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RESEARCH ARTICLE

APPLICATION OF PHOSPHORUS AND POTASSIUM FOR SOYBEAN (*Glycine max* L.) RESPONSE IN ACIDIC SOILS OF WOLAITA ZONE, SOUTHERN ETHIOPIA

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ABSTRACT

This study was conducted with the objective to evaluate soybean (Glycine max L.) response to P and K fertilizer application under greenhouse condition in a pot experiment. Four representative surface soil (0-20 cm) samples were collected from Damot Sore, Boloso Bombe, Damot Pulasa, and Humbo Districts. Four rates of P (0, 23, 46 and 69 kg P_2O_5 ha^{-1}) in the form of triple super phosphate (TSP) and four rates of K (0, 21.5, 43 and 64.5 kg K_2O ha^{-1}) in the form of potassium chloride (KCl) were used. The soil samples collected were planted with soybean and the treatments were arranged in a completely randomized design (CRD) with two factors in three replications. The dry weight content and P and K concentrations in the leaves of soybean plant showed significant difference at $P < 0.05$ level by the application of treatments. The dry weights found by the application of P_{69} $K_{64.5}$ and P_{69} $K_{21.5}$ markedly higher than the dry weights of the other treatments and the highest K concentrations in the leaves of the soybean plant were observed by the application of P_{69} $K_{21.5}$ and P_{69} $K_{64.5}$ for Damot Sore District. For Boloso Bombe District, the highest P concentration was recorded by the application of P_{69} $K_{21.5}$, P_{69} K_{43} and P_{69} $K_{64.5}$ and the lowest P concentration was obtained by the application of P_0 K_0. The highest concentration of K in the plant leaves was observed by the application of P_{23} K_{43}. The amount of fertilizer applied at the rate of P_{46} $K_{21.5}$ significantly increased the K concentration in the leaves of soybean plant (43.6 g kg^{-1}) for Damot Pulasa Districts. For Humbo site, the amount of fertilizer applied at the rate of P_{46} $K_{21.5}$, significantly increased the K concentration in the leaves of soybean plant (43.6 g kg^{-1}) whereas, the control treatment (P_0 K_0) has the lowest K concentration in the leaves of the plant (12.1 g kg^{-1}). Therefore, application of P and K containing fertilizers had a positive impact on growth of the plants in acidic soils. However, further study is recommended to confirm these findings under field conditions.

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INTRODUCTION

Soybean is one of the most important crops in the world and has higher protein content than any other pulse (Giller and Dashiell, 2007). The crop is grown as a source of protein and oil for the human market and for the animal feed market. Consequently, it is the standard to which other plant protein sources are compared (Blair, 2008). Phosphorous (P), which is one of the most limiting plant nutrient and it is supplied mainly through chemical fertilizers application. Its deficiency constitutes a major limiting factor in the crop production of the world (George and Richardson, 2008). Plants require adequate P from the very early stages of growth for optimum crop production (Grant *et al*., 2001).

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The low in available P is because of intensive erosion, weathering and strong P fixation by free Fe and Al oxides (Sample *et al*., 1980; Stevenson, 1986). Potassium is an essential and major nutrient for crop production (Zhang *et al.*, 2011). Potassium (K) fertilizer recommendations are usually based on soil exchangeable K measurement which gives reasonable results in many soils and situations (Slaton *et al.*, 2010). Potassium regulates osmotic potential in plants and reduces incidence of diseases (Fageria, 2009). So far, no work has been done on soybean response to P and K application in acidic soils of Wolaita Zone, Southern Ethiopia. Therefore, the objective of this study was to evaluate the soybean response to P and K application under greenhouse condition.

MATERIALS AND METHODS

The study was conducted in selected parts of Wolaita Zone. These include Boloso Bombe, Damot Pulasa, Damot Sore and

Humbo Districts. The altitude of the zone ranges from 501 to 3000 masl (Mesfin *et al*., 2015).

Soil sampling, sample preparation and analysis

A bulk soil sample was taken from the top (0-20 cm) from acidic soils of Wolaita Zone (Boloso Bombe, Damot Pulasa, Damot Sore and Humbo Districts). The soil was air dried, ground and passed through a 2 mm sieve and analyzed for selected physicochemical properties according to standard laboratory procedures.

