International Journal of PharmTech Research
CODEN (USA): IJPRIF, ISSN: 0974-4304, ISSN(Online): 2455-9563
Vol.9, No.10, pp 551-557, 2016

Influence of silicon addition on the growth, yield and nutrient content of soybean (*Glycine max*) plants

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Abstract : Silicon (Si) is the second most common element in soil that has beneficial effects on living and non-living increase stress tolerance in plants. It can lead to increase production and product quality, reduce evaporation of perspiration, increase stimulation of some antioxidant enzymes and decreased sensitivity to some fungi. Therefore this study was conducted in order to compare the effect of different levels of Salicylic acid (SA) and method of addition. The different levels of salicylic acid (SA) were tested in two seasons in field experiment to assess their effects on improvement of growth and yield in soybean (Glycine max) plants in a complete randomized block design. The salicylic acid was added to soil in concentration of2.5, 5.0 and 7.5 kg fed^{-1}and sprayed at a rate of 250, 500 and 750 ppm. Data reported that the vegetative growth characters of soybean increased by increase the rate of salicylic acid fertilizer. The highest vegetative growth characters recorded with foliar application of 750 ppm fed^{-1}salicylic acid etc. Plant height (cm), number of branches, number of pods per plant, 100-seed weight (g), straw yield and seed yield (90.24 cm, 3.27, 63.42, 20.15g, 6.16Mg ha-1 and 5.35Mgha-1respectively). Foliar spraying of salicylic acid fertilizer had a significant effect on pigments (chlorophyll a, chlorophyll b and carotenoids) compared to control plants. The obtained results indicate that spraying plants with Salicylic acid at both investigated levels significantly increase N, P and K content in the leaf tissues than untreated plant. Seed protein followed the same trend obtained previously in nitrogen content the highest value is 32.77%. The highest value was recorded in spraying plants with 750 ppm salicylic acid in two study seasons.
Key words : salicylic acid fertilizer - growth - yield - nutrient content - soybean (Glycine max).

Introduction

Silicon (Si) is the most abundant in soil next to oxygen and comprises of 31% of its weight, 3-17% in soil solution. Silicon, as salicylic acid (0.1-0.6 mM) occurs as one of the main constituents of soil solution and it can be regarded as a plant nutrient[1]. It is most commonly found in soils in the form of solution as Salicylic Acid (H_4SiO_4)[2] and is taken up directly as salicylic acid[3]. Also, Silicon is translocated in the form of monosalicylic acid through the xylem in rice[4]. It primarily accumulates in leaves due to the distributed with the transpiration stream[5].Thesilica bodies are located in silica cells below the epidermis and in epidermal appendices in dried plant parts[6]. Being a dominant component of soil minerals the silicon has many important functions in environment. Although the silicon is not considered as an essential plant nutrient because most plants can be grown from seed to seed without its presence[7], however, many plants can accumulate silicon concentrations higherthan essential macronutrients[1]. Many studies have suggested the positive growth effects of silicon, including increased dry mass and yield, enhanced pollination[8] and most commonly increased disease resistance[9,10]. It reduces micronutrient and metal toxicity[11] even if not taken up in appreciable amounts[12].

Soybean is one of the most significant crops worldwide[13] and is considered an important source of oil and protein [14]. Soybean oil ranked number one in oil consumption among the major oil seed crops [15] and represents 54% in the worldwide market[16]. Also, Soybean is high protein content in seeds accounts for both feed and food utilization[17].It is a leguminous oilseed crop having worldwide adaptation and known as "Goldenbean" or" Miracal crop" of 20th century as it is the richest source of protein (40%) and oils (20%). Soybean being rich source of amino acid, unsaturated fatty acids, vitamins and minerals are being widely used in different forms and acquires. Also, Soybean (Glycinemax L. Merrill) is a source of complete food with a high nutrient content and good. Soybean seeds are a source of high quality protein, oligosaccharides, dietary fiber, minerals and phytochemical particularly isflavones[18].

The aim of this study was to compare the effect of different levels of Salicylic acid (SA) and method of addition on growth and productivity of soybean.

Materials and Methods

The field experiment was conducted in the private farm, Shibeen El Knatr, El Qualubia Governorate, Egypt for two successive summer growing seasons of 2013 and 2014 to study the effect of different levels of Salicylic acid (SA) and method of addition on growth and productivity of soybean. The experiment waslaid out according to the randomized complete block design (RCBD) with three replicates on a net plot area of 10.5 m^2. The soils used in the present work were analyzed according to[29, 20]and results are shown in Table 1.

Table 1: Some physical and chemical properties of a representative soil samplesof the experimental site before sowing.

