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(Original Article)

Rationalization of Irrigation Water Using Potassium and Foliar Spraying with Salicylic Acid of Soybean

Mahmoud A. Ayoub[1]; Elmahdy A. Teama[2]; El-Saady A. Ali[2]; Mohamed T. Said[2] and Howida E. Abdelkader[2*]

[1]Legumes Department, Field Crop Research Institute, Agriculture Research Center, Giza, Egypt.
[2]Agronomy Department, Faculty of Agriculture, Assiut University, Assiut, Egypt.

[*]Corresponding author e-mail: howidaahmed10@gmail.com
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Abstract

A field experiment was carried out during 2023 and 2024 seasons at the Agricultural Research Station Experimental Farm in Shandaweel Island, Sohag Governorate to study the effect of spraying soybean (Var. Giza-111) with different concentrations of salicylic acid (SA) and potassium sulphate under different levels of water stress on some vegetative and crop yield characteristics. The experiment was laid out in randomized complete block design (RCBD) using strip plot arrangement within split with three replicates. Three irrigation water amounts (2400, 2000 and 1800 m^3/fed/season) were distributed vertically while the four SA concentrations (control, 25, 75, and 100 ppm) were allocated horizontally and, potassium sulphate rate (control, 48 and 72 kg/fed,) as soil applications were arranged in sub plot. The results showed that adding potassium at a rate of 72 kg per fed and spraying soybeans at a rate of 100 ppm had a significant effect on the growth (plant height and number of branches/plant) and soybean productivity (number of pods/plant, weight of 100 seeds, weight of seeds/plant and seed yield/fed). The interaction results showed that adding potassium at a rate of 72 kg /fed. and spraying salicylic acid at a rate of 100 ppm saved the amount of irrigation water from 2400 m^3 to 1800 m^3.

Keywords: *Growth, Irrigation water quantities, Potassium, Salicylic acid, Soybean.*

Introduction

Soybean is the most important grain legume of the world, which contributes significantly to edible oil, protein concentrate for animal feed, food uses and various industrial products Hartman *et al*., (2011). Soybean cultivation is concentrated in Minya Governorate, followed by Beni Suef and then Assiut. The general average productivity per hectare during the previous years (from 2019/2020 to 2024/2025) is 2.84 tons/hectare, as the average cultivated area during that period is 17 thousand hectares, giving a production of 48 thousand tons (IPAD, 2025). Soybean is considered a crop of enormous potential for improving human diet as well as animal feed and features prominently as row material base for ago-industries.

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Salicylic acid (SA) is an endogenous plant growth regulator that plays a great role in plant growth, ion uptake, transport, interaction with other organisms and in responses to environmental stress. Majeed *et al*., (2016) indicates that number of pods per plant and number of seed per pod in mung bean were also affected significantly by drought stress and foliar application treatments and highest number of number of pods and seed per pod was recorded in foliar application by 100 ppm of SA and K at a rate of 1% treatment. The increase in growth parameters of water stressed plants in response to SA may be related to the induction of antioxidant responses that protect the plant from damage.

Spraying salicylic acid helps in many fields and horticulture crops reduce the harmful and negative effects of water shortages during drought periods and thus helps rationalize irrigation water consumption. El-Shafey (2017) concluded that foliar application of soybean plants with 200 ppm salicylic and irrigated at 25-30% available soil moisture depletion (ASMD) (wet treatment) stimulate the growth of soybean plants via the enhancement of the biosynthesis of photosynthetic pigments, improved yield as well as carbohydrates, protein and oil content of soybean seeds. Increasing water stress from 25-30% up to 65-70% (ASMD) decreased growth, yield components and metabolic processes, salicylic and ascorbic acids treatments lead to regulation plant metabolism and soybean performance under drought stress. The maximum values of water use efficiency were obtained when soybean plants were irrigated at 45-50% (ASMD) and sprayed with 200 ppm of salicylic.

Foliar spray of SA is useful to enhance plant growth and yield in various crops especially those grown in abiotic stress environments. Alimento *et al.*, (2021) reported that soybean plants which were sprayed salicylic acid (10 ml/1l) were the tallest (134. 73 cm) as compared to un sprayed plants. Salicylic acid application also increased grain weight (219.99 g), number of pods/plant (220), pod diameter (4.67 cm), and pod length (3.90 cm). Whereas foliar application of potassium resulted in increased computed yield of (446.38 tons/ha) at 14% moisture content. Generally, these suggest that either foliar application of salicylic acid or potassium may help to mitigate drought stress as exemplified by the yield and morphological response of soybean

Moreover, Kuchlan and Kuchlan (2023) found that foliar spray with 100 ppm salicylic acid at vegetative and at pod filling stage was very effective for better seed production to improve quantity as well as quality of soybean seeds. He added that the increase in plant height at vegetative stage was 6.4, 11.1 and 16.4 per cent more than control by foliar application of salicylic acid 50, 100 and 200 ppm respectively. At pod filling stage the plant height varied from 63.38-64.55 cm with SA treatment as compared to control 61.71 cm. At both stages, the plant height was observed maximum with 200 ppm SA followed by 100 ppm.

Hussain *et al.*, (2024) indicate that salicylic acid foliar spray had a significant impact number of branches/plant, number of pods/plant, number of seeds/pod, 100-seed weight (g) and Seed yield/fad (kg/fed.) of soybean. Soybean plants which were sprayed by 100 ppm salicylic acid exceeded the control and 50 ppm treatments in all previous measured traits in this study. As the highest mean values were 5.00 for number of branches/plant, 158.33 for number of pods/plant, 2.82 for number of

seeds/pod, 20.18g for 100-seed weight and 897.58 kg for seed yield/fed (kg/fed.) in the first season, while in the second season the highest average values were 5.58 for number of branches/plant, 166.59 for number of pods/plant, 2.87 for number of seeds/pod, 21.38 g for 100-seed weight and 1092.58 kg for seed yield/fad (kg/fed.).