Laboratory analysis and pot experiment

Available P was determined by Olsen methods (Olsen *et al.,* 1954) and the exchangeable K was determined by using 1 M NH_4OAc (Tekalign *et al.,* 1991). Soil pH was measured potentiometrically in H_2O and 1 M KCl solution following standard laboratory procedure (Freese *et al.,* 1995). Total exchangeable acidity was determined as described by Anderson (1993). Electrical conductivity of the soil samples were measured using conductivity meter (Van Reeuwijk, 1992). A green house experiment was carried out in a completely randomized design (CRD) with three replications and four rates of P (0, 23, 46 and 69) kg P_2O_5 per ha in the form of TSP and four rates of K (0, 21.5, 43 and 64.5) kg of K_2O per ha in the form of KCl following standard procedures (Okalebo *et al*., 2002).

Data analysis

Data recorded were analyzed using Statistical Analysis System version 9.13 (SAS Institute, 2004). The least significance difference (LSD) test was employed for the mean separation of different treatments that were found to be significantly different in statistical terms.

RESULTS AND DISCUSSION

Soil pH and electrical conductivity

The pH (H_2O) varied from 4.75 to 6.26 (Table 1) in which the lowest and the highest values were recorded at Damot Sore and Humbo sites, respectively.

According to Donald (2012), the pH ranges of the soils in the studied areas are from very strongly acidic to slightly acidic. According to Anon (1993), high soil acidity with 1 M KCl solution determination showed the presence of high potential acidity and weather able minerals. High amount of exchangeable acidity in Damot Sore and Boloso Bombe were observed in Table 1. This could likely due to the presence of substantial amount of sesquoxides in acid soils aggravate soil acidity (Table 1). According to Hazelton and Murphy (2007), exchangeable acidity in the two Districts are categorized or rated as very high. This finding is in agreement with Lindsay (1996) and Moore (2001) who reported that the solubility of Al containing minerals increase as the soil pH falls below 5.5 and suggested that the probability of Al toxicity to plants become higher.

The Olsen extractable P contents of the soils studied varied from 0.61 to 12.86 mg kg^{-1} as shown in Table 2. As per the rating established by Tekalign *et al*. (1991), the available P contents for Damot Sore, Boloso Bombe and Damot Pulasa Districts were qualifying very low to low range. Soil samples collected from these Districts were below the critical limit for available P. According to Tekalign *et al.* (1991) the critical level of available P is 8.5 mg kg^{-1}. For Humbo sites the available P contents were qualifying medium range. On the other hand, the exchangeable K varied markedly among the studied areas. The highest exchangeable K was observed in Humbo site. The lowest exchangeable K was observed in Boloso Bombe District. As per the ratings recommended by Barber (1984), the exchangeable K contents of the soils were qualified from low to high status. The results were in contrast to the common belief that Ethiopian soils are rich in K for the cultivated lands.

Effects of treatments on the concentration of P and K by the leaves of soybean

The soybean had significant difference in dry weights and P concentration in the leaves (Table 3) for Damot Sore District. The dry weights found by the application of P_{69} $K_{64.5}$ and P_{69} $K_{21.5}$ markedly higher than the dry weights of the other treatments. There were no significant differences at 95% confidence level between the dry weight obtained by the application of treatments P_{69} $K_{64.5}$ and P_{69} $K_{21.5}$. The reduced P and K concentration by the control treatment (P_0 K_0) is due to nutrient stress as a result of Steenberg effect (Jones, 1998).

Table 1. Soil pH and EC of soils of the study areas

Experimental site	pH (H_2O)	pH (KCl)	ΔpH	EC (ds m^{-1})	EA cmol(+) kg^{-1}
Damot Sore	4.75 ± 0.05	3.73 ± 0.05	-1.02 ± 0.03	0.005	3.53 ± 0.05
Boloso Bombe	5.22 ± 0.03	4.29 ± 0.05	-0.93± 0.03	0.110	3.06 ± 0.03
Damot Pulasa	5.73 ± 0.05	4.72 ± 0.04	-1.01 ±0.09	0.090	ND
Humbo	6.26 ± 0.05	5.13 ± 0.05	-1.13 ± 0.10	0.070	ND

ΔpH = change in pH; EC = electrical conductivity; EA = exchangeable acidity; ND = not detected