Soil characteristics	First season 2013	Second season 2014
Sand (%)	13.27	13.15
Silt (%)	29.88	29.82
Clay (%)	56.85	57.03
Textural class	Clay	Clay
CaCO3 (g kg^{-1})	25.10	22.31
OM (g kg^{-1})	16.54	14.21
pH (1:2.5)	8.26	8.22
EC (dS m^{-1}) (Soil paste)	1.21	1.13
Available N (mg kg^{-1})	41.00	45.00
Available P (mg kg^{-1})	9.64	8.47
Available K (mg kg^{-1})	398	398

The Experimental Treatments:

T1- control (Non fertilizer), T2- 100 % Recommended Dose Fertilizers NPK (100 % RDF),T3- 100% RDF + 2.5 kgfed^{-1}salicylic acid (soil addition), T4- 100% RDF+5.0 kg fed^{-1}salicylic acid (soil addition), T5- 100% RDF+7.5kgfed^{-1}salicylic acid (soil addition), T6- 100% RDF + 250 ppm salicylic acid (foliar spraying), T7- 100% RDF + 500 ppm salicylic acid (foliar spraying) T8- 100% RDF + 750 ppm salicylic acid (foliar spraying).

Fertilizers used

The NPK fertilizers were applied to the experimental plots as recommended by the Egyptian Ministry of Agriculture in form of ammonium sulphate (20.5% N), Calcium super phosphate (15%P_2O_5) and potassium sulfate (48%K_2O) at the rates of 75 kg N fad^{-1}, 15 kg P fad^{-1} and 15 kg Kfad^{-1}, respectively. All the agriculture recommended practices were followed as usual including the irrigation processes. The salicylic acid was added as 2.5, 5.0 and 7.5 kg per fad mixing with soil (as soil addition)and sprayed at a rate of 250, 500 and 750 ppm SiO_2 (as foliar spraying).Foliar treatments of silicon were sprayed three times at 35, 50 and 65 days after sowing.

Soybean seeds:

Soybean (*Glycine max L.*) seed iscultivar Giza 111was supplied by the Plant Breeding Department, Agriculture Research Center, Giza.

Experimental measurements

Growth and yield measurements the plant samples were collected at 45 and 90 days after sowing. The chlorophyll a, b and carotene were estimated in the fresh leaves as described by[19]. Shoot dry weight was obtained at the beginning bloom growth stage. The straw dry weight (defined as all the non-seed materials collected at the physiological maturity growth stage of soybean), grain yield, 100-seed weight, number of pods per plant, plant height and number of branches per plant were recorded at the physiological maturity growth stage of soybean.

Soil and plant analysis

Soil samples were collected from all experimental plots during plant harvesting, air dried and sieved to pass through a 2 mm sieve. Soil pH was determined in 1:2.5 (soil: water suspension). The collected plant materials i.e. shoot and seed were oven dried at 70° C for 48h, ground and sieved in a micro mile, then digested by the method described by [21].Total nitrogen, phosphorus and potassium estimated in the plant digest according to the method described by [22] The Crude protein was calculated by the following equation: Crude protein = N% × 6.25, according to[23].

Statistical analysis:

Data were statistically analyzed by using factorial completely randomized design. The means was compared using the least significant difference test (LSD) at 5% level according to[24].

Results

Growth & yield: The results shown in table 2 reveal that the studied growth parameters i.e. plant height, number of branches, number of pods per plant, 100-seed weight, straw yield and seed yield were higher in the added salicylic acid to plants in soil addition or foliar spraying compared with the control treatment. The highest values were obtained from the application of using spraying salicylic acid at a rate of 750 ppm. The increment effect of plant height(cm), number of branches, number of pods per plant, 100-seed weight(g), straw yield and seed yield by 90.24 cm, 3.27, 63.42, 20.15(g),6.16 (Mg ha^{-1}) and 5.35(Mgha^{-1})respectively.

