Original Research Article

EFFECTS OF POTASSIUM APPLICATION ONYIELD, PROTEINAND OIL CONTENT OFSELECTED SOYBEAN VARIETIES IN TRANS NZOIA COUNTY, KENYA

Abstract

There is low soybean production due to poor agronomic techniques, such as sub-optimal application of fertilizer among other factors.There are limited studies on the effects of potassium fertilizerapplication which is crucial in productivity, quality, and drought resistance. A study wasconducted at the Kenya Agricultural Livestock and Research Organization, Kitale demonstration farm to determine the effects of potassium fertilizer application on the yield and quality of soybean varieties. A 3 x 4 factorial experimentwas laid down in Randomised Complete Block Design and replicated three times. Thestudy had two factors, that is three soybean varieties(DPSB19, Gazelleand SB24) andfour levels of potassium (0 [control], 22.5, 45, and 67.5 kg K_2O ha^{-1}) applied as sulphate of potash fertilizer (50% K_2O)at planting, making a total of 12 treatments.Data collected included number of pods per plant, number of seeds per plant, weight of seed per plant and 1000-seed weight, grain yield, protein and oil content. Data collected was subjected to analysis of variance using Statistical Analysis System version 9.3 and significantly different means separatedusing Least Significance Difference at $\alpha = 0.05$.Application of potassium at the rate of 67.5 kg K_2O ha^{-1} resulted to higher number of pods per plant and number of seeds per plant at 78.97 and 243.40, and 44.47 and 141.20 in the varieties DPSB19 and Gazelle, while in SB24 higher recording of 51.23 and 162.40 was observed with 22.5 kg K_2O ha^{-1}. The higher 1000-seed weight was recorded in 22.5 kg K_2O ha^{-1} in DPSB19 and Gazelle varieties, while for SB24 it was recorded in 67.5 kg K_2O ha^{-1}.The highest grain yield recorded was 9156.45kg per ha, in DPSB19 in 22.5 kg K_2O ha^{-1}, 4517. 67.5kg per ha in Gazelle variety in 67.5 kg K_2O $ha^{-1}$and 6432.78kg per ha in SB24 variety in 22.5 kg K_2O ha^{-1}. The higher percentage oil content was observed in 45 K_2O kg ha^{-1} in DPSB19 (28.48%) and SB24 (23.38%) varieties, and in 22.5 kg K_2O ha^{-1}in Gazelle (19.38%) variety and the higher percentage protein content was recorded in 45 K_2O kg ha^{-1}in DPSB19 (42.99%) and Gazelle (40.56%), and in 45 K_2O kg ha^{-1}in SB24 (48.87%). These findings show that soybean farmers should apply potassium fertilizer for appropriate growth, increased yield, protein and oil content in different soybean varieties. It is recommended that application of potassium at 67.5 kg K_2O ha^{-1} be done for better soybean growth, yield and protein content and application of potassium at 45 kg K_2O ha^{-1} is done for high oil content.

Keywords: Soybean, Potassium, Seed weight, Yield, Protein content, Oil content

1.Introduction

Soybean (*Glycine max* L.) is a leguminous crop thatis mainly grown for its seeds which are processed for vegetableoil and high protein meal [1].In response to the growing demand for high-quality protein, both in humans and animal feed products, farmers are increasingly becoming interested in soybean cultivation [2]. Soybean can be grown throughout the year in the tropics and subtropics using simple agronomic practices and it improves the soil by naturally fixing nitrogen into the soil [3]. Soybean are rich in functional nutrients such as protein, essential amino acid, polyunsaturated fatty acid, minerals, vitamins and dietary fibre and in the industry, it is used for oil extraction and consumption of vegetable protein food [4].The constraints to soybean cultivation includes use of uncertified seed with low germination percentage; lack of certified seeds during planting season; high soil salt concentration; use of convectional agronomic technique in soybean farming; little information about soybean nutritional value if known by people; low adoption mechanisation especial during planting and post-harvest practices by farmer; poorly established marketing and supply system [5] and tendency to pod shattering [6].In order to realize higher yields in soybean production farmers are advised to select best soybean genotype based on their own agro-ecological conditions [7].The major causes of low yield in Africa can be attributed to low genotype stability, limited genetic based of cultivars, damage by insect pest and diseases, nutrient deficiency, poor application of fertilizer, lack of accessibility to certified soybean seed and lack of agronomic skill[8].

Soybean crop yield and yield components such as seed number and size are adversely affected by the fertilization [9], but the extent of the influence differs in genotypes and amount of the fertiliser applied [10]. Potassium is essential for improving quality of produce particularly oilseed crops and its requirement for different crops is varied [11]. Soybean plants grown without potassium have delayed seed maturity affecting the harvesting date [12]. Potassium deficient crops are susceptible to lodging [13], and this can lead to decline in yield by about 22% [14]. It has been reported that application of potassium as foliar fertilizer at flowering stage of the soy crop is a vital practice since it helps evade reduction in yield and also improve the quality of the soybean [15]. Khanam[16] indicated that application of potassium fertilizers increased the number of pods plantper plant, mass of nodule and number of nodules with potassium rate of 120 kg muriate of potash per ha, giving highest number of nodules. Soil deficient in potassium leads to abortion of flowers, pods and seeds in soybean crop which result to reduced yield [17].Liu [18] reported that the concentration levels of potassium, magnesium and iron in the soybean is positively influenced while, the level of copper concentration is negatively affected by the variety difference of the soybean and also application of the potassium to the soybean.

The production of soybean is approximately 600 kg ha^{-1} which is way lower than its possible yield of 3000 kg per hectare and this is mainly due to poor agronomic management techniques such as use of seed varieties that are not certified during planting, poor plant population due to wrong spacing and in appropriate application of fertilizer including application of potassium fertilizer.Farmers in Trans Nzoia use diammonium phosphate (DAP) to correct nutrient deficit since it supplies both phosphate and nitrogen, unfortunately DAP does not supply potassium and it contributes to increased soil acidity by discharging a proton during process of nitrification [19]. The NPK fertilizers available for use by the farmers during planting have no or they contain very low percentage of potassium. More studies have been done on nitrogen and phosphorous effect on the soybean production and less has been done to specify the rate of potassium to be applied to have optimum percentage oil and protein content, and yield of soybean. Potassium is kept in the ionic form (K^+) in cell sap of the plant cell and it activates many enzymes present within the plant cell hence it has numerous functions in the plant growth and nutrition that affect both yield and quality of the crop.

Potassium is a vital nutrient to soybean crop as it's involved in numerous cellular activities and reduces susceptibility of soybean to rust disease [20]. Due to its importance in plant growth and development, there is need to undertake more studies on optimisation of K application rates and its effects on growth, grain yield, protein and oil content of selected soybean varieties. The soybean varieties differ in genetic makeup, this can lead to difference in percentage seed protein content due to difference in mineral uptake from the soil and their ability to transport these minerals to the sink organ such as seed [7]. When selecting soybean varieties, it critical to select variety that is well adapted to agro-ecological conditions of where it's going to be planted and early maturing variety should be considered in areas that receive little rainfall to enable it escape late-season drought [21]. The purpose of this study was to determine the level of potassium fertilizer application for the optimum yield, protein and oil content of three soybean varieties.