Considering the importance of K and SA in improving soybean plants, the present study was conducted with the objectives (a) to rationalizing irrigation water by using K and SA on growth and yield of soybean under Upper Egypt and (b) to determine the best concentration of K and SA to stimulate physiological processes to enhance growth and yield in soybean.

Materials and Methods

A field experiment was carried out during 2023 and 2024 summer seasons at the Agricultural Research Station experimental Farm in Shandaweel Island, Sohag Governorate to study the effect of spraying salicylic acid (SA) (control, 25, 75, and 100 ppm) and potassium sulphate (0, 48 and 72 kg/fed) under different levels of water stress (2400, 2000 and 1800 m^3/fed) on some vegetative and crop yield characteristics of soybean. Planting soybean (Var. Giza-111) was done on 14th and 15th of June in 2023 and 2024 seasons, respectively. The experiment was laid out in random complete block design using strip plot arrangement within split with three replicates. Three irrigation water amounts were distributed, while the four SA concentrations were allocated horizontally potassium sulphate rate as soil application were arranged in sub plot. All experimental units received the amounts of water during growth season as furrow irrigation through water counter. Irrigation numbers were 4 for each treatment. The irrigation water quantity was added through the water counter as following, (4 irrigation times × 600 m^3) for Ir1, (4 irrigation times × 500 m^3) for Ir2 and (4 irrigation times × 450 m^3) for Ir3, in both seasons, respectively. Irrigation time was arranged with potassium fertilization time.

Potassium sulphate was applied at two rates; one at 45 days after sowing (DAS) (flowering stage) and the second was added at 60 days from cultivation (pod filling stage). Salicylic acid was applied two times in every season firstly in vegetative stage (after 25 DAS) at flowering stage and the secondly at 55 days from cultivation (pod filling stage). The experimental unit area was 3.5 × 3.0 m (1/400 fed). Wheat was the previous crop for this experiment in both seasons. All agricultural operations for soybeans were carried out according to the instructions of the Ministry of Agriculture.

Soil samples from the top layer (0-30 cm depth) were randomly collected, chemical analysis was determined was determined according to Jackson (1973) before planting for physical and chemical analysis (Table1).

Table 1. Some physical and chemical properties of the experimental soil

Seasons		2023	2024
Mechanical analysis%	Sand %	66.30	66.00
	Silt%	28.00	28.00
	Clay%	5.70	6.00
Soil texture		Sandy loam	Sandy loam
Chemical analysis	pH 1:1 suspension	8.33	8.29
	EC 1:1 Extract Dsm^{-1}	0.71	0.70
	$CaCO_3$ %	8.00	8.00
	Available nutrients Ppm		
	N	90.00	90.00
	P	4.15	4.13
	K	128.70	128.70

Soil Analysis was done in the laboratory of the soil, water and environmental Institute**.** ARC in (Shandaweel research Station)

Measured traits

Vegetative traits: Days to flowering, Days to maturity, plant height and number of branches/plant. Flowering was estimated when the flowering process was completed to 50%, while maturity was estimated when the ripening process reached 90%.

Yield and its components: A random sample of ten plants from each plot was taken at harvesting to the laboratory where the following characteristics were recorded: Number of pods/plant, 100-seed weight (g), seed yield/plant (g) and seed yield/fed (ton/fed).

Statistical analysis: Collected data were analyzed by MSTAT-C (1991) software package according to Gomez and Gomez (1984). Means were compared using Least Significant Difference (LSD) at 5% level of significant (Steel and Torrie, 1981).

Results and Discussions

1- Vegetative traits and days to 50 % flowering and 90% maturity

The results in Table 2 show the main effect of the three irrigation quantities tested, soil application of potassium sulphate and the foliar applications of salicylic acid on vegetative growth parameters (days to flowering, days to maturity, plant height and number of branches/plant of soybean plants in the two growing seasons of 2023 and 2024. The results exhibited significant differences between the three irrigation quantities.

Days to flowering and days to maturity were highly significantly affected by irrigation quantities except, days to flowering in the 1st season. The least days to flowering and maturity were recorded for irrigation quantity of (1800 m^3) (Ir3). These results expressed the earliness of flowering and maturity under the least water quantities of irrigation water (Ir3) compared to the other water quantities in both seasons, respectively.

The plants irrigated with 1800 m^3 (Ir3) recorded the highest mean value of vegetative growth parameters in comparison to irrigation quantities of 2400 m^3 (Ir1) or 2000 m^3 (Ir2) in the two growing seasons. The increase percentages in plant height and

number of branches/plant recorded 6.77 & 1.20% and 11.82 & 14.48% due to Ir3 compared to Ir1 in both seasons, respectively.

With respect to the main effect of the different soil application treatments of potassium sulphate on vegetative growth parameters, the results in Table 2 reveal that soil application of potassium sulphate significantly reduced the mean values of both flowering and maturity parameters. Days to flowering reduced from 41.61 to 39.55 and 41.27 to 39.31 with reduction percentages 5.2% & 5.0% in both seasons, respectively. Meanwhile, the reduction percentages in days to maturity reached 1.7% & 1.7% compared to K1 (48 kg/fed) in both seasons, respectively. Therefore, increasing the amount of potassium sulphate helps in early flowering and maturation of soybeans. Additionally, plant height and number of branches/plant significantly increased with increasing potassium sulphate rate. Obtained results, shown that K2 (72 kg potassium sulphate/fed) recorded the maximum values of plant height and number of branches/plant compared to (K0). The increase percentages in plant height and number of branches/plant recorded 7.69 & 8.32% and 17.12 & 17.17% due to K2 (72 kg/fed) compared to control treatment (K0) in both seasons, respectively.

