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Research Article

Productivity and Oil Content of Soybean as Affected by Potassium Fertilizer Rate, Time and Method of Application

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Abstract

Background and Objective: The demand for soybean is on the rise worldwide for its vegetable oil and high protein seed content. One of the reasons for the reduction in the crop's area in Egypt is the high production costs, especially with the rise in fertilizer prices. Soybean requires high rates of potassium compared to other summer crops like maize. The main aim of this study was to investigate the possibility of replacing the soil applied mineral potassium fertilizer with a foliar form without affecting seed yield or oil content of seeds. **Materials and Methods:** A 2 year study was conducted, under irrigated conditions, to study the effect of 57 and 114 kg ha^{-1} potassium (K_2O) applied to the soil and 0.58 and 1.16 kg ha^{-1} (K_2O) sprayed on plants as foliar application at 2 soybean growth stages (V_2-V_3 and R_2-R_3) on growth, yield and yield attributes in addition to seed oil percentage of Giza 22 and Giza 35 soybean cultivars. **Results:** Results indicated the importance of K fertilization for improving yield and oil percentage of soybean. Foliar fertilization at the rate of 1.16 kg ha^{-1} applied at the R_2-R_3 stage (about 60 days after sowing), was superior in seed yield/plant and seed yield ha^{-1} as opposed to the soil application of 57 kg ha^{-1} and equivalent to 114 kg ha^{-1} applied to the soil. **Conclusion:** Foliar application of potassium at the rate of 1.16 kg ha^{-1} applied at the R_2-R_3 stage of soybean can replace the recommended soil application of 57 kg K ha^{-1} under irrigated conditions in Egypt, reducing the amount of potassium applied by 98%. This will achieve the targeted seed yield and oil percentage of soybean at much lower costs of production.

Key words: Potassium fertilizer, foliar application, oil content, seed yield, soybean

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Improvement in soybean productivity is essential to meet the tremendous demand for vegetable oils and protein for humans in addition to local feed industry in Egypt. The country is forecasted to import 4.0 million t of soybean by 2019/2020, mainly from the USA, essential for local crushing facilities responsible for vegetable oil extraction and high-protein soybean meal production for animal and poultry industries[1]. Despite this demand for soybean in Egypt, the production area is slowly climbing to 15,000 ha in 2017, after falling to as low[1] as 3900 ha in 2000. The productivity for that same period mentioned before, however, improved from 2.7-3.3 t ha^{-1} and these values are comparable to the averages reported in the USA for the same period[2].

Soybean productivity and seed quality are greatly affected by the correct nutrient balance to the growing crop, especially the 3 macro-elements N, P and K. In Egypt, the Ministry of Agriculture and Land Reclamation (MALR) recommends 54 kg P_2O_5/ha to be incorporated into the soil during land preparation and 144 kg N ha^{-1}, if inoculation with rhizobium is not practiced, in addition to 57 kg K ha^{-1}, especially in the newly reclaimed areas applied 30-45 days after sowing. Because of the high production costs of soybean production in Egypt[3], these fertilizer recommendations will not be fully met in the future. The continuous hikes in mineral fertilizer prices force farmers to skip the addition of potassium and rely only on phosphorous and nitrogen for production. This trend has been reported in other countries causing high deficiency in K in soils due to the continuous removal of K by crops grown over time without substitution by fertilization, as opposed to phosphorus and nitrogen, which eventually will reflect on yield[4].