2.Materials and Methods

2.1. Study Site

The study was done at Kenya Agricultural and Livestock Research Organisation, Kitale (KALRO-Kitale)in two cultivations. The area is located at 0.9798^o N, 35.0167^o E in Trans NzoiaCounty. It's located between Mount Elgon and Cherangani hills at an altitude of 1,900 m above sea level and has mean temperature of 24˚C and receive an average annual rainfall of 1,300 mm.It has two rainy seasons:March to May and September to December. The site is found inAgroecological Zone(AEZ)UM4 [22] and it has humicferralsols[23]. Agriculture practice is the chief source of employment in Trans Nzoia with the main crops cultivated being cereals particularly maize, grain legumes like dry beans. Soybean is currently gain familiarity in the county.

2.2. Experimental Design

The factorial experiment had two factors, three soybean varieties (DPSB19, Gazelle and SB24) and four levels of potassium (control, 22.5 kg K_2O ha^{-1}, 45 K_2O kg ha^{-1} and 67.5 kg K_2O ha^{-1}) applied as sulphate of potash (50% K_2O)which was applied to the experimental units at planting.The experiment was setup in Randomised Complete Block Design (RCBD) and each treatment had three replicates.The control treatment comprised of 0 K_2O kg ha^{-1}.The treatment plots measured 2 m by 2 m with alleys measuring 0.5 m separating the plots and a path of 1 m between the blocks, and each treatment was replicated three times making a total of 36 plots. The experiment was carried out in two cultivations (i.e., trial I and trial II) using the same treatment combinations between the variety and rate of potassium fertiliser.

2.3. Planting Materials, Land Preparation, Planting and Field Maintenance

Thesoyabean varieties were sourced from KALRO Njoro while SB24 was obtained from KALRO-Kakamega and the sulphate of potash (50%K_2O), was sourced from MEA Limited in Nakuru.The vegetation present on the field including grasses and other annual weeds were cleared by slashing and ploughed using a disc plough and then the field was left for 2 weeks for all vegetation to decay then harrowed before planting. In each plot, furrows were made at the spacing of 45cm between the furrows and with the deep of 5cm, giving plant population of 444, 444 plants ha^{-1}. At planting DAP (18-46-0) fertilizer was applied in each plot at the rate of 125 kg per ha to supply 22.5 N kg ha^{-1} and 57.5 P_2O_5 kg ha^{-1}, this was mixed with given rates of K_2O then covered with thin soil before placing seeds at spacing of 5cm between the seeds within the furrow. Four levels of K_2O used; 0 K_2O kg/ha, 22.5 K_2O kg/ha, 45 K_2O

kg/ha and 67.5 K_2O kg/ha to supply 0 K kg/ha, 18.68 kg K/ha, 37.35 kg K/ha and 56.03 kg K/ha respectively. Seeds of all the three varieties except control were inoculated with BIOFIX rhizobia inoculant containing *Bradyrhizobiumjaponicum* at 10g per kg of seed to ensure full nitrogen fixation potential. The plots were thinned to one plant per 5cm at 15 DAS, and was kept weed free through hand weeding using hoe, first weed control was done on the 2^{nd} week after planting and the second weeding on the 5^{th} week after planting. Pest and disease control was done through spraying. Allmanagement practices were applied uniformly to avoid difference in data collected due to these practices.

2.4. Data Collection

During the study conducted between May 2019 and December 2020, data on soil initial status, yield, percentage oil and percentage protein content of soybean was collected.

2.4.1. Soil Analysis

Soil sample was collected from the field before tilling using soil auger from the depth of 0-15cm. The standard laboratory analysis procedure of the samples was done to measure soil organic carbon and total N (flash combustion method) using Thermo Scientific Flash 2000 Elemental Analyzer; the CN Analyzer [24], available N (NH_4^+ and NO_3^-) by automated caDrymatterium reduction method using Auto Analyzer, extractable P by the Olsen's method[25] and was determined using visible spectrophotometric method, extractable K by 1M ammonium acetate method at pH 7 (flame photometer) [26], soil pH by potentiometric method at a ratio of 1:2.5 soil: water using pH meter and particle size distribution[27]. The soil samples were air-dried, ground and sieved through a one millimeter mesh before using it for analysis.

2.4.2. Determination of the Effect Variety andRate of Potassium Application on the Yield of the Soybean

Number of Pods per Plant

The numbers of pods per plant from ten randomly sampled and tagged plants from the treatment plot was counted and the mean calculated to represent the number of pods $plant^{-1}$ in that plot during harvesting.

Number of seeds per plant

The total number of seeds was counted from the randomly sampled five tagged harvested plants and then mean number $plant^{-1}$ was calculated.

Weight of seeds/plant (g) and 1000-seed weight (g)

The weight of seeds per plant was obtained from the number of seeds per plant. A sample of 1000-seeds was taken from ten tagged plants; the seeds was weighed to determine 1000-seed weight for each treatment.

Grain Yield (kg/ha)

At maturity soybean from different plots was harvested and the grain dry weight without pods, was taken using weigh scale at 13 % moisture content. Seed moisture percentage was measured using moisture meter. The grain yield waslater extrapolated to yield in kg per hectare as per Xiang [28].

$$Yield\ (kg/ha) = Kg\ seed\ yield\ per\ sq.metre \times 10{,}000$$

2.4.3. Determination of the Effect Variety andRate of Potassium Application on the Quality of the Soybean

Protein Content of Soybean

The oven dried soybean samples of 0.3g were placed into digestion tubes. The digestion mixture measuring2.5ml of was added and digested for 120 minutes. The mixture was then cooled and transferred into 50ml volumetric flask and filled with distilled water to volume. Two 5mls aliquots of each sample were then taken for analysis [29].

Oil Content

The percentage oil content of the soybean was analyzed using Soxhlet extraction method where about 2g of the dried soybean seed sample was weighed (w_1) into a clean piece of cotton cloth. The sample was then wrapped securely in the cloth by tightening a thread around it. The wrapped sample was then immersed in the thimble of the Soxhlet extractor, using n-hexane and maintained at a temperature of 60^{o}C. This set-up was left in this condition for up to 5 hours so that all the fat in the sample was extracted. The oil was concentrated from the oil-solvent mixture by removing the defatted sample from the thimble and distilling off some, but not all of the solvent from the mixture in the flask. This extract was then left throughout the night on the well-ventilated area for a complete evaporation of the remaining solvent. In the morning, the flask with the sample was weighed continuously until a constant weight (w_2) was obtained. The flask was then emptied, cleaned thoroughly, and dried in an oven at 100^{o}C and weighed (w_3) The percentage crude fat was determined as in Dutta [30].

$$\% \text{ Crude Fat Content} = \frac{weightofextractedfat}{weightofsample} \text{x}100$$

$$\% \text{ Crude Fat Content} = \frac{w2 - w3}{w1} \times 100$$

2.5. Data Analysis

The data wasanalysed using Statistical Analysis Software(SAS) version 9.3 for analysis of variance. Least Significant Difference (LSD) was used for comparing significantly different means at probability level of 5%.

