J. of Plant Production, Mansoura Univ., