South Asian Journal of Agricultural Sciences

E-ISSN: xxxx-xxxx
P-ISSN: xxxx-xxxx
SAJAS 2021; 1(1): 43-47
Received: 16-11-2020
Accepted: 19-12-2020

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Response of pea to boron, amino acids and silicon spray

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Abstract
A field experiment was conducted in Al-Souera, 50 km south of Bagdad in the winter season 2019/2020 to study tow levels of boron spray (control and 2 mg L^{-1}), three levels of amino acids (control, 1.5 and 3 mg L^{-1}) and four levels of Silicon as potassium silicate (control, 1, 2 and 3 mg L^{-1}). Randomized complete block design with three replications was used. The spraying process was done in two periods (45 and 90 days after planting). Pea seeds were planted in hills 30 cm apart on ridges 80 cm apart. The results showed that boron spraying caused significant increases in plant length (112.27 cm), leaf area (101.2 cm^2), branches number per plant (8.4), leaves number per plant (88.41), chlorophyll index (43.91 SPAD), and plant dry seed yield (57.7 g). Amino acids spray treatments gave a significant effect and the level of 3 mg L^{-1} was superior in plant length (110.02 cm), leaf area (100.9 cm^2), branches number per plant (9.0), leaves number per plant (89.20), chlorophyll index (44.09 SPAD), and plant dry seed yield (57.9 g). The potassium silicate spraying caused significant effect compared to control treatment and the level of 3 mg L^{-1} was superior in plant length (110.61 cm), leaf area (99.7 cm^2), plant branches number (8,3), plant leaves number (80.02), and plant dry seed yield (50.7 g). The interactions between the factors caused a significant effect on many studied traits.

Keywords: amino acids, boron, silicon, pea

Introduction
Pea (*Pisum sativum* L.) is one of the legume plants which is grown for the perpose of its green and dried seeds, in addition to its importance in improving the soil. Pea growth and yield is influenced by many environmental and nutritional factors. Boron is one of the important nutrients and peas, as legumes, required B for normal growth processes and nodule development (Mahler and Shafii, 2009, 2004) [18]. Boron plays an important role in protecting and moving the IAA, which encourages the increase of cell division and expansion, and then increasing vegetative growth (Barker 2006, Pilbeam) [8]. Amino acids have an important role in many vital processes affecting plant growth and development, as it contributes to reducing the effect of drought and salinity stresses by changing the osmotic potential of plant tissue (Al-Said and Kamal, 2008) [7]. It has an important role in metabolic processes by involving in the synthesis of the enzyme and protect plants from the toxicity of ammonia. Amino acids spraying on the vegetative plant parts helps in overcoming the nutrient deficiency that occurs during growth (Abd El-Aal *et al*., 2010) [2]. Silicon has an important role in plant growth and yield, especially at biotic and abiotic stresses. Silicon may improve the activity of photosynthesis and then increasing the dry matter, which is associated with the efficiency of transport to obtain the best growth and yield (Korndofer and Lepsch, 2001) [17]. As well as it caused the reduction of free radical damage and increasing antioxidants enzyme activity (Jasim *et al*., 2018) [16].

Materials and Methods
The experiment was carried out during the winter season (2019/2020) in Al-Souera district (50 km southern Baghdad), in silt loam soil (table 1), to study pea plants response to two levels of boron (0 and 2 ml l^{-1} liters), three levels of amino acids (0, 1.5, 3.0 ml L^{-1}) and four levels of potassium silicate (0, 1, 2 and 3 ml L^{-1}). Randomized complete block design (RCBD) with three replications was used. The experimental unit (4* 3.2 m) included 4 ridges (4 m long and 0.8 m apart). The soil was fertilized by 150 kg ha^{-1} of DAP (18-44-0 NPK) at preparing the soil, and 25 kg ha^{-1} urea after two months. Pea seeds were planted on 10/1/2019 in hills 30 cm, and after three weeks it was thinned to one plant per hill. Boron (ethanolamine boron 11%), amino-acids (Free amino acids:24.8%), and silicon (a water solution of 35% $K_2O.4SiO_2$ and 12% K_2O) were sprayed twice onto the plants vegetative

pats 45 days after planting (14 November), and 45 days later the first spray (29 December). Plants were harvested in the first half of April 2020. The data were analyzed and the means were compared according to $LSD_{0.05}$.