3. RESULTS

3.1. Soil Analysis

Soil analysis was conducted at KALRO-Kakamega. It was observed that the pH was 6.06, organic carbon content was 1.18 %, total nitrogen was 0.24 %, while available P and exchangeable K was 96.98 mg/kg and 75.78 mg/kg respectively (Table 1).

3.2. Effect Variety andApplication of Different Rates of Potassium fertilizer on Soybean Yieldand Yield Components

3.2.1 Number of Pods per Plant

There was no significant ($p > 0.05$) difference in number of pods per plant between variety DPSB19, Gazelle and SB24 within and between trial I and II. However, there were significant influence of the different rates of potassium fertilizer within individual variety at ($p<0.05$) in trial I and II. Increase in number of pods per plant was recorded whencompared with control treatmentin DPSB19 in trial I and II, it increased from 52.90 and 30.67 (control treatment) to 72.60 and 34.90 in 22.5 kg K_2O per ha, 68.93 and 35.97 in 45 kg K_2O per ha, 78.97 and 35.03 in 67.5 kg K_2O per haboth in trial I and trial II (Table 2).

Similarly, in Gazelle variety no significant increase in pod per plant number was recorded in trial I, the pod number increased from 36.93 in control treatment to 43.30, 43.80 and 44.47 in 22.5 kg K_2O per ha, 45 kg K_2O per haand 67.5 kg K_2O per ha, respectively. The significant increase in pod number was recorded in trial II in 67.5 kg K_2O per hathat is from 26.97 to 31.27. Furthermore, in SB24 variety, the number of pods per plant increased in 45 kg K_2O per ha and 67.5 kg K_2O per hain trial I that was from 16.93 in control treatment to 22.97 and 21.30 respectively, while in trial II the 45 kg K_2O per ha recorded highest pod per plant from 41.57 to 51.23 (Table 2).

Table 1: Results of soil analysis of soil obtained from experimental site

Parameter	Units	Value
pH water	_	6.06
Organic Carbon	%	1.18
Total Nitrogen	%	0.24
Available P_2O_5	mg/kg	96.98
Exchangeable Ca	mg/kg	398.8
Exchangeable Mg	mg/kg	68.8
Exchangeable K	mg/kg	75.78
Available Zn	mg/kg	1.17
Available Cu	mg/kg	1.4
Available Fe	mg/kg	20.24
Available Mn	mg/kg	16.24
Texture	_	Loamy sand

3.2.2 Number of Seeds per Plant

There was significant($p < 0.05$) interaction for the two trials on number of pods per plant. The results showed a significant increase in the number of pods per plant in DPSB19 variety with treatment 22.5 kg K_2O per ha and 67.5 kg K_2O per ha in trial I as compared to control treatment. In DPSB19 variety the number of pods per plant increased from 161.60 and 94.80 to 238.60 and 104.60, 190.33 and 110.40, and 243.40 and 105.80 with 22.5 kg K_2O per ha, 45 kg K_2O per ha and 67.5 kg K_2O per ha respectively both in trial I and trial II (Table 2). In Gazelle variety the number of seeds per plant, showed no significant difference when compared to control treatment. However, increase in number of seeds per plant was observed in all treatments compared to control in trial I and in treatment 45 kg K_2O per haand 67.5 kg K_2O per ha in trial II (Table 2)

The number of seeds per plant increased from 119.20 and 79.60 to 131.00 and 93.40 in 45 kg K_2O per ha and, to 141.20 and 99.20 in 67.5 kg K_2O per ha both in trial I and trial II and to 127.60 seeds in 22.5 kg K_2O per ha in trial I. Furthermore, in SB24 variety in trial I no significant difference was observed when 22.5 kg K_2O per ha, 45 kg K_2O per haand 67.5 kg K_2O per ha were compared to control treatment. However, in trial II, 45 kg K_2O per ha showed a significant difference to control experiment. The number of seeds per plant increased from 53.80 seeds in trial I to 66.40 seeds (45 kg K_2O per ha) and 71.00 (67.5 kg K_2O per ha), and from 126.20 in trial II to 162.40

(22.5 kg K_2O per ha). The reduction in number was recorded in 22.5 kg K_2O per ha in trial I and in 45 kg K_2O per haand 67.5 kg K_2O per ha in trial II (Table 2).

Table 2: Interaction effect of soybeanvariety and rate ofpotassium application on number of pods per plant, seeds per plant, and weight of 1000-seeds of soybean

		Trial I			Trial II		
Variety	Potassium rate (kg/ha)	Number of pods per plant	Number of seeds per plant	One thousand seed weight	Number of pods per plant	Number of seeds per plant	One thousand seed weight
DPSB19	0	52.90c*	161.60bc	113.00bc	30.67de	94.80cdef	115.67d
	22.5	72.60ab	238.60a	128.50bc	34.90cd	104.60bcde	113.33d
	45	68.93b	190.33b	121.50bc	35.97bcd	110.40bcd	114.17d
	67.5	78.97a	243.40a	123.33bc	35.03cd	105.80bcd	115.33d
Gazelle	0	36.93d	119.20c	202.73ab	26.97ef	79.60ef	187.00a
	22.5	43.30d	127.60c	249.97a	24.60f	73.60f	166.00ab
	45	43.80cd	131.00c	227.20a	28.90ef	93.40def	173.17a
	67.5	44.47cd	141.20c	159.50abc	31.27de	99.20cdef	187.33a
SB24	0	16.93e	53.80d	104.17c	41.57b	126.20b	133.67cd
	22.5	15.07e	50.40d	105.00c	51.23a	162.40a	137.00cd
	45	22.97e	66.40d	110.00bc	39.73bc	107.27bcd	129.83cd
	67.5	21.30e	71.00d	105.67bc	39.67bc	119.60bc	145.47bc
CV%		1.967	1.974	2.074	1.967	1.974	2.074
$LSD_{(0.005)}$		9.460	42.528	97.486	5.677	25.634	24.626

*Means with the same letter along the column for the same variety are not significantly different at (α = 0.05)