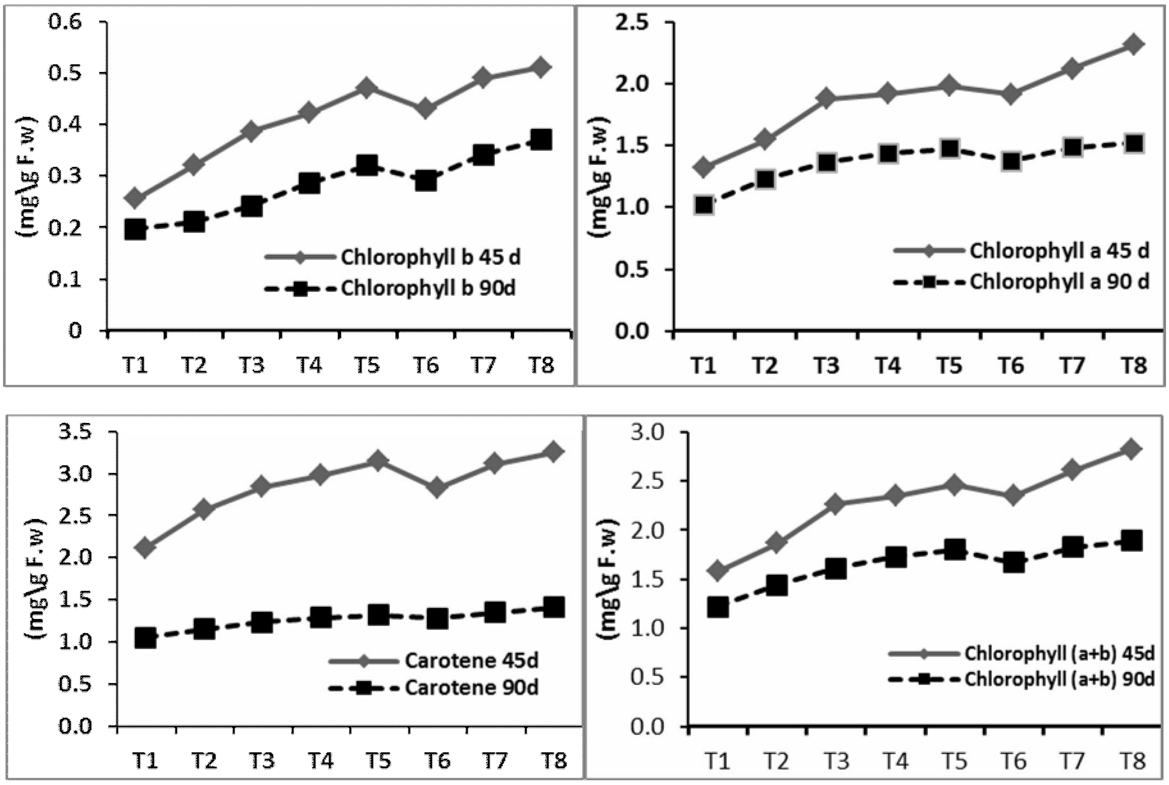
Table 2: Some growth parameters of soybean as affected by different levels of Salicylic Acid and the method of addition (Data mean values of two seasons).

Treatments	Plant height (cm)	Branch No. per plant	100-seed weight (g)	Pod No. per plant	Straw yield (Mg ha^{-1})	Seed yield (Mg ha^{-1})
T1- Control (Non fertilizer)	53.52	1.12	11.28	40.28	2.92	1.77
T2- RDF (100 %),	60.43	1.84	13.60	43.23	3.47	2.32
T3- RDF + 2.5 kg fed^{-1} (SA)	68.79	2.08	15.3	47.50	3.83	3.15
T4- RDF + 5.0 kg fed^{-1} (SA)	81.31	2.56	17.51	55.50	4.36	4.15
T5- RDF + 7.5 kg fed^{-1} (SA)	83.79	2.71	18.37	57.76	4.97	4.92
T6- RDF + 250 ppm (SA)	82.71	2.46	17.86	57.60	4.62	4.55
T7- RDF + 500 ppm (SA)	86.54	2.88	19.12	60.46	5.89	5.12
T8- RDF + 750 ppm (SA)	90.24	3.27	20.15	63.42	6.16	5.35
LSD (0.05)	**0.163**	**0.213**	**0.092**	**0.18**	**0.07**	**0.06**

Chemical Constituents

a. Leaf Pigments

It is clear from Fig.1 that spraying the plants with different levels of Salicylic acid increases the content of photosynthetic pigments (chlorophyll a, b, a+b and carotenoids)compared to control treatment. The highest values obtained from the application of using spraying Salicylic acid at a rate of 750 ppm.



T1- Control (Non fertilizer)	**T2**- RDF (100 %),	**T3**- RDF + 2.5 kg fed^{-1} (SA)	**T4**- RDF + 5.0 kg fed^{-1} (SA)
T5- RDF + 7.5 kg fed^{-1} (SA)	**T6**- RDF + 250 ppm (SA)	**T7**- RDF + 500 ppm (SA)	**T8**- RDF + 750 ppm (SA)

Fig 1: Chlorophyll a, b, a+b and carotene contents as affected by different levels of salicylicacid and method of addition at vegetative growth (Data mean of two seasons).

b. Nutrient Content

Data in Table 3 presented the response of nitrogen content to different treatments. The obtained results indicate that spraying plants with Salicylic acid at both investigated levels significantly increased N content in the leaf tissues than un treated. The highest results produced by 100% RDF + 750 ppm salicylic acid (foliar spraying).Seed protein followed the same trend obtained previously in nitrogen content was also increased by spraying plant with 750 ppm salicylic acid. The highest value is32.77%.