Table 1: Some physical and chemical properties of field soil

Characteristic	pH	Organic matter%	available N	available P	available K	Texture	EC
Value	7.2	1.51	32	16	101	Silt loam	3.3

Results and Discussion

Table (2) shows that boron spray caused a significant increase in plant length 112.27cm, compared to control treatment 100.65 cm. This result may be attributed to the positive role of boron in transporting carbohydrates from source to sink and protecting IAA that increases cell division and expansion, which gave the highest opportunity for growth (Barker and Pilbeam, 2006) [8]. It is known that increasing IAA concentration leads to increase internode elongation and consequently the increase of plant length. This is in agreement with Hathili and Al-Jabouri (2016) [11] that pea length was increased significantly at spraying with 50 mg l^{-1} boron. Amino acids spraying significantly increased plant length, and the level of 3.0 mg l^{-1} was significantly superior by giving the highest length of 110.02 cm compared to control treatment (100.87cm). This is consistent with Ghaith and Galal (2014) [9] on pea plants, Zewail (2014) [22], and Salama *et al* (2019) [20] on bean. Potassium silicate increasing plant length significantly, and the level of 3.0 mg L^{-1} was superior by giving the highest plant length 110.61 cm compared to control treatment (100.23 cm). This is due to silicon works to strengthen the cell walls, which leads to mechanical support of the plant's air parts (Guerriero *et al*, 2016) [10]. This is consistent with Jasim and Hadi (2017) [13, 14] on the broad bean, and Hussein and Muhammad (2017) [12] on eggplant. The interaction between boron, amino acids, and silicon caused a significant effect, and boron + 3.0 mg l-1 amino acids + 3.0 mg l-1 silicon gave the highest plant length 130.10 cm compared to the control treatment (82.80cm).

Table 2: Effect of boron, amino acids and Si spraying on plant length (cm)

Boron treatment	Amino acids	Potassium Silicate treatments Si 0	Si 1	Si 2	Si 3	boron * amino acids
B0	A0	82.80	91.97	99.87	101.93	94.14
	A1	100.37	103.37	112.60	103.60	105.07
	A2	94.83	107.13	106.87	102.13	102.74
B1	A0	108.57	111.30	104.77	105.77	107.60
	A1	107.93	108.80	110.73	120.13	111.90
	A2	106.90	107.90	124.33	130.10	117.31
Si mean		100.23	105.14	109.86	110.61	
$LSD_{0.05}$		Si = 4.338		T = 10.625		N.S
Interaction of boron * potassium silicate						Boron average
B0		92.67	100.94	106.44	102.56	100.65
B1		107.80	109.33	113.28	118.67	112.27
$LSD_{0.05}$		N.S				3.067
Interaction of amino acids * potassium silicate						Amino average
A0		95.68	101.63	102.32	103.85	100.87
A1		104.15	106.27	111.67	111.87	108.49
A2		100.87	107.52	115.60	116.12	110.02
$LSD_{0.05}$		N.S				3.757

Table (3) shows that spraying boron caused a significant increase in plant leaf area to 101.2 cm^2 compared to the control treatment (83.9 cm^2). Boron contributes to the transfer of most photosynthesis products from leaves to other parts of the plant, which is transmitted through the symplast system. Therefore it affects plant growth, and also has a role in the building cell wall and thus increasing their growth and branches number (Yasin, 2001). This was agreed with Al-Bayati and Hanashl (2016) [3] on cowpea. Amino acid spraying caused a significant increase in plant leaf area, and the level 1.5 mg L^{-1} was superior by giving 100.9 cm^2 compared to control treatment (83.2cm^2). This is consistent with Abbas and Salman (2018) [1] on cowpea and Zewail (2014) [22] on the bean. Potassium silicate caused a significant increase in plant leaf area, and the level 3.0 mg L^{-1} achieved the highest leaf area 99.7cm^2 compared to the control treatment that gave 89.3 cm^2. This result was agreed with Rohanipoor *et al*. (2013) [19] on maize.

Table 3: Effect of boron, amino acids and Si spraying on leaf area

Boron treatment	Amino acids	Potassium Silicate treatments Si 0	Si 1	Si 2	Si 3	boron * amino acids
B0	A0	69.5	72.3	74.2	84.4	75.1
	A1	78.2	81.9	87.9	95.9	86.0
	A2	90.8	88.7	89.3	94.2	90.8
B1	A0	85.2	88.4	92.6	99.1	91.3
	A1	100.4	93.0	101.8	109.1	101.1
	A2	111.5	105.1	112.2	115.8	111.1
Si mean		89.3	88.2	93.0	99.7	
$LSD_{0.05}$		Si = 6.80 T = N.S				N.S
Interaction of boron * potassium silicate						Boron average