3.2.3 Effect on 1000 Seed Weight

There was no significant difference ($p > 0.05$) in 1000-seed weight between varieties DPSB19, Gazelle and SB24 within and between trial I and II. However, there were increase in 1000-seed weight with integration of rhizobium with potassium fertilizer within DPSB19, Gazelle and SB24 variety in trial I and II. In DPSB19 variety, the weight increased from 113.00 g in control treatment to 128.50 g, 121.50 g and 123.33 g in 22.5 kg K_2O per ha, 45 kg K_2O per haand 67.5 kg K_2O per ha respectively in trial I while in trial II the weight changed from 115.67g (control treatment) to 113.33 g, 114.17 g and 115.33 g in 22.5 kg K_2O per ha, 45 kg K_2O per ha and 67.5 kg K_2O per ha, respectively (Table 2). Similarly, in Gazelle variety the 1000-seed weight increased from 202.73 g to 249.97 g and 227.20 g with 22.5 kg K_2O per ha and 45 kg K_2O per ha respectively. Reduced weight was observed with 67.5 kg K_2O per ha in trial I, while in trial II the 1000 seed weight reduced from 187.00 g to 166.00 g and 173.17 g with treatment 22.5 kg K_2O per ha and 45 kg K_2O per hawhile in 67.5 kg K_2O per ha it increased slightly to 187.33 g. Furthermore, in SB24 the weight of 1000 seeds increased from 104.17 g to 105.00 g, 110.00 g and 105.67 g in trail I with treatment 22.5 kg K_2O per ha, 45 kg K_2O per ha and 67.5 kg K_2O per ha,respectively. In trial II it increased from 133.67 g to 137.00 g in 22.5 kg K_2O per ha treatment and 145.47 g treatment in 67.5 kg K_2O per ha, reduce in weight of 1000 seed was observed in 45 kg K_2O per ha. (Table 2).

3.2.4 Effect on Seed Weight per Plant

There was no significant ($p < 0.05$) interaction between trial I and trial II on the seed weight per soybean plant. However, significant increase in seed weight per plant was observed with potassium application when compared to control treatment within DPSB19, Gazelle and SB24 varieties. In DPSB19 it was observed that the seed weight per plant increased, compared to control treatment (0kg K_2O/ha)to 30.59 g and 11.95 g in 22.5 kg K_2O per ha, 24.28 g and 12.61 g in 45 kg K_2O per ha and, 34.75 g and 11.92 g in 67.5 kg K_2O per haboth in trail I and II (Table 3).

Similarly, it was observed in the Gazelle variety that there is increase in seed weight per plant with increase in potassium application. The weight increased from 17.80 g and 16.50 g in control treatment to 19.95 g and 11.63 g in 22.5 kg K_2O per ha, 20.70 g and 16.40 g in 45 kg K_2O per ha and, 22.76 g and 19.77 g in 67.5 kg K_2O per ha both in trial I and II respectively. In SB24 variety the weight increase from 5.63 g and 16.73 g in control treatment to 5.32 g and 22.44 g, 7.29 g and 14.00 g, and 7.39 g and 15.50 g with application of potassium at the rate of 22.5 kg K_2O per ha, 45 kg K_2O per ha and 67.5 kg K_2O per ha both in trial I and trial II (Table 3).

Table 3: Interaction effect of soybeanvariety and rate ofpotassium application on seed weight per plant and grain yield per hectare of soybean

		Trial I		Trial II	
Soybean variety	Potassium rate (kg/ha)	Seed weight per plant (g)	Grain yield per hectare (kg)	Seed weight per plant (g)	Grain yield per hectare (kg)
DPSB19	0	18.54c	4324.73cde	11.047f	2431.52c
	22.5	30.59ab	9156.45a	11.95ef	2745.75c
	45	24.28bc	7949.34ab	12.61def	3016.81c
	67.5	34.75a	6395.18abc	11.92ef	3014.00c
Gazelle	0	17.89c	3836.72cdef	16.50bcd	2646.10c
	22.5	19.95c	4085.25cdef	11.63ef	1816.00c
	45	20.70c	3867.11cdef	16.40bcd	2671.49c
	67.5	22.75c	451767bcd	19.77ab	2589.72c
SB24	0	5.63d	874.24f	16.73bc	4597.37b
	22.5	5.32d	1002.13ef	22.44a	6432.78a
	45	7.29d	1283.17def	14.00cdef	4447.26b
	67.5	7.39d	1446.48def	15.50cde	4751.91b
CV%		1.974	2.074	1.974	2.074
$LSD_{(0.005)}$		7.220	3.43	3.907	1.35

*Means with the same letter along the column for the same variety are not significantly different at (α = 0.05).

3.2.5 Effect on Grain Yield

There was significantly interaction ($p < 0.05$) between trial I and trial II on grain yield. The results showed a significant difference in grain yield in DPSB19 variety in trial I as compared to control treatment. The increase in grain yield was observed in both trial I and trial II in DPSB19, the grain yield increased from 4325 kg/ha and 2432 kg/ha in control treatment to 9156 kg/ha and 2746 kg/ha, 7949 kg/ha and 3017 kg/ha, and 6395 kg/ha and 3014 kg/ha for 22.5 kg K_2O per ha, 45 kg K_2O per haand 67.5 kg K_2O per harespectively in both trial I and trial II (Table 3).

Similarly, in Gazelle variety increase in grain yield was recorded when compared to control treatment. The grain yield increased by 248 kg/ha and reduced by 830 kg/ha in 22.5 kg K_2O per ha; increased by 31 kg/ha and 25 kg/ha in 45 kg K_2O per ha and increased by 57 kg/ha in 67.5 kg K_2O per ha in trial I and II, respectively. The results in SB24 variety showed and increased in grain yield, from 874 kg/ha (control treatment) to 1002 kg/ha (22.5 kg K_2O per ha), 1283 kg/ha (45 kg K_2O per ha) and 1446.46 Kg/ha in trial I while in trial II it increased from 4597 Kg/ha in control treatment to 6432 kg/ha, 4447 kg/ha and 4751 kg/ha in 22.5 kg K_2O per ha, 45 kg K_2O per ha and 67.5 kg K_2O per ha respectively (Table 3).

3.3. Effect of SoybeanVariety andApplication of Different Rates of Potassium Fertilizer onPercentageSeed Oil and Protein Content

3.3.1 Oil Content

There was no significant (p > 0.05) difference in percentage oil content of soybean between trial 1 and trial II. However, significant response was recorded with application of different rates of potassium in the oil content of soybean within DPSB19, Gazelle and SB24 varieties at ($p<0.05$) in both trial I and trial II. For example, within DPSB19 variety, the oil content increased from 26.25 % and 23.75% in the control treatment to 27.83% and 26.33% in 22.5 kg K_2O per ha and 28.48% and 26.48% in 45 kg K_2O per ha, significant reduction in oil content to 25.43% (67.5 kg K_2O per ha) was observed in trial I when compared with 45 kg K_2O per ha and 23.93% was observed with 67.5 kg K_2O per ha in trial II (Table 4).

In gazelle variety no significant influence was observed in percentage of oil content with increase in potassium application in trial I but increase in oil content with increase in potassium application was recorded from 16.58 % in 0 kg K_2O per ha (control treatment) to 19.38 %, 17.467% and 18.10% in 22.5 kg K_2O per ha, 45 kg K_2O per ha and 67.5 kg K_2O per ha respectively, in trial II increase of potassium application from 0 kg K_2O per ha to 22.5 kg K_2O per ha significantly increased the percentage oil content from 14.58% to 18.05 %, no difference in significance was observed in45 kg K_2O per ha (15.80%) and 67.5 kg K_2O per ha (16.27%) when compared with control treatment. Furthermore, in SB24 variety, no significant influence was observed with varied rate of K application when compared to control treatment. The percentage oil content increased from 22.18% and 19.68% (control treatment) to 22.38% and 20.22% (22.5 kg K_2O per ha), 23.38% and 21.72% (45 kg K_2O per ha), and 22.77% and 20.77% (67.5 kg K_2O per ha) both in trial I and trial II (Table 4).