Table 2. Phosphorus and potassium content of soils of the study areas

Experimental site	P (mg kg^{-1})	K (cmol(+) kg^{-1})
Damot Sore	1.46	0.45
Boloso Bombe	0.61	0.25
Damot Pulasa	7.73	0.43
Humbo	12.86	1.34

Table 3. Interaction effects of the applications of P and K on plant dry weight, concentration of P and K for Damot Sore District

P_2O_5 rate (kg ha^{-1})	K_2O rate (kg ha^{-1})	Dry weight (g pot^{-1})	P conc. (mg kg^{-1})	P conc. (%)	K conc. (g kg^{-1})	K conc. (%)
0	0	5.53^{g}	1512.7^{k}	0.15^{k}	12.19^{jk}	1.21^{jk}
	21.5	4.31^{h}	1982.6^{g}	0.19^{g}	16.96^{bc}	1.69^{bc}
	43	8.2^{cd}	1989.6^{g}	0.19^{g}	16.36^{cde}	1.63^{cde}
	64.5	5.79^{g}	2032.3^{f}	0.20^{f}	14.16^{gh}	1.41^{gh}
23	0	5.45^{g}	1885.1^{i}	0.18^{i}	13.04^{ij}	1.30^{ij}
	21.5	6.25^{f}	1847.5^{j}	0.18^{j}	12.16^{jk}	1.21^{jk}
	43	7.91^{d}	1879.9^{ij}	0.18ij	16.20^{cde}	1.62^{cde}
	64.5	7.02^{e}	1948.2^{h}	0.19^{h}	15.96^{de}	1.59^{de}
46	0	7.93^{d}	2028.4^{f}	0.20^{f}	11.40^{k}	1.14^{k}
	21.5	6.7^{ef}	2198.6^{cd}	0.22^{cd}	14.70^{fg}	1.47^{fg}
	43	8.42^{bc}	1947.8^{h}	0.19^{h}	13.44^{hi}	1.34^{hi}
	64.5	7.88^{d}	2143.6^{e}	0.21^{e}	15.53^{ef}	1.55^{ef}
69	0	8.32^{bcd}	2167.6^{de}	0.21^{de}	13.93^{ghi}	1.39^{ghi}
	21.5	8.95^{a}	2452.6^{a}	0.24^{a}	17.36^{ab}	1.73^{ab}
	43	8.73^{ab}	2202.6^{c}	0.22^{c}	16.8^{cd}	1.68^{cd}
	64.5	9.14^{a}	2338.0^{b}	0.23^{b}	18.23^{a}	1.82^{a}
$LSD_{(0.05)}$		0.46	30.42	0.003	0.88	0.08
CV		3.74	0.98	0.98	3.66	3.66

Means within a column followed by same letter are not significantly different from each other at P > 0.05; LSD = least significant difference; CV = coefficient of variation of treatments

Table 4. Interaction effects of the applications of P and K on plant dry weight, concentration of P and K for Boloso Bombe District

P_2O_5 rate (kg ha^{-1})	K_2O rate (kg ha^{-1})	Dry weight (g pot^{-1})	P conc. (mg kg^{-1})	P conc. (%)	K conc. (g kg^{-1})	K conc. (%)
0	0	4.07^{h}	937.1^{k}	0.09^{k}	8.83^{m}	0.81^{m}
	21.5	3.60^{i}	1009.0^{j}	0.10^{j}	10.83^{k}	1.08^{k}
	43	4.75^{f}	1097.6^{i}	0.11^{i}	17.30^{g}	1.73^{g}
	64.5	6.39^{bc}	672.0^{l}	0.06^{l}	14.53^{j}	1.45^{j}
23	0	5.68^{e}	1858.5^{h}	0.18^{h}	8.66^{m}	0.86^{m}
	21.5	5.66^{e}	2132.9^{f}	0.21^{f}	24.30^{d}	2.43^{d}
	43	5.47^{e}	2185.7^{de}	0.22^{de}	35.5^{a}	3.55^{a}
	64.5	6.79^{a}	2149.4^{ef}	0.21^{ef}	30.1^{b}	3.01^{b}
46	0	6.20^{cd}	2082.1^{g}	0.20^{g}	9.66^{l}	0.96^{l}
	21.5	6.50^{b}	2201.3^{d}	0.22^{d}	16.50^{h}	1.65^{h}
	43	5.57^{e}	2575.7^{b}	0.26^{b}	22.83^{e}	2.28^{e}
	64.5	6.33^{bc}	2573.6^{b}	0.26^{b}	16.90^{gh}	1.69^{gh}
69	0	4.47^{g}	2299.4^{c}	0.23^{c}	15.90^{i}	1.59^{i}
	21.5	6.77^{a}	2688.0^{a}	0.27^{a}	21.90^{f}	2.19^{f}
	43	6.10^{d}	2707.7^{a}	0.27^{a}	29.30^{c}	2.93^{c}
	64.5	6.88^{a}	2719.7^{a}	0.27^{a}	29.16^{c}	2.91^{c}
$LSD_{(0.05)}$		0.23	40.88	0.004	0.52	0.052
CV		2.40	1.28	1.28	1.73	1.73