Table 2. Means of vegetative traits and days to 50 % flowering and 90% maturity of soybean as affected by K - application rates, foliar application of salicylic acid under different irrigation water quantity during the two seasons of 2023 and 2024

Traits	Days to flowering 50%		Days to maturity 90%		Plant height (cm)		Number of branches plant-1	
Seasons	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**
Treatments								
				(Ir)				
Ir1 (2400 m3)	40.75	40.55	118.4	118.4	82.26	82.08	3.434	3.316
Ir2 (2000 m3)	40.34	40.18	118.0	117.9	83.82	83.07	3.616	3.524
Ir3 (1800 m3)	40.35	39.94	117.7	117.6	86.35	85.07	3.840	3.796
F-test	n.s	**	**	**	**	**	**	**
LSD 0.05	--	0.28	0.16	0.16	0.31	0.49	0.09	0.05
				(K)				
K0 (0 kg/fed)	41.61	41.27	119.0	119.0	80.87	79.90	3.400	3.325
K1 (48kg/fed)	40.29	40.09	118.1	117.9	84.47	83.78	3.508	3.416
K2 (72kg/fed)	39.55	39.31	117.0	117.0	87.09	86.55	3.982	3.896
F-test	**	**	**	**	**	**	**	**
LSD 0.05	0.24	0.25	0.23	0.30	0.28	0.25	0.11	0.08
				(Sa)				
Sa0 (0 ppm)	42.15	41.60	122.7	122.7	80.13	79.33	3.109	3.071
Sa1 (25 ppm)	41.21	40.78	120.8	120.7	82.38	81.41	3.381	3.298
Sa2 (75 ppm)	39.77	39.66	116.4	116.4	85.01	84.42	3.773	3.686
Sa3 (100ppm)	38.80	38.85	112.3	112.1	89.05	88.47	4.256	4.127
F-test	**	**	**	**	**	**	**	**
LSD 0.05	0.22	0.23	0.32	0.26	0.44	0.40	0.08	0.11

Where, ns and ** mean non-significant and significant at 1% level of probability, respectively

Concerning the main effect of the different foliar applications of salicylic acid treatments on vegetative growth parameters, the results in Table 2 denote that the application of salicylic acid significantly increased the mean values of vegetative

growth parameters, in relation to the control treatment in both seasons. Increasing the concentration of SA reduced the days to flowering and maturity and at the same time, increased plant height and number of branches/plant. Plant height and number of branches/plant were significantly by (11.13 &11.52%) and (36.89 & 34.39%) due to foliar application by salicylic acid at 100 ppm compared to the control treatment in both seasons, respectively. This could be explained under the basis of the role of salicylic in amelioration of the adverse effects of water stress. Its role in the defensive mechanism against biotic and abiotic stress has confirmed. Or may be affecting directly on specific enzymes function or may activate the genes responsible for protective mechanisms (Horvath *et al*., 2007).

Additionally, Fathy *et al.*, (2000) reported that SA and vitamins were protective of cell membranes and their binding transporter proteins (H+ - ATP-ase membrane pumps), maintained their structure and function against the toxic and destructive effects reactive oxygen species (ROS) during stress, in turn, more absorption and translocation of minerals. Moreover, Al-Sharnouby *et al.*, (2023) reported that the foliar spray treatments with SA gave the highest values for all the studied traits, growth characteristics, i.e. plant height, number of branches, number of leaves, dry weight of the Green Bean (*Phaseolus vulgaris* L.) plants under salinity stress plant.

- The first order interaction

Concerning the first order interaction between (Ir × K) (Table 3), the obtained results illustrated that the earliest mean value of days to flowering was obtained from the plants that received combined application of (Ir3 (1800 m^3/fed) and 72 kg potassium sulphate /fed,). Meanwhile, days to maturity were not affected by this interaction in both seasons. Also, results shown that, the highest mean values of plant height and number of branches/plant in both seasons were obtained from the soybean plants that received combined application of (1800 m^3/fed) and (72 kg potassium sulphate /fed,).

Demonstrated results in Table 3 show that both days to flowering and to maturity were not affected by the interaction between Ir and SA except days to flowering in the 1st season, which was affected significantly by this interaction (Ir3 × SA3). Also, plant height was significantly affected by the interaction between Ir3 and SA3. On the contrary of that, number of branches/plant was not affected by this interaction in both seasons.

In relation to the first order interaction between K and SA, results of all traits appeared to be significantly affected except days to flowering in the 1st season. The interaction between K2 and SA3, recorded the earliest days to maturity and gives the maximum values of plant height and number of branches/plant in both seasons. These results in agreement with those obtained by Majeed *et al.*, (2016). Sujatha (2001) in a study revealed that foliar application of SA on green gram increased the plant height, number of leaves and LAI. Also, Sangakkara *et al*., (2001) found that application of K fertilizer and plant growth regulators mitigates the adverse effects of drought stress and improves the pod production that effectively contributes to seed yield.

Table 3. Means of vegetative traits and days to 50 % flowering and 90% maturity of soybean as affected by the interaction between Irr × K, Irr × SA and K × SA during the two seasons of 2023 and 2024

Traits		Days to flowering 50%		Days to maturity 90%		Plant height (cm)		Number branches plant^{-1}	
Seasons		**2023**	**2024**	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**
Treatments									
(Ir) vs (K)									
Ir1 (2400m^3)	**K0**	42.04	41.81	119.4	119.5	79.47	79.21	3.200	3.100
	K1	40.30	40.13	118.3	118.2	81.74	81.75	3.278	3.150
	K2	39.92	39.70	117.4	117.4	85.58	85.29	3.824	3.699
Ir2 (2000m^3)	**K0**	41.54	41.33	119.1	119.0	80.46	79.34	3.433	3.358
	K1	39.96	39.95	118.0	117.9	84.28	83.61	3.480	3.374
	K2	39.51	39.27	117.0	116.9	86.72	86.26	3.935	3.842
Ir3 (1800m^3)	**K0**	41.24	40.68	118.5	118.5	82.70	81.14	3.568	3.518
	K1	40.60	40.20	117.9	117.6	87.41	85.97	3.765	3.723
	K2	39.22	38.95	116.6	116.6	88.96	88.09	4.186	4.147
F-test		**	**	n.s	n.s	**	**	n.s	n.s
LSD 0.05		0.38	0.39	--	--	0.48	0.43	--	--
Irr. (I) vs (SA)									
Ir1 (2400 m^3)	**Sa0**	42.20	41.90	122.9	123.3	79.12	78.35	2.926	2.873
	Sa1	41.48	41.06	120.9	120.9	81.00	80.40	3.184	3.114
	Sa2	39.89	39.84	116.9	116.8	82.81	82.51	3.581	3.467
	Sa3	39.44	39.38	112.8	112.6	86.12	87.08	4.044	3.811
Ir2 (2000 m^3)	**Sa0**	42.12	41.64	122.6	122.4	79.60	79.01	3.059	3.011
	Sa1	41.13	40.82	120.9	120.8	81.90	80.76	3.387	3.258
	Sa2	39.42	39.51	116.4	116.4	84.68	84.29	3.773	3.662
	Sa3	38.68	38.75	112.3	112.2	89.09	88.23	4.244	4.167
Ir3 (1800 m^3)	**Sa0**	42.13	41.24	122.5	122.5	81.67	80.63	3.342	3.330
	Sa1	41.01	40.47	120.6	120.4	84.25	83.06	3.573	3.521
	Sa2	40.00	39.64	115.9	116.0	87.55	86.47	3.966	3.930
	Sa3	38.28	38.42	111.7	111.4	91.95	90.11	4.478	4.403
F-test		**	n.s	n.s	n.s	**	*	n.s	n.s
LSD 0.05		0.38	--	--	--	0.75	0.69	--	--
K0 (0 kg/fed)	**Sa0**	43.14	42.32	123.1	123.2	77.54	76.36	2.870	2.830
	Sa1	42.38	42.06	121.6	121.5	80.30	78.93	3.169	3.104
	Sa2	41.06	40.91	118.3	118.2	81.67	81.37	3.540	3.441
	Sa3	39.84	39.80	113.1	113.0	83.99	82.93	4.022	3.926
K1 (48kg/fed)	**Sa0**	42.07	41.51	122.7	122.6	80.36	79.46	3.028	2.991
	Sa1	40.94	40.56	120.9	120.7	82.71	81.72	3.292	3.210
	Sa2	39.53	39.57	116.1	116.4	85.06	84.45	3.488	3.407
	Sa3	38.60	38.72	112.5	112.1	89.76	89.48	4.222	4.056
K2 (72kg/fed)	**Sa0**	41.23	40.96	122.3	122.4	82.49	82.16	3.429	3.393
	Sa1	40.29	39.73	119.8	119.9	84.14	83.58	3.683	3.579
	Sa2	38.72	38.52	114.8	114.6	88.30	87.44	4.292	4.211
	Sa3	37.95	38.03	111.1	111.1	93.41	93.01	4.522	4.400
F-test		n.s	**	**	**	**	**	**	*
LSD 0.05		--	0.39	0.55	0.45	0.75	0.69	0.15	0.19

Where, ns, * and ** mean non-significant and significant at 5 and 1% level of probability, respectively

- The second order interaction

The obtained results in Table 4 reveal that days to flowering and maturity did not significantly affect by the second order interaction (Ir × K × SA) except days to flowering in the 1st season, which the interaction Ir3 × K2 × SA3 recorded the earliest days to flowering. Also, this interaction registered the maximum values of plant height and number of branches/plant in both seasons except number of branches/plant in the

2nd season. The demonstrated results registered that plant height of soybean was highly significantly increased as a results of the 3rd interaction between (1800 m^3 as irrigation water combined with 72 kg potassium sulphate and 100 ppm foliar application of salicylic acid) in both seasons, respectively. Among the treatments foliar spray of salicylic acid 40 ppm twice at pre and post flowering stage of crop growth recorded maximum grain yield (3593 kg ha^{-1}) and straw yield (8735 kg ha^{-1}) compared to other treatments. Also, Salicylic acid in sesame reduced the number of flowering days as reported by Umadevi (1998).