3.3.2 Protein Content

There was no significant difference (p > 0.05) in percentage protein content of soybean varietiesbetween DPSB19, Gazelle and SB24 within and between trial I and II. However, there were significant influence of the different rates of potassium fertilizer within individual variety at ($p \leq 0.05$) in trial I and II. In DPSB19 increase in percentage protein content was observed both in trial I and trial II when compared to control treatment, increase from 32.12% and 39.78 % in control treatment to 34.52% and 42.18 %, 35.02 % and 42.68 %, and 35.34 % and 43.00 % were observed in 22.5

kg K_2O per ha, 45 kg K_2O per haand 67.5 kg K_2O per ha, respectively for trial I and II (Table 4).

Table 4: Interaction effect of soybeanvariety and rate ofpotassium application on percentage oil and protein Content of Soybean on Trial I and II

		Trial I		Trial II	
SoybeanVariety	Potassium rate (kg/ha)	% Oil	% Protein	% Oil	% Protein
DPSB19	0	26.25ab*	32.12cde	23.75abc	39.78cde
	22.5	27.83ab	34.52bcd	26.33a	42.18bcd
	45	28.48a	35.02bcd	26.48a	42.68bcd
	67.5	25.43bc	35.34bc	23.93ab	42.99bc
Gazelle	0	16.58f	26.62f	14.58g	34.28f
	22.5	19.38ef	29.57ef	18.05ef	37.22ef
	45	17.47f	30.69def	15.80fg	38.35def
	67.5	18.10f	32.90bcde	16.27fg	40.56bcde
SB24	0	22.18de	36.92ab	19.68de	44.58ab
	22.5	22.38d	40.47a	20.22de	48.13a
	45	23.38cd	41.21a	21.72bcd	48.87a
	67.5	22.77cd	40.42a	20.77cde	48.08a
CV%		2.07387	2.07387	2.07387	2.07387
$LSD_{(0.005)}$		2.8095	4.3368	3.0919	4.3368

*Means with the same letter along the column for the same variety are not significantly different at (α = 0.05).

More so, in Gazelle variety, increase in percentage protein content were recorded compared to control treatment. It was observed that the percentage protein content increased from 26.62% and 34.28% in control treatment to 29.57% and 37.22% (22.5 kg K_2O per ha), 30.69% and 38.35% (45 kg K_2O per ha) and a significant difference was recorded with treatment 67.5 kg K_2O per ha(32.90% and 40.56%) in both trial I and trial II. Furthermore, in SB24, increase in protein percentage was observed with different K application compared with control treatment, higher protein percentage was recorded with 45 kg K_2O per ha(41.21% and 48.87%) from 36.92% and 44.58% in control experiment in trial I and trial II, while 40.47% and 48.13%, and 40.42% and 48.08% were recorded in 22.5 kg K_2O per ha and 67.5 kg K_2O per habothin trial I and trial II (Table 4).

4. DISCUSSION

4.1. Soil Analysis

The soil from the study field had near neutral reaction with pH of 6.06, this is ideal for the availability of most plant nutrients required in soybean bean production. Available Zinc, copper and cations calcium and magnesium were adequate. According to Dugje[31] soybean production does well in the soil of pH 4.5-8, hence the soil pH of the field of study could not constrain production since it's within the recommended range. The texture of the soil in the field of study is loamy sand this is attributed to low level of potassium which is enhanced through application of potash fertilizer.

4.2. Effect Variety andApplication of Different Rates of Potassium fertilizer on Soybean Yield parameters

The number of pods per plant, sampled from treatment plots showed no significant differencebetween trial I and trial II. However, there was significant influence of potassium application on the number of pods and also the number of pods varied between different soybeanvarieties used in this study. The influence of different levels of potassium on the number of pods per plant may be due to efficient transportation of photosynthates from the leaves to the pods which are sink organs.Greater quantity of photosynthates may have prompted the initiation and maintenance of more pods per soybean plant. According to Cakmak[32], the optimal supply of potassium establishes osmotic potential in the phloem and this helps to translocatephotosynthates from leaves to sink organs. The finding of this study are also in harmony with those of Gerardeaux[33] who observed that translocation of photosynthates in the phloem to the roots of potassium deficient plants is significantly reduced. The variation in the number of pods per plant among the varieties may be brought about by differences in uptake, utilization, and the resulting growth habit such as increasing the formation of more pods per plant. Variety DPSB19 recorded highest number of pods with 67.5 kg K_2O per ha since it is an early maturing variety and probably the high pod numbers were as a result of its genetic makeup. This conforms to findings of Baijukya[34] and Mahasi[35] who observed that different varieties of soybean vary in terms of pod number.

From this study it was observed that increased number of branches influenced the number of pods per plant which later on influenced the number of seeds per plant. The increased application of potassium increased the number of seeds per plant this is probably by making quantity and transportation of photosynthates efficient which resulted from increasedleaf number and leaf area index which promotes efficient absorption of light energy for photosynthesis. This facilitate efficient synthesis of photosynthates and effective translocation of this photosynthates to sink organ through phloem. The findings of this study are similar to those of Xiang[28] and Kolar [36] who reported high leaf area with application of potassium as compared to control treatment of potassium. The high seed number per plant can also be attributed to increased pod fill and maintenance ratio or capacity of the plant due to application of potassium. This observation agreed with finding of Xiang[28]who observed that the filled pod ratio increased with potassium application while unfilled pod ratio increase with potassium deficiency. The unfilled pod ratio of soybean was also recorded to decline with increased potassium application by Sale [37].Rathore[38],Hemeid[39]and Bhadiyatar[40]observed increased pod number in legume plant with application of potassium and this was associated to importance of potassium to quality parameter to this oil seed crop and its help in balancing nutrition of crops, transport sugar and water hence its favorable effects on podformation.

In this study it was observed that application of potassium to different soybean varietiesincreased 1000-seed weight, seed weight per soybean plant and grain yield of soybean. These attributes can be related to the number of seed per plant, pod filled and maintenance ratio and the weight of the resultant seed. Application of potassium increases these yield component probably due to improved soil fertility through application of sulphate of potash fertilizer which improved the availability of other nutrients and their absorption by soybean plant. The increase 1000-seed weight, seed weight per soybean plant and grain yield of soybean can also be attributed to increase in transportation of assimilates to the seed leading to better maintenance than abortion and increased seed weight. The effective synthesis of photosynthatesafter application of the potassium fertilizer can also be associated to increased number of leaves and leaf area index that are critical towards increase of 1000-seed weight, seed weight per soybean plant and grain yield of soybean. This agreed with findings of Amanullah[41] who found that spraying potassium at rate of 3% K_2O on the crop significantly increased leaf area index. Rengel[42]observed that higher growth rate in crops may due to increased efficiency of photosynthesis in leaves resulting from the effective potassium uptake by roots which activates enzymes and is also involved in adenosine triphosphate synthesis resulting to proper filling of the pods which results to higher yields. Theresults of this study further stand in harmony with the findings ofAkram[43], Aown[44] and Khanam[16] who stated that potassium enhanced the net assimilation rate (NAR).