B0	79.5	80.9	83.8	91.5	83.9
B1	99.0	95.5	102.2	108.0	101.2
$LSD_{0.05}$	N.S				4.81
Interaction of amino acids * potassium silicate					Amino average
A0	77.3	80.3	83.4	91.7	83.2
A1	89.3	87.4	94.8	102.5	93.5
A2	101.2	96.9	100.8	105.0	100.9
$LSD_{0.05}$	N.S				5.89

Table (4) shows that boron spraying had a significant effect on increasing plant branches number (8.4) compared to the control treatment (7.5). This is consistent with Al-Juhaishi, (2019) [4]. Amino acids spraying caused a significant increase in plant branches number, and the level 3.0 mg L^{-1} was superior and gave 9.0 branches compared to control treatment which gave 7.1. This is in agreement with Zewail (2014) [22] on bean and Salama *et al* (2019) [20] on bean plants. Potassium silicate caused a significant increase and 3.0 mg l^{-1} gave 8.3 branches compared to the control treatment (7.6). This is consistent with Jasim and Hadi (2017 a) [13, 14] on broad bean and Al-Rubaie (2019) [6] on oats. The interaction between boron with amino acids had a significant effect, and boron+3.0 mg l^{-1} amino acids gave the highest plant branches number (9.7 branches) compared to the control treatment (6. 7).

Table 4: Effect of boron, amino acids and Si spraying on number of branches of the plant

Boron treatment	Amino acids	Potassium Silicate treatments				boron * amino acids
		Si 0	Si 1	Si 2	Si 3	
B0	A0	6.5	6.8	6.7	6.7	6.7
	A1	7.5	7.5	7.9	7.7	7.7
	A2	7.6	7.8	8.7	9.1	8.3
B1	A0	7.1	7.3	7.6	7.7	7.4
	A1	7.7	8.2	8.0	8.5	8.1
	A2	9.1	9.5	9.8	10.3	9.7
Si mean		7.6	7.9	8.1	8.3	
$LSD_{0.05}$		Si = 0.43 T = N.S				0.53
Interaction of boron * potassium silicate						Boron average
B0		7.2	7.4	7.7	7.8	7.5
B1		8.0	8.3	8.5	8.8	8.4
$LSD_{0.05}$		N.S				0.30
Interaction of amino acids * potassium silicate						Amino average
A0		6.8	7.1	7.1	7.2	7.1
A1		7.6	7.8	7.9	8.1	7.9
A2		8.4	8.6	9.2	9.7	9.0
$LSD_{0.05}$		N.S				0.37

Table (5) shows that boron spraying had a significant effect on increasing plant leaves number (88.41), compared to the control treatment (63.20). This is consistent with Al-Bayati and Hanashl (2016) [3] on cowpea. Amino acid spraying caused a significant increase in plant leaves number, and the level 3.0 mg l^{-1} was superior by giving 89.20 leaves compared to control treatment (63.07). This is consistent with Zewail (2014) [22] on bean and Salama *et al* (2019) [20] on the bean. Potassium silicate caused a significant increase, and the level 3.0 mg L^{-1} achieved 80.02 leaves compared to the control treatment (70.12 leaves). This is consistent with Jasim and Hadi (2017 a) [13, 14] on broad bean and Hussein and Muhammad (2017) [12] on eggplant. The interaction of boron and amino acids caused a significant effect, and boron+ 3.0 mg l^{-1} amino acid was superior by giving 104.53 leaves compared to the control treatment that gave 50.07 leaves. The interaction of amino acids and potassium silicates caused a significant effect, and the treatment of 3.0 amino acids + 3.0 potassium silicates gave 96.93 leaves compared to control treatment (57.50).

Table 5: Effect of boron, amino acids and Si spraying on plant leaves number

Boron treatment	Amino acids	Potassium Silicate treatments				boron * amino acids
		Si 0	Si 1	Si 2	Si 3	
B0	A0	45.80	46.80	51.57	56.10	50.07
	A1	59.07	66.30	68.23	69.03	65.66
	A2	64.47	72.70	77.60	80.73	73.87
B1	A0	69.20	77.67	77.17	80.30	76.08
	A1	88.77	83.70	85.13	80.80	84.60
	A2	93.40	103.13	108.47	113.13	104.53
Si mean		70.12	75.05	78.03	80.02	
$LSD_{0.05}$		Si = 3.813 T = N.S				4.670
Interaction of boron * potassium silicate						Boron average
B0		56.44	61.93	65.80	68.62	63.20
B1		83.79	88.17	90.26	91.41	88.41
$LSD_{0.05}$		N.S				2.696