Means within a column followed by same letter are not significantly different from each other at P > 0.05; LSD = least significant difference; CV = coefficient of variation of treatments

Table 5. Interaction effects of the applications of P and K on plant dry weight, concentration of P and K for Damot Pulasa District

P_2O_5 rate (kg ha^{-1})	K_2O rate (kg ha^{-1})	Dry weight (g pot^{-1})	P conc. (mg kg^{-1})	P conc. (%)	K conc. (g kg^{-1})	K conc. (%)
0	0	8.35^{j}	1887.2^{m}	0.18^{m}	12.1^{i}	1.21^{i}
	21.5	10.72^{i}	2157.1^{k}	0.21^{k}	26.2^{g}	2.62^{g}
	43	13.20^{c}	2145.2^{k}	0.21^{k}	25.8^{g}	2.58^{g}
	64.5	12.46^{de}	2420.0^{h}	0.24^{h}	33.1^{ef}	3.31^{ef}
23	0	13.62^{b}	1968.3^{l}	0.19^{l}	12.0^{i}	1.20^{i}
	21.5	11.45^{gh}	2234.7^{j}	0.22^{j}	38.8^{b}	3.88^{b}
	43	11.37^{gh}	2660.3^{e}	0.26^{e}	37.1^{bc}	3.71^{bc}
	64.5	11.51^{fgh}	2737.3^{c}	0.27^{c}	36.0^{cd}	3.60^{cd}
46	0	11.33^{h}	2440.0^{g}	0.24^{g}	15.0^{h}	1.50^{h}
	21.5	11.68^{fg}	2334.1^{i}	0.23^{i}	43.6^{a}	4.36^{a}
	43	14.35^{a}	2713.3^{d}	0.27^{d}	34.4^{de}	3.44^{de}
	64.5	11.42^{gh}	2859.3^{b}	0.28^{b}	35.3^{cd}	3.53^{cd}
69	0	12.29^{e}	2449.3^{g}	0.24^{g}	14.6^{h}	1.46^{h}
	21.5	13.42^{bc}	2643.5^{f}	0.26^{f}	33.0^{ef}	3.30^{ef}
	43	11.82^{f}	2860.5^{b}	0.28^{b}	31.3^{f}	3.13^{f}
	64.5	12.65^{d}	2933.2^{a}	0.29^{a}	31.3^{f}	3.13^{f}
$LSD_{(0.05)}$		0.34	8.93	0.0008	2.21	0.22
CV		1.70	0.32	0.32	4.67	4.67

Means within a column followed by same letter are not significantly different from each other at P > 0.05; LSD = least significant difference; CV = coefficient of variation of treatments

Table 6. Interaction effects of the applications of P and K on plant dry weight, concentration of P and K for Humbo District