Apart from leaf area index and transportation of photosynthates, potassium also influences photosynthetic pigments that includes the level of chlorophyll a, b and carotenoids. These pigments determine how soybean crop can harness the sunlight energy for use in the photosynthetic process. This conforms to the finding ofFarhad[45] who observed that photosynthetic pigments increased significantly when plants were treated with potassium as compared with untreated plants in legume crops. The variation in 1000-seed weight and seed weight could probably, be attributed to application of potassium which provided adequate plant nutrients that subsequently, enhanced grain yield of soybean.Habibzadeh[46] recorded highest 1000-seed weight with potassium treatment at the rate of 225 kg K/ha.In study potassium application probably played a role in utilization of nitrate and other plant nutrient by soybean plant which were absorbed and translocate to the seed and played a key role in seed filling and maintenance of the resultant seed that consequently increased the seed weight plant, thousand seed weight and grain yield per hectare.

According to Xu [47] application of potassium affects carbon assimilation and distribution by regulatingcarbon metabolizing enzymes which promotes growth and root development improving its ability to absorb nitrate.This better absorption of nitrate may have contributed to better seed weight and grain yield. According to the findings of Yadav [48] and Read [49] potassium application played a key role in increasing the crop yield by promoting tolerance to all plants biotic and abiotic stress. Further,Abdi [50] established that spraying of a plant with potassium increased 1000 grain weight by increasing the enzyme activation and subsequently easing nutrient translocation from photosynthetic areas to the grain. This could explain the reason why there was increased seed weight per plant, thousand seed weight and grain yield after application of potassium fertilizer in this study.

4.3. Effect Variety andApplication of Different Rates of Potassium fertilizer on protein and oil content of Soybean

The percentage protein and oil content of soybean have been reported as the most important parameters of soybean seed quality [51]. In the present study it was observed that there was insignificant variation in percentage oil content of soybean with application of varied rate of potassium fertilizerin different soybean varieties.Among varied varieties andrates of potassium application, the highest oil content (28.48 %) was observed in DPSB19 variety with application of potassium at rate of 45 kg K_2O per hectare while, the lowest percentage oil content (14.58 %) was recorded with treatment K0 (0 kg K_2O per ha) in Gazelle variety. This shows that application of potassium fertilizer affects the oil and protein content differently among the soybean varieties. This observation is in harmony with findings of Farhad[45],Haq[52] and Seguin [53] who recorded insignificant influence of application of potassium to percentage oil content.

Yin [54] recorded an increase in seed oil content while seed protein content of soybean decreased with application of potassium. According to Bhadiyatar[40] potassium promotes peg formation, nodulation, synthesis of sugar and starch and help in pod growth and development in oil seed crops.In the present study the percentage protein content of soybean was observed to increase with increase in the rate of potassium. The highest percentage protein content (48.87%) was recorded with SB24 variety with treatment of potassium at rate of 45 kg K_2O per hactare and the lowest percentage protein (26.62%) was recorded with Gazelle variety with potassium treatment at rate of 0 kg K_2O per hactare (control treatment). This increase in percentage protein content with increase in potassium application could, be probably be associated with role played by potassium in transportation of photosynthates which are transported to seeds and used in synthesis of protein.

Potassium plays important role in increasing leaf area index which increases the photosynthates related to protein synthesis. This observation is in harmony with report of Wang [55] who reported that potassium deficient crop has a reduced rate of photosynthesis, lower rate of transpiration and poor opening and closing of stomatalwhich is then followed by a decline in RUBISCO activity.RUBISCO activity is key in protein synthesis and content in plants. The necrosis of leaf and turning brown in colouris one of the potassium deficiency symptom observed in the soybean leaf with severe deficiency while yellowing of leaflet margin is common in mild deficiency of potassiumwhich lowers the photosynthetic area of the leaf. Thislowers the accumulation rate of photosynthatesand consequently reducing the amount of protein stored in the soybean seeds[56]. According to finding of Alpaslan [57]the recorded percentage oil and protein content of soybean ranges between 19.0-23.5% and 34.9-39.6%, respectively.

Farhad[45] recorded a significant increase in protein content of soybean with application of potassium where the highest percentage protein content of 42.23% was observed with potassium treatment at rate of 70 kg K/ha and the lowest percentage of 38.70 with control treatment (0 kg K_2O/ha). The variation in percentage oil and protein of soybean between trial I and trial II can be attributed to mid-season drought that was experienced during trial II. The drought could have lowered the percentage oil content and increased protein content. This is in harmony with findings of Dornbos[58] who reported an increase in protein content by 4.4% points and decline in oil content by 2.6% point when soybean was exposed to drought conditions.

CONCLUSION

There was a significant effect variety andapplication of different rate of potassium to the yield of soybean. The highest grain yield recorded was 9156.452 kg per ha, in DPSB19 in22.5 kg K_2O per ha, 4517. 667 kg per ha in Gazelle variety in 67.5 kg K_2O per ha and 6432.781 kg per ha in SB24 variety in 22.5 kg K_2O per ha. Lastly, there was significant response of application of different rate of potassium to the protein content and oil content of the soybean varieties. The higher percentage oil content was observed in 45 kg K_2O per ha in DPSB19 and SB24 varieties, and in 22.5 kg K_2O per ha in Gazelle variety.The study recommends that for the farmer to realize higher grain yield of soybean, in the adoption of DPSB19, Gazelle and SB24 varieties, application of K_2O at 67.5 kg/ha is recommended during planting.To achieve high percentage of oil content in soybean grain where the farmer adopts DPSB19, SB24 and Gazelle varieties application of K_2O at 45 kg/ha is recommended.To achieve high percentage of proteincontent in soybean grain where the farmer adopts DPSB19, SB24 and Gazelle varieties application of K_2O at67.5 kg/ha is recommended.

References

[1]. Hyten, D. L., Pantalone, V. R., Sams, C. E., Saxton, A. M., Landau-Ellis, D., Stefaniak, T. R., & Schmidt, M. E. (2004). Seed quality QTL in a prominent soybean population. *Theoretical and Applied Genetics*, *109*(3), 552-561.

[2]. Szostak, B., Glowacka, A., Kasiczak, A., Kieltyka-Dadasiewicz, A., &Bakowski, M. (2020). Nutritional value of soybeans and the yield of protein and fat depending on the cultivar and nitrogen application. *Journal of Elementology*, *25*(1).