Interaction of amino acids * potassium silicate					Amino average
A0	57.50	62.23	64.37	68.20	63.07
A1	73.92	75.00	76.68	74.92	75.13
A2	78.93	87.92	93.03	96.93	89.20
$LSD_{0.05}$	6.605				3.303

Table (6) shows that boron spray caused a significant increase in chlorophyll index to 43.91(SPAD), compared to the control treatment 41.12 (SPAD). This is consistent with Al-Qazzaz (2014) [5] on chickpea. Amino acid spraying increasing chlorophyll index significantly, and the level 3.0 mg l^{-1} was superior and gave 44.09(SPAD) compared to a control treatment (40.84 SPAD). This is consistent with Al-Qazzaz (2014) [5] on chickpea. The triple interaction between boron, amino acids, and silicon caused a significant effect, and boron+ amino acids 3.0 mg l^{-1}+ 3.0 mg l-1 silicon gave the highest rate of 43.86 (SPAD) compared to the control treatment which gave 35.83(SPAD).

Table 6: Effect of boron, amino acids and Si spraying on chlorophyll index (SPAD)

Boron treatment	**Amino acids**	**Potassium Silicate treatments**				**boron * amino acids**
		Si 0	**Si 1**	**Si 2**	**Si 3**	
B0	A0	35.83	39.97	40.23	41.57	39.40
	A1	41.33	41.93	40.60	42.07	41.48
	A2	43.83	41.77	40.43	43.87	42.47
B1	A0	41.10	39.87	44.33	43.83	42.28
	A1	46.40	42.93	41.33	44.33	43.75
	A2	42.33	46.77	46.23	47.47	45.70
Si mean		41.81	42.21	42.19	43.86	
$LSD_{0.05}$		Si = N.S T = 4.106				N.S
Interaction of boron * potassium silicate						Boron average
B0		40.33	41.22	40.42	42.50	41.12
B1		43.28	43.19	43.97	45.21	43.91
$LSD_{0.05}$		N.S				1.185
Interaction of amino acids * potassium silicate						Amino average
A0		38.47	39.92	42.28	42.70	40.84
A1		43.87	42.43	40.97	43.20	42.62
A2		43.08	44.27	43.33	45.67	44.09
$LSD_{0.05}$		N.S				1.452

Table (7) shows that boron spraying had a significant effect on increasing plant green pods yield (57.7 g), compared to the control treatment (39.8 g). This is consistent with Jasim and Al-Dulaime (2014) [15] on broad bean and Al-Bayati and Hanashl (2016) [3] on cowpea. Amino acids spraying caused a significant increase in plant green pods yield, and the level 3.0 mg l^{-1} was superior by giving 57.9 g compared to control treatment (39.5 g). This is consistent with Salama *et al* (2019) [20] and Zewail (2014) [22] on the bean. Potassium silicate caused a significant increase, and the level 2.0 mg L^{-1} achieved 51.1 g compared to the control treatment (45.0 g). This is consistent with Jasim and Hadi (2017 b) [13, 14] on the broad bean. The interaction of boron and amino acids caused a significant effect, and boron+ 3.0 mg L^{-1} amino acid was superior by giving 71.8 g compared to the control treatment that gave 28.3 g. The interaction of boron and amino acids caused a significant effect, and the treatment of boron+ 3.0 mg L^{-1} amino acids gave 69.2 g compared to control treatment (31.5 g).

Table 7: Effect of boron, amino acids and Si spraying on plant dry seed yield (g)

Boron treatment	**Amino acids**	**Potassium Silicate treatments**				**boron * amino acids**
		Si 0	**Si 1**	**Si 2**	**Si 3**	
B0	A0	28.3	29.7	33.6	34.5	31.5
	A1	36.9	42.7	38.1	46.5	41.1
	A2	42.2	47.4	49.8	48.0	46.9
B1	A0	44.7	47.0	48.7	50.1	47.6
	A1	51.2	52.7	64.8	56.9	56.4
	A2	66.5	69.2	71.8	68.1	69.2
Si mean		45.0	48.1	51.1	50.7	
$LSD_{0.05}$		Si=2.7 T= 6.6				3.3
Interaction of boron * potassium silicate						Boron average
B0		35.8	39.9	40.5	43.0	39.8
B 1		54.1	56.3	61.8	58.4	57.7
$LSD_{0.05}$		N.S				1.0
Interaction of amino acids * potassium silicate						Amino average
A0		36.5	38.4	41.2	42.8	39.5
A1		44.5	47.7	51.5	51.7	48.9
A2		54.4	58.3	60.8	58.1	57.9
$LSD_{0.05}$		N.S				2.3

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