Table 3: Nitrogen content of grain and straw as affected by different levels of Salicylic acid and method of addition. (Data mean values of two seasons)

Treatments	Beginning bloom shoot (mg g^{-1})	Physiological maturity		Protein (%)
		Grain (mg g^{-1})	Straw (mg g^{-1})	
T1- Control (Non fertilizer)	40.18	36.11	9.40	22.57
T2- RDF (100 %),	44.49	40.73	12.42	25.46
T3- RDF + 2.5 kg fed^{-1} (SA)	48.36	45.30	15.44	28.31
T4- RDF + 5.0 kg fed^{-1} (SA)	50.29	47.80	17.39	29.87
T5- RDF + 7.5 kg fed^{-1} (SA)	51.22	49.48	18.47	30.92
T6- RDF + 250 ppm (SA)	50.65	48.63	18.33	30.39
T7- RDF + 500 ppm (SA)	53.24	51.56	18.50	32.02
T8- RDF + 750 ppm (SA)	54.18	52.44	19.47	32.77
LSD (0.05)	**0.456**	**0.461**	**0.505**	**0.288**

Results in Table 4 reveals that spraying the plants with different levels of salicylic acid increased P and K content in shoot at the beginning bloom growth stage and in straw and grain at the physiological maturity growth stage. The highest values of P and K content recorded with plants sprayed 750 ppm salicylic acid.

Table 4: Phosphorus and potassium content in grain and straw of soybean as affected by different levels of Salicylic acid and method of addition (Data mean values of two seasons).

Treatments	Phosphorus (P) (mg g^{-1})			potassium (K) (mg g^{-1})		
	Beginning bloom shoot	Physiological maturity		Beginning bloom shoot	Physiological maturity	
		grain	Straw		grain	Straw
T1- Control (Non fertilizer)	2.97	2.12	1.24	51.28	11.59	23.37
T2- RDF (100 %),	4.21	2.66	1.43	62.92	15.53	26.46
T3- RDF + 2.5 kg fed^{-1} (SA)	5.21	2.94	1.78	68.30	17.21	29.51
T4- RDF + 5.0 kg fed^{-1} (SA)	5.96	3.13	2.03	71.41	19.40	32.81
T5- RDF + 7.5 kg fed^{-1} (SA)	5.87	3.56	2.31	75.47	19.89	33.75
T6- RDF + 250 ppm (SA)	4.93	3.25	2.05	71.54	19.34	33.16
T7- RDF + 500 ppm (SA)	5.95	4.09	2.23	74.88	20.85	35.15
T8- RDF + 750 ppm (SA)	6.11	4.28	2.37	76.71	21.12	35.90
LSD (0.05)	**0.368**	**0.109**	**0.082**	**0.203**	**0.075**	**0.127**

Discussion

The present study, reported that the use of silicon improves the growth of plant. This effect may be due to the prominent role of silicon in improving plant water status[25]. The benefits of using silicon indirect effects such as increased capacity and efficiency of photosynthesis, transpiration and thus reduce shoot growth related [26.27,28]observed that in the presence of silicon increases plant growth by improving the mechanical strength of stems and leaves on light absorption and photosynthetic capacity of the plant is increased. [29]found that adding 50 mg^{-l} potassium silicate or nutrient Hot Lady Rose cut increases the number of flowers. It has been found by various workers that silicon has many positive effects on the growth and yield as well physiology and metabolism of different crops. [30]observed that silicon increased plant height, leaf area and dry mass of wheat even under drought. Similarly, the indirect effects of silicon also cause increase in growth and yield in cereals.[31] concluded that there is a high phosphate uptake in rice with silicon application which directly correlates the increased growth and yield.[32] showed that when Salicylic acid was applied at a rate of 0.25-0.50%as fertilizer, the rate of germination was increased. While if its level exceeded the limits it was found harmful resultantly reduced the germination rate and also affected the total crop stand as well as yield.[33] found that added 180 kg ha^{-1} of Silicon increased dry matter, yield, nitrogen and phosphate levels in the grain and straw of rice. This suggests that silicon in lesser amounts can be beneficial in increasing grain yield and growth of cereal crops. Si can be involved in the metabolic or physiological activity in higher plants exposed to a biotic stresses. Si can be involved in the metabolic or physiological activity in higher plants exposed to a biotic stresses, proper Si nutrition can increase salt resistance by plants [34, 35].

Conclusion

Finely, we could concluded that addition of salicylic acid to plant by the rat of 750 ppm were recommended to obtain the highest growth parameters, chemical constituent and mineral composition that will lead to the best quality in soybean plant.

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