[3]. Agyenim-Boateng, K. G., Zhang, S., Zhang, S., Khattak, A. N., Shaibu, A., Abdelghany, A. M., ... & Sun, J. (2023). The nutritional composition of the vegetable soybean (Maodou) and its potential in combatting malnutrition. *Frontiers in Nutrition*, *9*, 3069.

[4]. Lu, J., Cheng, J. H., Xu, Y., Chen, Y., Qian, K., & Zhang, Y. (2023). Effect of germination on nutritional quality of soybean. *Food Science and Technology*, *43*, e008323.

[5]. Islam, K. S., Ali, M. M., Shahrin, S., Cheesman, S., Alam, S. N., and Krupnik, T. J. (2022). Simple and effective management methods that can improve soybean production in Bangladesh.

[6]. Singh, G., (2010). The Soybean: Botany, Production, and Uses. *CAB International, Oxfordshire, UK.*

[7]. Agegn, A., Bitew, Y., &Ayalew, D. (2022). Response of yield and quality of soybean [*Glycine max* (L.) Merrill] varieties to blended NPSZnB fertilizer rates in Northwestern Ethiopia. *Heliyon*, e09499.

[8]. Hailemariam, M. and Tesfaye, A. (2018). Progress of soybean [*Glycine max (L.) Merrill*] breeding and genetics research in Ethiopia. *JNSR*, 8:70.

[9]. Larry, J.G., Dale G. B., and Harry, C. M. (1986). P nutrition during seed development. *Plant Physiol.*, 82(4): 1008-1012.

[10]. Pandey, R. K., Herrera, W. A. T., and Pendieton, J. W. (1984). Water stress response to grain legumes under irrigated gradient. I .Yield and yield components. *Agron. J.*, 76: 549-553.

[11]. Mali, D. V., Jadhav, S. D., Sonune, B. A., Gore, R. P., Jadhav, S. M., &Konde, N. M. (2017). Effect of various levels of potassium on yield of soybean and soil nutrient status of farmer's field in Vertisol. *International Journal of Chemical Studies*, *5*(5), 688-69.

[12]. Jeffers, D. L., Schmitthenner, A. F., &Kroetz, M. E. (1982). Potassium Fertilization Effects on Phomopsis Seed Infection, Seed Quality, and Yield of Soybeans 1. *Agronomy Journal*, *74*(5), 886-890.

[13]. Xu, Y. W., Zou, Y. T., Amjad, M. H., Zeng, J. W., Guan, L. L., Liu, Q. and Wu, W. (2011). Optimization of potassium for proper growth and physiological response of *Houttuyniacoradatathunb*. *Environ. Exp. Bot.*, 71: 292-297.

[14]. Noor, R. B. M. and Caviness, C. E. (1980). Influence of induced lodging on pod distribution and seed yield in soybeans. *Agron. J.*, 72: 904-906.

[15]. Vijay, V., Dalal, R. P. S., Beniwal, B. S., and Saini, H. (2016). Impact of foliar application of potassium and its spray schedule on yield and quality of sweet orange (Citrus sinensis) cv. Jaffa. *Journal of Applied and Natural Science*, *8*(4), 1893-1898.

[16]. Khanam, M., Islam, M.S., Ali, M.H., Chowdhury, I.F., and Masum, S.M. (2016). Performance of Soybean under Different Levels of Phosphorus and Potassium. *Bangladesh Agronomy Journal*. 19: 99. 10.3329/baj.v19i1.29876.

[17]. Ortel, C., Roberts, T. L., Slaton, N. A., Ross, W. J., Purcell, L. C., Hurst, B., Hoegenauer, K., VictorioPessotto, M., Followell, C. A., and Smartt, A. (2021). In-Season Potassium Management in Soybean: Balancing Economics and Yield Maximization. *ASA, CSSA, SSSA International Annual Meeting, Salt Lake City, UT.*

[18]. Liu, C., Wang, X., Chen, H., Xia, H., Tu. B., Li, Y., Zhang, Q. and Liu, X. (2022) Nutritional quality of different potassium efficiency types of vegetable soybean as affected by potassium nutrition. *Food Quality and Safety*.6, 1-11.

[19]. Owino, C. O. (2010). Fertilizer options for Sustainable Maize (*Zea mays L.*) Production in Trans-Nzoia district of Kenya. African Journal of Agricultural Research Vol. 5(11), pp. 1208-1212.

[20]. Zambolim, L., Mochko, A.C.R., Parreira, D.F., and Valadares, S.V. (2019). Potassium Fertilization Reduces the Severity of Asian Soybean Rust under High Disease Pressure. Journal of Agricultural Science.11.116.10.5539/jas.v11n11p116.

[21]. Kananji, G.A.D., Yohane, E., Siyeni, D., Mtambo, L., Kachulu, L., Chisama, B.F., Malaidza, H.,Tchuwa, F. and Mulekano,O.(2013).A guide to soybean production in malawi.https://www.researchgate.net/publication/265736526.

[22]. Jaetzold, R., and Schmidt, H. (2005). *Farm Management Handbook of Kenya*, Natural Conditions and farm management information part A, West Kenya, Ministry of Agriculture, Nairobi, Kenya.

[23]. Mwangi, T.J.K., Muyekho, F.N., Gatei, J.N., Kathuli P. and Wekesa, F. (1997). *Review of soils and soil fertility management practices in north of the Rift Valley province of Kenya*. P.27-44.

[24]. Krotz, L., Galotta, W. and Giazzi, G. (2000). Nitrogen Determination in Soils and Plants by Flash Combustion using Argon as Carrier Gas. Retrieved from http://apps.thermoscientific.com/media/cmd/hypersite-events/Pittcon 2014/posters/PN42209_PC2014.pdf.

[25]. Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean, L. A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circ. 939.

[26]. Okalebo, J. R., Gathua, K.W. and Woomer P.L. (2002). *Laboratory Methods of Soil and Plant Analysis: A Working Manual Second Edition*. TCBF-CIAT and SACRED Africa, Nairobi, Kenya. pp 22-78.

[27]. Bowman, G. M., and Hutka, J. (2002). *Particle Size Analysis. In Soil Physical Measurement and Interpretation for Land Evaluation*. Pp 224-239.CSIRO Publishing: Victoria.

[28]. Xiang, D. B., Yong T. W., Yang, W. Y., Wan Y., Gong, W. Z., Cui, L. and Lei, T. (2012). Effect of phosphorus and potassium nutrition on growth and yield of soybean in relay strip intercropping system. *Sci. Res. Essays*. 7(3): 342-351.

[29]. Bremner, J. M. (1996). Nitrogen□total. *Methods of soil analysis: Part 3 Chemical methods*, *5*, 1085-1121.