Although potassium is not an integral component of any cellular organelle or structural part of the plant[5], its deficiency causes poor root system development, weak stalks, poor and shriveled seeds and fruits in addition to susceptibility to diseases[6]. The importance of K for soybean has been investigated by many researchers under a wide range of growing environments and cultural practices, however, results on the amount of K required by soybean, the application method, the time of application and its effect on seed yield and yield components were in many cases inconsistent. Regarding the effect of K fertilization rates on soybean[7], there were no significant changes in total seed oil and protein content in response to K fertilization (0, 66 and 132 kg K ha^{-1}), although total seed K concentration in plants and linolenic acid in seeds increased with higher levels of K fertilization. The effect of five K levels[8] (0, 45, 90, 134 and 179 kg ha^{-1}) on yield, oil% and oil composition in soybean showed in consistent effects on yield, however, the increase in seed oil% was positively correlated with K rates up to 134 kg ha^{-1}. On the other hand Abbasi *et al.*[9], reported an increase in seed yield from 15 to 45% when K was employed up to a rate of 80 kg ha^{-1} compared to the control, depending on the year.

Soybean seeds require up to 73% more K than corn grains[10] and because of the large amounts of K required by soybean, Imas and Magen[11] proposed that foliar application is not recommended and cited studies that observed foliar burning due to potassium foliar application leading to reduction in yield. These suggestions did not hamper research on foliar application of K. Pande *et al.*[12], studied 2 rates of foliar application (1.75 and 2.5%) of K (K_2SO_4) at the beginning of seed pod initiation stage (R_3) and compared those rates to soil application rates of 1.9 and 3.8 g kg^{-1} of K_2SO_4 on seed oil content. Their results indicated insignificant effects for K foliar applications on oil% compared to the control, while soil applications showed inconsistent results. In an attempt to cut on costs of production, the effect of foliar K fertilizer forms in combination with glyphosate to achieve both weed control and K fertilization in a single spray was investigated[13]. Spraying the K and glyphosate separately or in a mixture at the V_4-V_5 stage of development showed that increasing levels of K between 2.2 and 17.6 kg ha^{-1}, generally increased yield in absence of glyphosate, but the increase was dependent on the form of K applied and the year. In addition, an increase of 7-10% of oil content in the seed was observed with the increase in K level, suggesting the usefulness of foliar application of K for soybean.

As to when K should be applied to soybean, a highly significant linear regression ($R^2 = 0.95$) for the K use efficiency in the shoot of soybean as a function of plant age as opposed to a quadratic relationship for upland rice, corn and dry beans was observed[6]. These results point out the importance of K for soybean plants along the entire growth period. Zambiazzi[14] studied the effect of time of application of K (20, 30, 40 and 50 days after sowing) at the rate of 120 kg ha^{-1} on soybean plant height, yield and K content in the plant and found no effect of the timing of application as top dressing on the studied traits. Split application of K applied to soybean compared to single addition of 25, 50 and 75 kg ha^{-1} at sowing was recomended[15]. Improvement in seed yield was observed with increasing K rates compared to the control and with the increase in splitting (up to 3 splits, at sowing, planting and pod development) compared to single or 2 splits.

Because of the high prices of K for top dressing, liquid formulas could be a cheaper and more efficient source of potassium for soybean. Thus, the aim of this study was to investigate the effect of mineral potassium fertilization rates, time and method of application on seed production and oil content of 2 soybean cultivars under irrigated conditions.

MATERIALS AND METHODS

Study area: Field experiments were conducted at the Agricultural Research Station of the Faculty of Agriculture, Alexandria University, Egypt, where sowing was performed on the 1st May in both 2017 and 2018 summer season. The trial was conducted on a field characterized by a clay soil (62% clay, 20% silt and 17.5% sand), of a pH of 8.36, EC of 2.23 dS m^{-1} and the available macro-elements were N =1.0 ppm, P = 9.6 ppm and K = 32.8 ppm.