Table 4. Means of vegetative traits and days to 50 % flowering and 90% maturity of soybean as affected by the second order interaction (Ir × K × SA) during the two seasons of 2023 and 2024

Traits			Days to flowering 50%		Days to maturity 90%		Plant height (cm)		Number of branches $plant^{-1}$	
Seasons			2023	2024	2023	2024	2023	2024	2023	2024
Treatments										
Ir1	K0	Sa0	43.37	42.97	123.3	123.9	76.20	75.87	2.700	2.633
		Sa1	42.67	42.63	121.8	121.9	80.00	78.88	3.067	3.000
		Sa2	41.30	41.10	119.0	118.7	80.27	80.24	3.400	3.267
		Sa3	40.83	40.53	113.5	113.3	81.41	81.86	3.633	3.500
	K1	Sa0	41.80	41.47	123.1	123.2	79.36	77.49	2.867	2.833
		Sa1	40.93	40.43	120.8	120.6	80.40	79.97	2.933	2.900
		Sa2	39.45	39.57	116.6	116.7	81.58	81.43	3.243	3.133
		Sa3	39.00	39.03	112.7	112.5	85.61	88.10	4.067	3.733
	K2	Sa0	41.43	41.27	122.3	122.6	81.80	81.68	3.210	3.153
		Sa1	40.83	40.12	120.1	120.1	82.60	82.36	3.553	3.443
		Sa2	38.93	38.87	115.1	115.0	86.57	85.85	4.100	4.000
		Sa3	38.48	38.57	112.1	112.0	91.36	91.28	4.433	4.200
Ir2	K0	Sa0	43.03	42.20	123.0	122.9	77.37	75.52	2.800	2.767
		Sa1	42.43	42.25	121.9	121.4	79.55	77.67	3.163	3.097
		Sa2	40.68	40.83	118.3	118.4	81.32	81.27	3.633	3.500
		Sa3	40.00	40.03	113.3	113.1	83.60	82.92	4.133	4.067
	K1	Sa0	41.98	41.77	122.5	122.2	79.38	79.60	2.967	2.900
		Sa1	40.40	40.45	120.8	120.8	82.32	81.46	3.310	3.177
		Sa2	39.03	39.20	116.1	116.3	85.48	85.26	3.410	3.320
		Sa3	38.43	38.37	112.4	112.3	89.94	88.13	4.233	4.100
	K2	Sa0	41.33	40.97	122.3	122.2	82.06	81.91	3.410	3.367
		Sa1	40.57	39.77	119.9	120.0	83.83	83.16	3.687	3.500
		Sa2	38.53	38.50	114.8	114.5	87.24	86.33	4.277	4.167
		Sa3	37.60	37.85	111.1	111.0	93.74	93.64	4.367	4.333
Ir3	K0	Sa0	43.03	41.80	122.9	122.8	79.04	77.70	3.110	3.090
		Sa1	42.03	41.30	121.0	121.0	81.36	80.23	3.277	3.217
		Sa2	41.20	40.78	117.7	117.4	83.41	82.60	3.587	3.557
		Sa3	38.70	38.83	112.6	112.6	86.97	84.01	4.300	4.210
	K1	Sa0	42.43	41.30	122.4	122.3	82.35	81.29	3.250	3.240
		Sa1	41.50	40.80	121.2	120.6	85.41	83.74	3.633	3.553
		Sa2	40.10	39.93	115.7	116.1	88.13	86.65	3.810	3.767
		Sa3	38.37	38.77	112.4	111.5	93.74	92.20	4.367	4.333
	K2	Sa0	40.93	40.63	122.2	122.2	83.62	82.89	3.667	3.660
		Sa1	39.48	39.30	119.5	119.7	85.98	85.22	3.810	3.793
		Sa2	38.70	38.20	114.3	114.3	91.10	90.14	4.500	4.467
		Sa3	37.77	37.67	110.2	110.3	95.12	94.11	4.767	4.667
F-test			*	n.s	n.s	n.s	**	**	*	n.s
LSD 0.05			0.66	--	--	--	1.31	1.19	0.25	--

Where, ns, * and ** mean non-significant and significant at 5 and 1% level of probability, respectively

2- Soybean Yield and its components

Obtained data of Table 5 indicated that number of pods/plant, 100 seed weight; seed yield/plant and Seed yield/fed. (Ton/fed.) were affected significantly, by irrigation water quantity. All traits under the study were significantly higher under the lowest irrigation water quantity 1800 m^3 per fed.

The increase percentages in number of pods/plant, 100 seed weight, seed yield /plant and seed yield/fed., due to irrigation water quantity 1800 m3 per fed., recorded 5.04 &5.44%, 4.47 & 3.75%, 1.20 & 1.14% and 1.12 &1.16% compared to irrigation water quantity 2400 m^3 per fed. in both seasons, respectively. This might be explained under the basis that the quantity of irrigation water (1800m^3/fed) satisfied for plant under these condition of soil characteristics and climate condition in this region El-Shafey (2017) show that, water deficit stress increased antioxidants content (peroxidase and polyphenol oxidase) significantly, but content of them were more at mild (45-50% ASMD) than high water deficit stress (65-70% ASMD).

Concerning the main effect of K-application, results reveal that all Soybean yield and its components under the study were significantly affected by the different rates of potassium sulphate. Application of potassium sulphate at a rate of 72 kg/fed., increased number of pods/plant by 13.18 & 12.70%, 100 seed weight by 6.16 & 7.09%, seed yield/plant by (1.19 & 1.31%) and seed yield/fed by (1.21 & 1.27%) in both seasons, respectively.

Regarding the main effect of spraying salicylic acid levels, increasing foliar application concentrations significantly increased all soybean yield and its components in the two growing seasons. Data in Table 5 shown that the maximum values of all studied yield and its components traits registered as a result of 100 ppm of salicylic acid foliar application in both seasons. This might be due to enhancement of growth attributing characters. Dawood *et al.* (2012) observed that increase in kernel yield and yield components of sunflower by salicylic acid were due to the effect of physiological and biochemical processes that led to amelioration in vegetative growth, active assimilation and translocation from source to sink. These results in agreement with those obtained by El-Shafey (2017) whom found that foliar spray of salicylic and ascorbic acids singly or in combination, significantly increased all investigated yield components of soybean except number of pods/ plant in both growing seasons where, the maximum values of seed weight/ plant, 100 seed weight and harvest index were recorded when the plants were sprayed with 100 ppm SA + 100 ppm ASC and 200 ppm of ASC or SA, respectively in both growing seasons.