P_2O_5 rate (kg ha^{-1})	K_2O rate (kg ha^{-1})	Dry weight (g pot^{-1})	P conc. (mg kg^{-1})	P conc. (%)	K conc. (g kg^{-1})	K conc. (%)
0	0	10.36^{h}	2100.0^{o}	0.21^{o}	21.4^{fg}	2.14^{fg}
	21.5	12.94^{f}	2012.5^{p}	0.20^{p}	20.3^{h}	2.03^{h}
	43	14.56^{d}	2324.8^{k}	0.23^{k}	24.5^{a}	2.45^{a}
	64.5	10.14^{h}	2141.2^{n}	0.21^{n}	24.8^{a}	2.48^{a}
23	0	12.41^{g}	2242.9^{l}	0.22^{l}	20.7^{gh}	2.07^{gh}
	21.5	15.98^{c}	2192.7^{m}	0.22^{m}	23.7^{bc}	2.37^{bc}
	43	17.36^{a}	2335.6^{j}	0.23^{j}	18.8^{i}	1.88^{i}
	64.5	14.73^{d}	2496.8^{h}	0.25^{h}	23.1^{d}	2.31^{d}
46	0	15.53^{c}	2635.8^{f}	0.26^{f}	17.0^{j}	1.70^{j}
	21.5	15.62^{c}	2415.4^{i}	0.24^{i}	22.0^{e}	2.20^{e}
	43	13.98^{e}	2694.9^{d}	0.27^{d}	24.3^{ab}	2.43^{ab}
	64.5	11.96^{g}	2758.4^{c}	0.28^{c}	23.5^{cd}	2.35^{cd}
69	0	16.90^{ab}	2611.6^{g}	0.26^{g}	22.0^{ef}	2.20^{ef}
	21.5	16.49^{b}	2682.0^{e}	0.27^{e}	23.4^{cd}	2.34^{cd}
	43	12.33^{g}	2931.6^{b}	0.29^{b}	23.2^{cd}	2.32^{cd}
	64.5	15.00^{d}	3246.3^{a}	0.32^{a}	22.9^{d}	2.29^{d}
$LSD_{(0.05)}$		0.50	9.05	0.0009	0.63	0.03
CV		2.17	0.24	0.24	1.75	1.75

Means within a column followed by same letter are not significantly different from each other at P > 0.05; LSD = least significant difference; CV = coefficient of variation of treatments

The Olsen P content for the soil of Damot Sore District was qualifying very low range. This may be due to the P fixation with Fe and Al by favorable acidic soil reaction. For the studied soybean variety, significant difference ($p < 0.05$), was observed by the application of different treatments for P concentration in the leaves. Although the concentration of P in the leaves of soybean plant increased from 0.15 to 0.23%, the amount of P obtained in the leaves sample was below the expected or sufficiency range. Jones (1991), suggested that expected or sufficiency range of leaves of soybean plant was from 0.26 to 0.5% for P. The low P concentration in the leaves of soybean plant might be due to the low pH of the soil, high exchangeable acidity of the soil and appreciable amount of sesquoxides found in the soil which inhibit the nutrient concentration of the plant.

At pH below 5, the concentration of exchangeable Al increases and displaces other exchangeable cations such as Ca, Mg and K from the soil cation exchange sites and decreases the growth of the plant (Sivaguru and Horst, 1998). The exchangeable K content of the soil in this site was qualifying the medium range.. The soybean plant responds significantly to the application of K fertilization in Damot Sore District. According to Hussin *et al*. (1986), in intensively cultivated soils, K fertilization experiment showed that non exchangeable forms of K plays an important role in K concentration by plants. The highest K concentrations in the leaves of the soybean plant were observed by the application of P_{69} $K_{21.5}$ and P_{69} $K_{64.5}$. Jones (1991) indicated that the sufficiency range of K concentration in the leaves of soybean is from 1.71 to 2.5%.

The concentration of K by the application of P_{69} $K_{21.5}$ and P_{69} $K_{64.5}$ treatments were 1.73 and 1.83%, respectively qualifying the sufficiency range of K concentration in the leaves of the plant. The application of P and K containing fertilizers increased the concentrations of P and K in the leaves of the soybean plant as depicted in Table 4. The concentration of P in the leave samples of soybean plants varied markedly by the application of different treatments as shown in Table 4. The highest P concentration was recorded by the application of P_{69} $K_{21.5,}$ P_{69} K_{43} and P_{69} $K_{64.5}$ and the lowest P concentration was obtained by the application of P_0 K_0 (Table 4).

The P concentrations in the leaves of soybean plants showed significant differences ($p < 0.05$), for the majority of treatments tested in this study. However, insignificant variations ($p > 0.05$), were observed for some of the treatments examined in this study. The concentration of P in the leaves of the plant ranged from 0.09 to 0.27% (Table 4). Jones (1991) showed that expected or sufficiency range of leaves of soybean plant was from 0.26 to 0.5% for P. The sufficiency range for the leaves of soybean plant was obtained by the application of P_{46} K_{43}, P_{46} $K_{64.5}$, P_{69} $K_{21.5}$, P_{69} K_{43} and P_{69} $K_{64.5}$. For the studied site, significant differences ($p < 0.05$), were observed by the applications of different treatments tested for the concentration of K by the soybean plant. Unlike for Damot Sore District, the highest concentration of K in the plant leaves for Boloso Bombe District was observed by the application of P_{23} K_{43}. The soybean plant responds to the application of K fertilization in intensively cultivated soil (Boloso Bombe District). This is likely due to the non exchangeable forms of K play an important role in K concentration by plants. The results are in agreement with other studies (Goulding, 1984; Lal *et al.,* 1990).