Plant material and treatments: Seeds of the 2 investigated soybean cultivars, Giza 22 and Giza 35, were sown in mid May split-plot experiment with 3 replicates. The main plots were allocated to the treatments that were a combination of cultivar and time of potassium fertilizer application either at V_2-V_3 or at R_2-R_3 growth stages. The early application at the V_2-V_3 vegetative stage (where the 2nd and 3rd trifoliate leaves have appeared), coincided with 30 days after sowing (DAS), while the late application, at the R_2-R_3 reproductive stage (where the flower buds appeared and up to seed set), coincided with 60 DAS. The subplots, on the other hand, contained 5 treatments as follows:

T1 = 0 kg K ha^{-1} of potassium
T2 = 57 kg K_2O ha^{-1} of potassium applied to the soil (57 kg ha^{-1}-soil) *
T3 = 114 kg K_2O ha^{-1} of potassium applied to the soil (114 kg ha^{-1}-soil)
T4 = 0.58 kg K_2O ha^{-1} of potassium as foliar spray (0.58 kg ha^{-1}-foliar)**
T5 = 1.16 kg K_2O ha^{-1} of potassium as foliar spray (1.16 kg ha^{-1}-foliar)

* Soil applied potassium was in the concentration of 48% K_2O, ** Foliar applied potassium was in the concentration of 36.5% K_2O.

Each of the experimental plots was made up of 3 ridges 3 meters long and 70 cm apart, resulting in an experimental plot area of 6.3 m^2. Four seeds were sown in hills 15 cm apart on both sides of the ridge, then thinned to 2 plants/hill at 21 days after sowing to achieve the recommended plant density of 380,000 plants ha^{-1}. Each season, a single dose of 54 kg P ha^{-1} was applied with seed bed preparation, 144 kg N ha^{-1} were split into two equal doses and applied at 30 and 45 DAS. Other cultural practices, including irrigation and pest control, were performed as recommended.

Sampling and laboratory analysis: At harvest, 5 plants were taken randomly from the guarded ridge from each plot and data on plant height (cm), number of branches/plant and number of pods/plant were recorded. After air drying, the number of seeds/pod, weight of 100-seed weight (g) and seed yield of a single plant (g), as an average of the 5 plants, were also recorded. Seed yield/ha was estimated after harvesting the entire guarded ridge and oil percentage was determined in seed samples using Soxhlet extractor[16].

Statistical analysis: Data were statistically analyzed using the SAS 9.3 software[17] for ANOVA for each year separately and a combined analysis over the 2 years of study was undertaken due to the homogeneity of error's variance[18]. Significance was declared at $p<0.05$ and the least significant difference (LSD) procedure was used for comparison of means of the studied treatments.

RESULTS

Season-related effects: Insignificant effects for the growing seasons and the interactions between the growing season and any of the studied factors on the 8 studied traits were observed (Table 1).

Cultivar-related effects: Significant variations were observed between the 2 studied cultivars regarding the number of branches/plant and oil percentage (Table 1). Furthermore, significant interactions between the cultivar and the potassium level were recorded for the number of branches/plant, seed yield/plant, seed yield ha^{-1} and oil percentage but the 3-way interaction was insignificant for all studied traits (Table 1). In general, the cultivar Giza 35 had a significantly higher number of branches (4.65 branches/plant), although this increase in number of branches did not result in any improvement in the number of pods/plant, seed yield/plant or seed yield ha^{-1} (Table 2). Also seeds of the cultivar Giza 35 showed a higher oil percentage (24.32%) compared to 23.95% for the cultivar Giza 22 (Table 2).

Potassium fertilizer-related effects: Significant effects for K fertilization rates and application method (soil applied or foliar sprayed on the plants) were observed for all studied traits (Table 1). For the plant height, number of seeds/pod, number

Table 1: Summary of the analysis of variance for soybean growth, yield and yield attributes combined over the 2 seasons of 2017 and 2018