Table 5. Means of yield and its components traits of soybean as affected by K - application rates and foliar application with salicylic acid under different irrigation water quantities during the two seasons of 2023 and 2024

Traits	Number of pods per plant		100 seed weight(g)		seed yield per plant(g)		Seed yield/fed. (ton/fed.)	
Seasons	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**
Treatments								
Ir. (I)								
Ir1	117.1	115.9	18.99	18.94	122.6	122.7	1.595	1.595
Ir2	120.7	119.8	19.25	19.04	122.9	122.9	1.597	1.597
Ir3	123.0	122.2	19.84	19.65	124.1	124.1	1.613	1.612
F-test	**	**	**	**	**	**	**	**
LSD 0.05	1.24	0.57	0.20	0.07	0.10	0.23	0.014	0.003
(K)								
K0	112.3	111.8	18.66	18.46	122.5	122.4	1.592	1.591
K1	121.3	120.2	19.60	19.40	123.2	123.3	1.602	1.602
K2	127.1	126.0	19.81	19.77	123.9	124.0	1.611	1.612
F-test	**	**	**	**	**	**	**	**
LSD 0.05	0.75	0.90	0.20	0.21	0.12	0.16	0.002	0.002
(Sa)								
Sa0	112.6	111.7	17.58	17.64	121.8	121.9	1.583	1.584
Sa1	115.9	114.9	18.20	18.05	122.5	122.5	1.593	1.593
Sa2	121.3	120.1	19.61	19.43	123.9	123.8	1.610	1.610
Sa3	131.2	130.5	22.04	21.72	124.7	124.6	1.621	1.620
F-test	**	**	**	**	**	**	**	**
LSD 0.05	0.75	0.90	0.15	0.16	0.14	0.13	0.002	0.002

Where ** mean significant at 1% level of probability.

Concerning the interaction between Ir and K the obtained results in Table 6 illustrate that mean values of number of pods/plant was obtained from the plants that received combined application of Ir3 (1800 m^3/fed) and 72 kg potassium sulphate /fed, in the 1st season. On the contrary of that, results of No. of pods/plant recorded insignificant effect in the 2nd season. Also, results shown that the highest mean value 100 seed weight and seed yield/plant were obtained from the plants that received combined application of Ir3 (1800 m^3/fed) and 72 kg potassium sulphate /fed. Additionally, the maximum yield /fed was recorded due to interaction of Ir3 (1800 m^3/fed) and 72 kg potassium sulphate/fed, which reached 3.622 & 3.623 ton/fed in both seasons, respectively.

Here too, the results in Table 6 show that all yield traits significantly affected by the interaction between Ir and SA in both seasons. Also, No. of pods/plant, 100 seed weight, seed yield/plant and yield/fed were significantly affected by the interaction in favor of Ir3 and SA3 which recorded the maximum average values of pods number/plant (135.8 and 135.0), 100 seed weight (22.49 and 22.60 gm), seed yield/plant (125.8 and 125.8gm) and seed yield/fed (1.636 and 1.636 ton/fed) in both seasons, respectively. In this respect, El-Shafey (2017) reported that the interaction between soil moisture stress and foliar application of SA had significant effect on peroxidase and polyphenol oxidase activities. The highest values of two enzymes activities were obtained when soybean plants irrigated at medium treatment (50-55%) (ASMD) and foliar spraying with salicylic acid at 200 ppm and 100 ppm salicylic+100 ppm ascorbic acid. In this concern, salicylic pretreated soybean plants stimulation of antioxidants might be achieved by SA-induced protein synthesis.

Table 6. Means of seed yield and its components of soybean as affected by the interaction between Ir × K, Ir × SA and K × SA during the two seasons of 2023 and 2024

