, in straw potassium uptake was higher in 1% KNO_3 at 25-30 DAS and 60-65 DAS (T_7) followed by 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8). The lowest potassium uptake in seed and straw was observed in Control (No spray) (T_1).

The total uptake of potassium was found significant due to the treatment difference. Treatment of 1 % KNO_3 at 25-30 DAS and 60-65 DAS (T_7) recorded significantly higher uptake of potassium and at par with treatment of 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8) followed by treatment of 1% KNO_3 at 60-65 DAS (T_5), 2 % KNO_3 at 60-65 DAS (T_6), 1% KNO_3 at 25-30 DAS (T_3) and 2% KNO_3 at 25-30 DAS (T_4) which were at par with each other. Total uptake of potassium was lowest in treatment of control (T_1). The results were supported by Umar *et al.,* (1999).

4.6. Water use efficiency (kg ha/mm)

Data on water use efficiency of soybean as influenced by different treatments are given in Table 23 and depicted in Fig. 12.

Treatment of foliar application of 1 % KNO_3 at 25-30 DAS and 60- 65 DAS (T_7) recorded maximum water use efficiency (10.04) and followed by application of 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) which recorded water use efficiency of (9.83), 1% KNO_3 at 60-65 DAS (T_5), 1% KNO3 at 25-30 DAS (T_3). The lowest water use efficiency of (7.70) was observed in T_1 (control).

Table 23. Water use efficiency (kg ha/mm) of soybean as influenced by different treatments

Treatments	WUE (kg ha/mm)
T_1 - Control (No Spray)	7.70
T_2 - Water Spray at 25-30 DAS and 60-65 DAS	7.89
T_3 - 1% KNO_3 at 25-30 DAS	8.85
T_4 - 2% KNO_3 at 25-30 DAS	8.24
T_5 - 1% KNO_3 at 60-65 DAS	9.15
T_6 - 2% KNO_3 at 60-65 DAS	8.07
T_7 - 1% KNO_3 at 25-30 DAS and 60-65 DASs	10.04
T_8 - 2% KNO_3 at 25-30 DAS and 60-65 DAS	9.83
GM	8.72

At harvest application of 1 % KNO_3 at 25-30 and DAS 60-65 DAS (T_7) recorded significantly higher water use efficiency (10.04) and found at par with application of 2 % KNO_3 at 25-30 DAS and 60-65 DAS (T_8) which recorded . water use efficiency of (9.83). The lowest water use efficiency of (7.70) was observed in T1 (control).

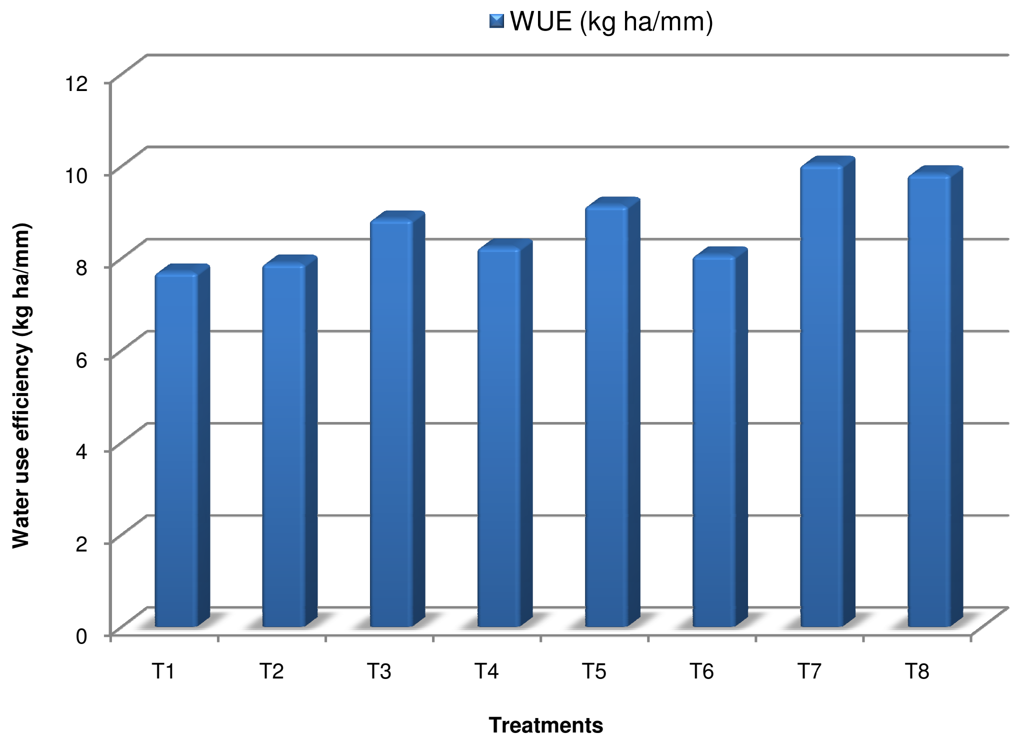


Fig. 12. Water use efficiency (kg ha/mm) of soybean as influenced by different treatments

CHAPTER V

SUMMARY AND CONCLUSION

The present investigation **"Effect of foliar application of potash on growth and yield of soybean under rainfed condition"** was conducted during *kharif* season of 2017 -18 at Agronomy Farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experiment was laid out in randomized block design with eight treatments and replicated three times. The treatment comprised of Control (No Spray), Water Spray at 25-30 DAS and 60-65 DAS, 1% KNO_3 at 25-30 DAS, 2% KNO_3 at 25-30 DAS, 1% KNO_3 at 60-65 DAS, 2 % KNO_3 at 60-65 DAS, 1% KNO_3 at 25-30 and 60-65 DAS and 2% KNO_3 at 25-30 DAS and 60-65 DAS.