Source of variation	df	Plant height	Number of branches/plant	Number of seeds/pod	Number of pods/plant	Seed yield /plant	100-seed weight	Seed yield ha^{-1}	Oil (%)
Replicate	2	1007.86	2.63	0.15	29.69	0.004	0.14	0.005	0.724
Season (A)	1	9.08^{ns}	0.37^{ns}	0.68^{ns}	239.78^{ns}	1.134^{ns}	12.84^{ns}	0.558^{ns}	121.500^{ns}
Error (a)	2	537.18	3.65^{ns}	0.08	36.40	0.081	1.32	0.110	8.100
Cultivar (B)	1	336.68^{ns}	6.57**	0.03^{ns}	0.13^{ns}	0.007^{ns}	0.48^{ns}	0.0001^{ns}	4.14**
Growth stage at application (C)	1	594.08^{ns}	2.83**	0.54**	2.85^{ns}	0.142^{ns}	37.40**	0.089^{ns}	43.89**
B×C	1	9.08^{ns}	0.01^{ns}	0.003^{ns}	0.23^{ns}	0.065^{ns}	0.00004^{ns}	0.008^{ns}	0.78^{ns}
Error (b)	12	147.48	0.30	0.06	9.18	0.045	0.36	0.023	0.21
K level (D)	4	711.01*	4.47**	0.22*	143.11**	11.627**	13.01**	2.272**	17.95**
B×D	4	261.36^{ns}	3.59*	0.11^{ns}	34.99^{ns}	0.623**	0.45^{ns}	0.124 **	2.48**
C×D	4	79.18^{ns}	1.86^{ns}	0.10^{ns}	21.50^{ns}	0.362**	1.16^{ns}	0.047^{ns}	1.90**
B×C×D	4	141.26^{ns}	0.28^{ns}	0.02^{ns}	16.37^{ns}	0.177^{ns}	1.15^{ns}	0.071^{ns}	0.50^{ns}
Error (c)	64	220.51	1.09	0.08	18.96	0.096	0.47	0.031	0.48

ns: Not significant at 0.05 level of probability, *,**Significant at 0.05 and 0.01 levels of probability, respectively

Table 2: Mean values for plant growth, yield and yield attributes as affected by the growing season, soybean cultivar, potassium level/application form and plant growth stage at which potassium was applied

Treatments	Plant height (cm)	Number of branches/plant	Number of seeds/pod	Number of pods/plant	Seed yield /plant	100-seed weight	Seed yield ha^{-1}	Oil (%)
Growing season								
2017	97.67^{a}	4.36^{a}	2.67^{a}	28.53^{a}	10.62^{a}	14.29^{a}	3.00^{a}	25.23^{a}
2018	98.22^{a}	4.47^{a}	2.47^{a}	33.07^{a}	10.86^{a}	13.63^{a}	3.13^{a}	23.04^{a}
Cultivars								
Giza 22	96.27^{a}	4.18^{b}	2.55^{a}	30.77^{a}	10.73^{a}	14.02^{a}	3.07^{a}	23.95^{b}
Giza 35	99.62^{a}	4.65^{a}	2.58^{a}	30.83^{a}	10.75^{a}	13.90^{a}	3.06^{a}	24.32^{a}
Plant growth stage at application								
V_2-V_3	95.72^{a}	4.56^{a}	2.63^{a}	30.96^{a}	10.70^{a}	13.40b	3.04^{a}	23.53^{b}
R_2-R_3	100.17^{a}	4.26^{b}	2.45^{b}	30.65^{a}	10.77^{a}	14.52^{a}	3.09^{a}	24.74^{a}
K level/application form								
Control	101.67^{a}	4.06^{b}	2.58^{ab}	29.83^{bc}	9.70^{d}	12.79^{d}	2.61^{d}	22.84^{d}
57 kg ha^{-1}-soil	103.54^{a}	4.27^{b}	2.51^{b}	31.51^{b}	10.94^{b}	14.20^{b}	3.15^{b}	25.00^{a}
114 kg ha^{-1}-soil	89.71^{b}	5.07^{a}	2.46^{b}	34.11^{a}	11.29^{a}	13.74^{c}	3.31^{a}	24.63^{ab}
0.58 kg ha^{-1}-foliar	95.83^{ab}	4.60^{ab}	2.72^{a}	27.43^{c}	10.40^{c}	14.4^{ab}	2.91^{c}	24.49^{b}
1.16 kg ha^{-1}-foliar	98.96^{a}	4.05^{b}	2.56^{ab}	31.13^{b}	11.37^{a}	14.67^{a}	3.35^{a}	23.70^{c}