Traits		N of pods per plant		100 seed weight(g)		seed yield per plant(g)		Seed yield/fed. (ton/fed.)	
Seasons		2023	2024	2023	2024	2023	2024	2023	2024
Treatments									
Irr. (I) vs (K)									
Ir1	K0	109.2	108.6	18.62	18.41	122.1	122.2	1.587	1.588
	K1	118.2	116.6	19.15	19.21	122.5	122.6	1.593	1.594
	K2	123.8	122.6	19.19	19.21	123.4	123.4	1.603	1.604
Ir2	K0	112.2	112.0	18.92	18.63	122.1	122.1	1.586	1.587
	K1	122.8	121.5	19.47	19.11	123.0	123.0	1.599	1.599
	K2	127.0	125.9	19.35	19.38	123.6	123.6	1.606	1.606
Ir3	K0	115.4	114.8	18.45	18.34	123.2	123.0	1.602	1.599
	K1	123.0	122.5	20.18	19.87	124.2	124.2	1.615	1.614
	K2	130.5	129.4	20.89	20.74	124.9	125.0	1.624	1.624
F-test		*	n.s	**	**	**	**	**	**
LSD 0.05		1.29	--	0.35	0.36	0.20	0.27	0.003	0.004
Irr. (I) vs (Sa)									
Ir1	Sa0	111.3	109.4	17.32	17.51	121.6	121.8	1.580	1.583
	Sa1	113.9	113.1	18.09	17.92	122.2	122.3	1.588	1.589
	Sa2	117.0	115.7	18.99	19.04	123.1	123.0	1.600	1.599
	Sa3	126.0	125.5	21.54	21.30	123.8	123.9	1.609	1.611
Ir2	Sa0	113.2	112.7	17.65	17.74	121.5	121.6	1.579	1.580
	Sa1	115.9	114.7	17.84	17.89	122.3	122.3	1.590	1.589
	Sa2	121.8	120.8	19.42	19.26	123.4	123.5	1.604	1.605
	Sa3	131.9	130.9	22.08	21.27	124.3	124.2	1.616	1.614
Ir3	Sa0	113.1	113.0	17.77	17.67	122.3	122.3	1.590	1.590
	Sa1	117.9	117.0	18.68	18.34	123.2	123.1	1.601	1.600
	Sa2	125.0	123.9	20.41	19.98	125.1	125.0	1.627	1.625
	Sa3	135.8	135.0	22.49	22.60	125.8	125.8	1.636	1.635
F-test		**	**	**	**	**	**	**	**
LSD 0.05		1.29	1.57	0.26	0.27	0.24	0.22	0.003	0.003
K0	Sa0	105.1	105.1	17.03	17.06	121.0	121.1	1.573	1.574
	Sa1	109.3	108.6	17.52	17.24	121.8	121.8	1.583	1.583
	Sa2	115.9	114.9	18.83	18.73	123.1	122.9	1.600	1.598
	Sa3	118.8	118.5	21.27	20.81	124.0	123.9	1.611	1.610
K1	Sa0	115.0	113.9	17.80	17.78	121.7	121.8	1.582	1.583
	Sa1	117.5	116.3	18.39	18.32	122.7	122.7	1.595	1.595
	Sa2	121.4	120.5	19.86	19.56	123.9	124.0	1.611	1.612
	Sa3	131.3	130.1	22.33	21.92	124.7	124.5	1.621	1.618
K2	Sa0	117.5	116.1	17.91	18.08	122.7	122.7	1.595	1.595
	Sa1	120.9	120.0	18.70	18.60	123.1	123.1	1.600	1.600
	Sa2	126.4	125.0	20.13	19.98	124.6	124.6	1.620	1.619
	Sa3	143.6	142.8	22.51	22.44	125.3	125.6	1.629	1.632
F-test		**	**	n.s	n.s	*	**	*	**
LSD 0.05		1.29	1.57	--	--	0.24	0.22	0.003	0.003

Where ns, * and ** mean non-significant and significant at 5 and 1% level of probability, respectively.

In relation to the first order interaction between K and SA, results of all traits appeared to be significantly affected except 100 seed weight in both seasons. The interaction between K2 and SA3 gives the maximum values of No. of pods/plant (143.6 and 142.8) and seed yield/plant (125.3 and 125.6) in both seasons. The interaction between K2 and SA3 recorded the highest values of Soybean yield/fed which reached 3.635 & 3.641 ton/fed in comparison to other treatments in both

seasons, respectively. The previous findings are attributed to the role of salicylic acid for enhancement growth and reduce the harmful effects of biotic and abiotic stress which led to high photosynthesis process and accumulated high products in plants and consequently increased seed yield and its attributes. Similar findings were in agreement with the works of Mageed *et al*. (2016) revealed that foliar application of SA and K improved the crop under drought stress condition, but significant improvement in yield attributes was recorded by combined application of SA and K.

- The second order interaction

The results obtained in Table 7 reveal that all yield and its components traits under the study significantly affected by the second order interaction (Ir × K × SA) in both seasons. The interaction Ir3 × K2 × SA3 recorded the highest values of No. of pods/plant, 100 seed weight: seed yield/plant and soybean yield/fed., in both seasons.

Table 7. Means of seed yield and its components of soybean as affected by the interaction between Ir × K × SA during the two seasons of 2023 and 2024

Traits			No. of pods per plant		100 seed weight(g)		seed yield per plant(g)		Seed yield/fed. (ton/fed.)	
Seasons			2023	2024	2023	2024	2023	2024	2023	2024
Treatments										
Ir1	K0	Sa0	103.0	102.5	17.01	17.06	120.9	121.2	1.572	1.575
		Sa1	106.8	106.5	17.97	17.40	121.2	121.6	1.576	1.581
		Sa2	110.5	109.7	18.67	18.78	122.6	122.3	1.593	1.590
		Sa3	115.6	115.4	20.83	20.40	123.5	123.6	1.606	1.607
	K1	Sa0	113.6	110.9	17.54	17.71	121.0	121.4	1.573	1.578
		Sa1	115.6	114.3	18.03	18.20	122.3	122.2	1.590	1.589
		Sa2	116.2	115.2	19.11	19.19	123.0	123.1	1.598	1.600
		Sa3	127.2	126.1	21.90	21.74	123.8	123.7	1.609	1.608
	K2	Sa0	116.5	114.9	17.40	17.76	122.7	122.7	1.596	1.595
		Sa1	119.4	118.3	18.27	18.16	122.9	122.9	1.598	1.598
		Sa2	124.0	122.2	19.20	19.15	123.6	123.6	1.607	1.607
		Sa3	135.3	134.9	21.89	21.75	124.1	124.4	1.614	1.618
Ir2	K0	Sa0	106.0	107.1	17.30	17.40	120.9	121.0	1.572	1.573
		Sa1	109.5	108.5	17.35	17.42	121.8	121.6	1.583	1.581
		Sa2	115.3	114.5	19.07	19.02	122.2	122.5	1.589	1.592
		Sa3	118.1	117.8	21.95	20.69	123.3	123.3	1.603	1.602
	K1	Sa0	116.8	115.7	17.82	17.75	121.1	121.2	1.575	1.575
		Sa1	118.8	116.6	18.07	18.09	122.2	122.3	1.588	1.590
		Sa2	122.9	122.0	19.75	19.32	123.9	123.8	1.610	1.610
		Sa3	132.6	131.5	22.23	21.28	124.7	124.5	1.622	1.619
	K2	Sa0	116.7	115.3	17.83	18.07	122.4	122.6	1.591	1.593
		Sa1	119.2	119.0	18.09	18.17	122.9	122.8	1.597	1.596
		Sa2	127.1	125.9	19.43	19.43	124.1	124.1	1.613	1.613
		Sa3	145.0	143.5	22.06	21.83	124.9	124.8	1.624	1.622
Ir3	K0	Sa0	105.3	105.7	16.79	16.72	121.2	121.2	1.575	1.576
		Sa1	111.8	110.8	17.23	16.91	122.4	122.2	1.591	1.588
		Sa2	122.0	120.6	18.75	18.39	124.4	124.0	1.617	1.612
		Sa3	122.6	122.1	21.03	21.33	125.0	124.7	1.625	1.622
	K1	Sa0	114.6	115.2	18.04	17.89	122.8	122.8	1.597	1.597
		Sa1	118.0	117.8	19.07	18.66	123.6	123.5	1.606	1.606
		Sa2	125.1	124.3	20.73	20.18	125.0	125.0	1.625	1.625
		Sa3	134.1	132.5	22.87	22.75	125.5	125.2	1.632	1.628
	K2	Sa0	119.3	118.1	18.49	18.41	123.0	122.8	1.599	1.597
		Sa1	124.0	122.5	19.74	19.45	123.6	123.6	1.606	1.606
		Sa2	128.0	126.7	21.75	21.36	126.0	126.0	1.639	1.637
		Sa3	150.6	150.1	23.57	23.73	127.0	127.4	1.651	1.657
F-test			**	**	**	n.s	**	**	**	**
LSD 0.05			2.24	2.71	0.44	--	0.41	0.38	0.012	0.011