[30]. Dutta, R., Sarkar, U. and Mukherjee, A. (2014) "Extraction of oil from Crotalaria Juncea seeds in a modified Soxhlet apparatus: Physical and chemical characterization of a prospective bio-fuel", *Fuel*, 116:794-802.
[31]. Dugje, I., Omoigui, L., Ekeleme, A., Kamara, A. and Ajeigbe, H. (2009). Farmers' Guide to Cowpea Production in West Africa. *IITA*, 1-25.
[32]. Cakmak, I. (2005). The role of potassium in alleviating detrimental effects of abiotic stresses in plants. *J. Plant Nutr. Soil Sci.* 168, 521–530. doi: 10.1002/jpln.200420485.
[33]. Gerardeaux, E., Jordan-Meille, L., Constantin, J., Pellerin, S., and Dingkuhn, M. (2010). Changes in plant morphology and dry matter partitioning caused by potassium deficiency in *Gossypiumhirsutum(L.)*. *Environ.Exp.Bot*. 67,451459. doi:10.1016/j.envexpbot.209.09.008.
[34]. Baijukya, F., Giller, K.E., Vanlawe, B., Danshiel. K., Karanja, N., Woomer, P.L., and Abaidoa, R. (2013). Soybean, common beans, cowpeas and groundnut varieties with high Biological Nitrogen Fixation Potential (Six Milestone Report). *N2Africa Report No. 56*.
[35]. Mahasi, J. M., Vanaluwe, B., Mursoy, R. C., Mbehero, P. and Mukalama, J. (2010). Increasing Productivity of Soybean in Western Kenya through Evaluation and Farmer Participatory Variety Selection. *KARI Biennial Conference*. Pp326-334.
[36]. Kolar, J. S., and Grewal, H. S. (1994). Effect of split application of potassium on growth, yield and potassium accumulation by soybean. *Fertilizer research*, *39*(3), 217-222.
[37]. Sale, P.W, and Campbell L.C. (1986). Yield and composition of soybean seed as a function of potassium supply. *Plant Soil*, 96(3): 317-325.
[38]. Rathore, S. S., Chaudhary, D. R., Vaisya, L. K., Shekhawat, K., and Bhatt, B. P. (2014). Schoenite and potassium sulphate: Indigenous potassic fertilizer for rainfed groundnut (*Arachishypogaea L.*).
[39]. Hemeid, N. (2015). Effect of different sources and levels of potassium fertilization on productivity of peanut grown under sandy soil conditions. *Journal of Soil Sciences and Agricultural Engineering*, *6*(12), 1441-1454.
[40]. Bhadiyatar, A.A., Patel, J.M. and Malav, J.K. (2022).Effect of potassium and sulphur on growth, yield attributes and yield of summer groundnut in loamy sand.*The Pharma Innovation Journal* 2022; 11(2): 2704-2707.
[41]. Amanullah, M. H. K. (2016). Difference in dry matter accumulation with variable rates of sulphur and potassium application under calcareous soils in *Brassica napus* vs. *B. juncea*. *Journal of Oilseed Brassica*, *1*(1), 241-248.
[42]. Rengel, Z., and Damon, P. M. (2008). Crops and genotypes differ in efficiency of potassium uptake and use. *PhysiologiaPlantarum*, *133*(4), 624-636.
[43]. Akram, M., Ashraf, M. Y., Ahmad, R., Rafiq, M., Ahmad, I., & Iqbal, J. (2010). Allometry and yield components of maize (Zea mays L.) hybrids to various potassium levels under saline conditions. *Archives of Biological Sciences*, *62*(4), 1053-1061.
[44]. Aown, M., Raza S., Saleem M., Anjum S., Khaliq T. and Wahid M. (2012). Foliar application of potassium under water deficit conditions improved the growth and yield of wheat (*Triticumaestivum L.*). *J. of Animal & Plant Sci*., 22(2): 431-437.

[45]. Farhad, I. S. M., Islam, M. N., Hoque, S., and Bhuiyan, M. S. I. (2010). Role of potassium and sulphur on the growth, yield and oil content of soybean (*Glycine max L.*). *An Academic Journal of Plant Sciences*, *3*(2), 99-103.

[46]. Habibzadeh, F., Amini, I. and Mirnia, S.K. (2004).Effects of different potassium and zinc applicationson yield and yield components of soybean (*Glycine max L.*) in Mazandaran province. *Pajouhesh-va-Sazandegi-In-Agron.-and-Hort*., 61(4): 18-24.

[47]. Xu, X., Du, X., Wang, F., Sha, J., Chen, Q., Tian, G., Zhu, Z., Ge, S., and Jiang, Y. (2020). Effects of Potassium Levels on Plant Growth, Accumulation and Distribution of Carbon, and Nitrate Metabolism in Apple Dwarf Rootstock Seedlings. *Frontiers in plant science*.11:904.

[48]. Yadav, R.L.; N.L. Sen and B.L. Yadav (2003). Response of onion to nitrogen and potassium fertilization under semi-arid condition of Rajasthan. *Indian J.Horti*, 60: 176 – 178.

[49]. Read, J.J., Reddy, R.K. and Jenkins, J.H. (2006). Yield and fiber quality of upland cotton as influenced by nitrogen and potassium nutrition. *European J.Agron*, 24:282-290.

[50]. Abdi, M.; G. Nour-Mohamedi and A. Golchin (2002). The influence of foliar nutrition of urea and potassium chloride on grain yield, grain protein contents, yield components and leaf relative water content of Sardari wheat under rainfed conditions. *J. Agric.Sci*., 8(1): 29-38.

[51]. Weber, E. J. (1985). Role of potassium in oil metabolism, pp. 425–442. *In* R. D. Munson (ed.), Potassium in agriculture. ASA, CSSA and SSSA,Madison, WI.

[52]. Haq, M. U., and A. P. Mallarino. (2005). Response of soybean grain oil and protein concentration to foliar and soil fertilization. *Agron. J.* 97: 910–918.

[53]. Seguin, P., and W. Zheng. (2006). Potassium, phosphorus, sulfur, and boron fertilization effects on soybean isoflavone content and other seed characteristics. *J. Plant Nutr*. 29: 681–698.

[54]. Yin, X. H. and Vyn, T. J. (2003). Potassium placement effects on yield and seed composition of no-till soybean seeded in alternate row widths. *Agronomy Journal*. 95:126-132.

[55]. Wang, X.G., Zhao, X.H., Jiang, C.J., Li, C.H., Shan, C.O.N.G., Di, W.U., Chen, Y.Q., Yu, H.Q. and Wang, C.Y., (2015). Effects of potassium deficiency on photosynthesis and photoprotection mechanisms in soybean (*Glycine max (L.)*Merr.). *Journal of Integrative Agriculture*, *14*(5), pp.856-863.

[56]. Mallarino A. (2018). Iowa State University, Integrated Crop Management Extension and outreach.https://crops.extension.iastate.edu/cropnews/2018/08/soybean-potassium-deficiency-symptoms-during-early-and-late-growing-stages. Accessed 07 July 2022.

[57]. Alpaslan, M., Boydak, Erkan and Demirci, M. (2017). Protein content and oil composition of soybean and sesame seeds grown in the Harran (GAP) area of Turkey.

[58]. Dornbos, D.L. and Mullen, R.E. (1992) Soybean seed protein and oil contents and fatty acid composition adjustments by drought and temperature.*J Am Oil Chem Soc*.69**:**228–231.