Means followed by the same letters within the same column are insignificantly different at 0.05 level of probability

of pods/plant and 100-seed weight, variations were observed only for the main effects, while for number of branches/plant, seed yield/plant, seed yield ha^{-1} and oil (%) significant interactions were observed between cultivar and/or date of potassium application. Results of the main effects (Table 2), indicated in conclusive effects of K on either plant height or number of seeds/plant compared to the control. However, a prominent increase in the number of pods/plant was observed with the 114 kg ha^{-1}-soil application that significantly surpassed the control by 14.35%. On the other hand, the least number of pods/plant (27.43) was observed for the 0.58 kg ha^{-1}-foliar that was insignificantly different from the control. As to the 100-seed weight, the highest values (14.4 and 14.67 g) were recorded when 0.58 and 1.16 kg ha^{-1}-foliar were applied, respectively. Regarding the seed yield/plant, the highest improvement compared to the control amounted to 17.22% for 1.16 kg ha^{-1}-foliar application and that was insignificantly different from the 16.39% improvement for 114 kg ha^{-1}-soil application compared to the control. Similarly, an improvement of 28.35% in seed yield ha^{-1} was observed for 1.16 kg ha^{-1}-foliar application and that was insignificantly different from the 26.82% recorded for 114 kg ha^{-1}-soil application as compared to the control. As to the seed oil percentage, the highest significant improvement was observed when 57 or 114 kg ha^{-1}-soil were applied, with an improvement of 9.46% and 7.84% in oil percentage, compared to the control, respectively (Table 2).

Growth stage at application-related effects: Effects of the stage at which the potassium fertilization was applied were significant for the number of branches/plant, number of seeds/pod, 100-seed weight and oil percentage (Table 1). The application of K fertilization at the early growth stages (V_2-V_3 stage) significantly improved the number of branches/plant from 4.26-4.56 and the number of seeds/pod from 2.45-2.63, compared to the late stage of maturity (R_2-R_3) as seen in Table (2). On the other hand, the late potassium fertilization significantly increased the 100-seed

Table 3: Mean values for number of branches, seed yield/plant, yield ha^{-1} and oil% as affected by the interaction between the cultivar and the potassium level/application method

Cultivars	K level/application method	Number of branches/plant	Seed yield/plant (g)	Seed yield/ha (t)	Oil (%)
Giza 22	Control	3.78^{c}	9.69^{f}	2.65^{f}	22.54^{f}
	57 kg ha^{-1}-soil	4.07^{c}	10.97^{bc}	3.16^{c}	25.25^{a}
	114 kg ha^{-1}-soil	4.41^{bc}	11.15^{b}	3.24^{bc}	24.66^{bcd}
	0.58 kg ha^{-1}-foliar	4.19^{bc}	10.64^{d}	3.01^{d}	24.12^{d}
	1.16 kg ha^{-1}-foliar	4.43^{bc}	11.21^{b}	3.27^{bc}	23.16^{e}
Giza 35	Control	4.34^{bc}	9.71^{f}	2.59^{f}	23.14^{e}
	57 kg ha^{-1}-soil	4.46^{bc}	10.91^{c}	3.13^{cd}	24.75^{abc}
	114 kg ha^{-1}-soil	5.73^{a}	11.42^{ab}	3.37^{ab}	24.59^{bcd}
	0.58 kg ha^{-1}-foliar	5.02^{ab}	10.15^{e}	2.82^{e}	24.86^{ab}
	1.16 kg ha^{-1}-foliar	3.67^{c}	11.53^{a}	3.42^{a}	24.24^{cd}