Where ns and ** mean non-significant and significant at 1% level of probability, respectively.

Number of pods/plant recorded 150.6 and 150.1, 100 seed weight recorded 23.57 and 23.73 gm, seed yield/plant recorded 127.0 and 127.4 gm and soybean yield/fed recorded 1.651 and 1.657 ton/fed as a result of the interaction Ir3 × K2 × SA3. Moreover, El-Nwehy *et al.*, (2020) Foliar application of potassium humate increased the growth, grain yield and oil content of soybeans under water stress conditions as a 21-days irrigation treatment. The results of the experiments showed that the foliar application of potassium humate in an amount of 4 gm / L under water stress is an effective strategy for improving soybean productivity compared to others. grain yield (1795 kg / fed.) was obtained with 2 gm / L K-humate foliar spray as a relative increase of 41% in a 14-days irrigation treatment. The highest value of grain yield (1344 kg /fed) was achieved with 4 gm / L K-humate in 21 days irrigation with relative increase being 41%.

Conclusion

From the previous results, it could be concluded that, the combination between irrigation water quantities 1800 m^3 and soil application of potassium sulphate at a rate of 72 kg/fed. combined by foliar application by 100 ppm salicylic acid (at flowering and pod filling), had the highest mean values of vegetative, yield and its components traits of soybean (Var. Giza-111) under the conditions of Sohag governorate.

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ترشيد مياه الري باستخدام البوتاسيوم والرش الورقي بحمض الساليسيليك في فول الصويا

محمود عبد العزيز أيوب[1]، المهدي عبد المطلب المهدي طعيمه[2]، السعدي عبد الحميد على[2]، محمد ثروت سعيد عبد العال[2]، هويدا عز الدين عبد القادر[2]*

[1]قسم المحاصيل البقولية، معهد المحاصيل الحقلية، مركز البحوث الزراعية، الجيزة، مصر.
[2]قسم المحاصيل، كلية الزراعة، جامعة أسيوط، أسيوط، مصر.

الملخص

تم إجراء تجربة حقلية خلال موسمي 2023 و2024 في المزرعة التجريبية لمحطة البحوث الزراعية بجزيرة شندويل بمحافظة سوهاج على فول الصويا (الصنف جيزة 111) لترشيد استهلاك مياه الري عن طريق إضافة البوتاسيوم ورش مستويات مختلفة من حمض الساليسيليك. ونفذت التجربة باستخدام تصميم القطاعات كاملة العشوائية بترتيب الشرائح المنشقة بثلاث مكررات. تم توزيع ثلاث كميات ري (1800، 2000، 2400م^3) رأسيا وتركيزات الرش الورقي بمستويات حمض الساليسيليك (الكنترول، 25 ،7575،00 جزء في المليون) افقيا بينما وضعت مستويات الاضافة الارضية بكبريتات البوتاسيوم (الكنترول، 48 و72 كجم/ فدان) في القطع المنشقة.

وأظهرت النتائج أن إضافة البوتاسيوم بمعدل 72 كجم/فدان ورش فول الصويا بمعدل 100 جزء في المليون كان له تأثير معنوي على النمو (ارتفاع النبات وعدد الأفرع/نبات) وإنتاجية فول الصويا (عدد القرون/نبات، وزن 100 بذرة، وزن البذور/نبات، محصول البذور/فدان). وأظهرت نتائج التفاعل أن إضافة البوتاسيوم بمعدل 72 كجم/فدان ورش حمض الساليسيليك بمعدل 100 جزء في المليون وفر كمية مياه الري من 2400 إلى 1800م3.

الكلمات المفتاحية: *كميات مياه الري، البوتاسيوم، النمو، حمض الساليسيليك، فول الصويا.*