The soil of experimental plot was clay in texture. Soil was slightly alkaline in reaction. As regards to fertility status, the soil was low in available Nitrogen and available Phosphorus, high in available Potassium and medium in organic carbon.

Summary

The findings during the course of investigation are summarized as below.

1. The difference in growth characters were not marked at significance levels at 20 DAS. As the crop advanced in age, significant differences from 40 DAS were observed and differences continue to be significant till harvest. Growth characters viz., plant height, number of branches, number of functional trifoliate leaves, leaf area, dry matter were found significantly maximum with treatment 1 % KNO_3 at 25-30 and 60-65 DAS and at par with the treatment of 2% KNO_3 at 25-30 DAS and 60-65 DAS.
2. Yield attributes and yield viz., number of pods per plant, pod weight per plant, grain weight per plant and grain yield (kg ha^{-1}) were

recorded significantly superior in treatment 1% KNO_3 at 25-30 and 60-65 DAS (T_7) and at par with 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8).

3. Relative water content, chlorophyll, root length and root nodules were found significant in treatment of 1% KNO_3 at 25-30 and 60-65 DAS (T_7) and at par with 2% KNO_3 at 25-30 DAS and 60- 65 DAS (T_8). Lowest relative water content, chlorophyll, root length and root nodules were observed in control (No spray) treatment.

4. Whereas, straw yield, biological yield were significantly higher in treatment of 1% KNO_3 at 25-30 and 60-65 DAS and at par with treatment 2% KNO_3 at 25-30 and 60-65 DAS (T_8). Maximum harvest index was observed in 1% KNO3 at 25-30 and 60-65 DAS followed by 2% KNO_3 at 25-30 and 60-65 DAS, 1% KNO_3 at 60-65 DAS, 2% KNO_3 at 60-65 DAS, 1% KNO_3 at 25-30 DAS and 2% KNO_3 at 25-30 DAS. Lowest harvest index was observed in treatment of control (No Spray).

5. Uptake of nitrogen, phosphorus and potassium by seed and straw was significantly higher in 1% KNO_3 at 25-30 and 60-65 DAS and at par with 2% KNO_3 at 25-30 DAS and 60-65 DAS. Similarly total uptake of nitrogen, phosphorus and potassium was significantly maximum in 1 % KNO_3 at 25-30 and 60-65 DAS at par 2% KNO_3 at 25-30 DAS and 60-65 DAS. Lowest uptake of nutrients (N, P and K) by seed and straw and total uptake of nutrients (N, P and K) were observed in treatment of control (No spray).

6. Gross monetary returns and net monetary returns were found significantly maximum in 1% KNO_3 at 25-30 and 60-65 DAS (T_7) and at par with 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8). Similarly, GMR and NMR was found statistically at par in treatments of foliar application of 1 % and 2 % KNO_3 at 25-30 DAS (T_3, T_4, T_5 and T_6). Maximum B:C ratio was observed in 1% KNO_3 at 25-30 and 60-65 DAS (T_7) and followed by 1% KNO_3 at 60-65 DAS (T_7), 1% KNO_3 at

25-30 DAS (T_3) 2% KNO_3 at 25-30 DAS and 60-65 DAS (T_8), 2% KNO_3 at 60-65 DAS (T_6). Least B:C ratio was recorded in treatment of control (No spray).

7. Maximum water use efficiency observed in treatment of 1% KNO_3 at 25-30 and 60-65 DAS (T_7) followed by treatment of 2% KNO_3 at 25-30 and 60-65 DAS (T_7). Least water use efficiency observed in treatment of control (No spray).

Conclusions

The following conclusions could be drawn from the present investigation.

1. Application of 1 % KNO_3 at 25-30 DAS and 60-65 DAS recorded higher growth attributes.
2. Seed yield (kg ha^{-1}), straw yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index were observed in 1 % KNO_3 at 25-30 DAS and 60-65 DAS.
3. Relative water content, chlorophyll, root length and root nodules were found maximum in treatment of 1% KNO_3 at 25-30 and 60-65DAS.
4. Maximum water use efficiency observed in treatment of 1% KNO_3 at 25-30 and 60-65 DAS (T_7) followed by treatment of 2% KNO_3 at 25-30 and 60-65 DAS (T_7). Least water use efficiency observed in treatment of control (No spray).
5. Nutrients uptake (N, P and K) by grain and straw and total uptake of nutrients (N, P and K) was higher in 1 % KNO_3 at 25-30 DAS and 60-65 DAS.
6. Gross monetary returns, net monetary returns and B:C ratio were recorded maximum with 1% KNO_3 at 25-30 DAS and 60-65 DAS.

These conclusions are based on the results of one year investigation and therefore it needs further experimentation to give valid recommendation.

CHAPTER VI

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APPENDIX I

Cost of Cultivation
Per unit cost of input and output

Sr. No.	Items	Unit	Rs. $Unit^{-1}$
A.	**Input cost**		
1.	Hired Human Labour		
	a. Male	Day	230
	b. Female	Day	230
2.	Preparatory tillage	Hectare	6000
3.	Intercultural Operations		
	a. Thinning and gap filling	Day	460
	b. Hoeing	Hectare	1000
	c. Weeding	Hectare	3450
4.	Seed	Kg	60
5.	Sowing with seed treatment	Hectare	1570
6.	Fertilizers		
	a. Urea	Kg	06
	b. SSP	Kg	7.60
	c. MOP	Kg	11.60
7.	Cost of Spray		
	a. Potassium Nitrate	Kg	130
	b. Spraying cost		460
8.	Plant protection		500
9.	Harvesting and winnowing		4600
B.	**Output Cost**		
1.	Soybean seed	Quintal	3500
2.	Soybean straw	Quintal	200