Means followed by the same letters within the same column are insignificantly different at 0.05 level of probability

Table 4: Mean values for seed yield/plant and oil% as affected by the interaction between the plant growth stage at application and the potassium level/application method

Plant growth stage at application	K level/application method	Seed yield/plant (g)	Oil (%)
V_2-V_3	Control	9.86^{e}	22.53^{f}
	57 kg ha^{-1}-soil	10.80^{d}	24.16^{cd}
	114 kg ha^{-1}-soil	11.15^{bc}	23.91^{d}
	0.58 kg ha^{-1}-foliar	10.34^{e}	24.19^{cd}
	1.16 kg ha^{-1}-foliar	11.37^{ab}	22.84^{ef}
R_2-R_3	Control	9.54^{f}	23.15^{e}
	57 kg ha^{-1}-soil	11.08^{c}	25.85^{a}
	114 kg ha^{-1}-soil	11.43^{a}	25.34^{ab}
	0.58 kg ha^{-1}-foliar	10.45^{e}	24.79^{bc}
	1.16 kg ha^{-1}-foliar	11.36^{ab}	24.55^{c}

Means followed by the same letters within the same column are insignificantly different at 0.05 level of probability

weight from 13.40-14.52 g and oil percentage in seeds from 23.53-24.74% compared to the early fertilization (Table 2).

Interaction between cultivar and potassium fertilizer level/application-related effects: Under potassium fertilization levels and methods of application, the cultivar Giza 22 showed insignificant differences regarding the number of branches/plant, although a trend for an increase in the number of branches was observed with potassium application compared to the control (Table 3). On the other hand, Giza 35 treated with either 0.58 kg ha^{-1}-foliar or 114 kg ha^{-1}-soil produced the highest significant number of branches/plant, amounting to 5.02 and 5.73, respectively (Table 3). The two cultivars showed a significant level of improvement in seed yield/plant, seed yield ha^{-1} and oil percentage compared to the control under all potassium levels and methods of application employed. The maximum seed yield/plant and seed yield ha^{-1} for both cultivars was recorded when plants were treated with either 114 kg ha^{-1}-soil or 1.16 kg ha^{-1}-foliar (Table 3). The highest oil percentage (25.25%) was observed for the cultivar Giza 22 fertilized with 57 kg ha^{-1}-soil and that was insignificantly different from the values of 24.86% and 24.75% for Giza 35 fertilized with 0.58 kg ha^{-1}-foliar or 57 kg ha^{-1}-soil, respectively.

Interaction between plant growth stage and potassium fertilizer level/application-related effects: As seen from Table (4), the highest seed yield/plant (11.43 g) was recorded when 114 kg ha^{-1}-soil was applied at R_2-R_3 stage and that was insignificantly different from 11.36 g/plant obtained with 1.16 kg ha^{-1}-foliar applied at the same growth stage or when 1.16 kg ha^{-1}-foliar (11.37g) was applied at V_2-V_3 growth stage. The application of 0.58 kg ha^{-1}-foliar, whether applied at the early or late stage produced the least significant values for seed yield/plant. The highest oil percentages (25.85% and 25.34%) were observed when 57 kg ha^{-1}-soil and 114 kg ha^{-1}-soil were applied at the R_2-R_3 stage, respectively (Table 4).

DISCUSSION

The results presented here support the importance of potassium for improving soybean 100-seed weight, seed yield and oil percentage (Table 2). The average seed yield ha^{-1} and oil percentage of the cultivars Giza 22 and Giza 35 presented in this study were generally higher than those reported previously in Egypt[19], where the average seed yield and oil percentage of Giza 22 were 2.96 t ha^{-1} and 17.62%, respectively and the values for Giza 35 were 2.63 t ha^{-1} and 22.03%, respectively. These results indicated a great potential for yield improvement beyond the 3.0 t ha^{-1} threshold and better oil percentage when the recommended production package was fully implemented. Results also indicated that the improvement in soybean yield due to potassium fertilization is more related to the increase in seed weight rather than number of seeds/pod as seen in Table 2. This observation is in agreement with Imas and Magen[11] who indicated that potassium fertilization improved yield by increasing seed size. However, the results disagreed with those of Coale and Grove[20], who noticed an improvement in yield as a response to K fertilization that was attributed to the higher number of seeds/pod.