The low available P in Damot Pulasa District implies that the studied soil was P deficient. The low contents of available P observed in the soil of the study area was in agreement with the research findings reported by previous authors (Yihenew, 2002; Berhane and Sahlemedhin, 2003) that the availability of P under most soils of Ethiopia were low due to the impacts of fixation, abundant loss by crop harvest and erosion and the inherent P deficiency of the soils since little or no P fertilizers had been applied. The dry weight content, P and K concentration in the leaves of soybean plant showed significant difference by the application of different treatments as shown in Table 5. The amount of fertilizer applied at the rate of P_{46} $K_{21.5}$, significantly increased the K concentration in the leaves of soybean plant (43.6 g kg^{-1}) whereas, the control treatment (P_0 K_0) significantly decreased K concentration in the leaves of the plant (12.1 g kg^{-1}). For most of the treatments applied, significant differences ($p < 0.05$), were observed for K concentration by the leaves of plant species. Yet, non significant differences ($p > 0.05$), were found some of the treatments applied (Table 5). A considerable increase in K concentration by the application of P and K containing fertilizers in Damot Pulassa District is favorably due to the less available K reserves play a significant role in K uptake by the plant. This is in line with the research findings reported by Liu and Bates (1990). According to Jones (1991) the sufficiency range of K concentration in the leaves of soybean plant is 1.71 to 2.50%. All the treatments applied in this study were in the sufficiency range for K concentration in the leaves of the plant except P_0 K_0, P_{23} K_0, P_{46} K_0 and P_{69} K_0. In the same way, the concentration of P in the leaves of the plant species showed significant differences ($p < 0.05$), except P_0 $K_{21.5}$ and P_0 K_{43} and P_{46} K_0 and P_{69} K_0. The highest P concentration observed by the application of P_{69} $K_{64.5}$ could be explained by the enhancement of P availability through water soluble TSP. According to Chien *et al.* (1987) application of water soluble P via TSP might have led to higher P availability through a better root system development.

As depicted in Table 6, the soybean had significantly different dry weights and P concentration. The dry weights obtained by the application of P_{23} K_{43} and P_{69} K_0 markedly higher than the dry weights of the other treatments (Table 6). The lowest plant dry weight belonged to P_0 K_0 (10.36 g pot^{-1}). There were no significant differences at ($p < 0.05$) found for some of the treatments applied for the dry weight obtained in this study. The available P content of the soil in Humbo District was above the critical level. However, by the application of control treatment, the P concentration in the leaves of the soybean plant was not found in the sufficiency range. This could probably due to the mineralogy of the soil. Increasing P and K containing fertilizers increased the concentration of P in the leaves of soybean plant. This is due to the applied fertilizer facilitate the root growth and enabling the plants to explore for more water and nutrients from the soil solution and ultimately making the nutrients available to plants. The exchangeable K content of the soil in this District was qualifying the high range. Increasing P and K containing fertilizers has little effect on increasing the K concentration by the leaves of the soybean plant (Table 6). The highest concentration of K in the leaves of soybean was observed by the application of P_0 K_{43} and P_0 $K_{64.5}$. Jones (1991) indicated that the sufficiency range of K concentration in the leaves of soybean is from 1.71 to 2.5%. All treatments applied were found in the sufficiency range of K concentration in the leaves of the plant.

Conclusion

The application of P and K containing fertilizers had a positive impact on increasing dry weight of the plant and the concentration of P and K in the leaves of the soybean plant. The applied fertilizer enabling the plants to explore for more water and nutrients from the soil solution and ultimately making the nutrients available to plants. In general, increasing P and K containing fertilizers increased the concentrations of P and K in the leaves of the soybean plant and satisfy the sufficiency range of these nutrients. Hence, researchers focused on sound management practices of acid soils and site specific fertilizers recommendation to enhance the productivity of soybean under filed condition.

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