Based on the results shown from this study, the stage at which potassium was applied had obvious effects on the number of seeds/pod, 100-seed weight and oil percentage but no effects on seed yield. These results partially disagreed with the results of Zambiazzi *et al.*[14], who found no effects for the time of application (20, 30, 40 and 50 DAS) of 120 kg K ha^{-1} applied as top-dress on agronomic traits and grain yield of 8 soybean cultivars. Although the authors attributed this lack of response to the potassium application time to the surplus of K in the soil under study, it seems that the fact that these experiments were grown under rain fed conditions, may also have influenced the uptake of the fertilizer by the root system as low moisture water level in the rhizosphere reduces K uptake[6]. The late potassium fertilization seemed to positively affect oil percentage in the seeds in this study and these results were in agreement with Tiwari *et al.*[21], who reported that K is not crucial for young soybean seedlings, however, the K requirements reach their peak at the rapid vegetative stage and most of the K is then moved to the seeds during seed filling, where most of the K is stored.

Foliar application of potassium, tested here, showed better effects on 100-seed weight than soil applied potassium. This may be explained by the direct replenishing of leaf K as its being pulled by the pods, thus neither affecting photosynthesis nor awaiting for K supply from the shoot or root systems. Another important observation was that the higher rate of foliar fertilization (1.16 kg ha^{-1}-foliar) caused a general reduction in oil percentage in the seeds, compared to other treatments and this negative effect was pronounced at the V_2-V_3 stage where oil percentage was reduced to 22.84%, being insignificantly different from the control 22.53%, with no potassium applied. These observations suggest the possible usefulness of split foliar application of K as observed by the improvement in physiological efficiency of K due to splitting of the optimum dose of soil applied K indicated by Kolar and Grewal[15].

It was suggested that in order to achieve the goal of 3.0 t ha^{-1}, soybean requires 144 kg N, 54 kg P_2O_5 and 57 kg of K_2O ha^{-1} applied to the soil[11]. Our results suggested that under the recommended nitrogen and phosphorus fertilization levels, the foliar potassium fertilization at the rate of 1.16 kg ha^{-1} applied at the R_2-R_3 growth stage (almost 60 days after sowing), was superior in seed yield/plant and seed yield ha^{-1} as opposed to the recommended soil application of potassium at the rate of 57 kg ha^{-1} and equivalent to 114 kg ha^{-1} applied to the soil. Although a 1.0% reduction in oil percentage in the seeds is expected compared to 114 kg ha^{-1}, the foliar application of 1.16 kg ha^{-1} will cut on the fertilization costs required for an average yield of 3.0 t ha^{-1} expected from soybean under irrigated conditions.

CONCLUSION

Foliar application of potassium at the rate of 1.16 kg ha^{-1} applied at the R_2-R_3 stage of soybean can replace the recommended soil application of 57 kg K ha^{-1} under irrigated conditions in Egypt. This will achieve the targeted seed yield and oil percentage of soybean at much lower costs of production.

SIGNIFICANCE STATEMENT

This study discovered that soybean yield and oil percentage will not be affected if plants received their potassium requirements via the root system, in the traditional soil application method, or via their leaves through foliage spray at the R_2-R_3 growth stage. The suggested foliar application of potassium reduced the amount of potassium fertilizer applied by 98%, which makes soybean production more cost effective for farmers and reduces the hazards of excess fertilizers released into the environment.

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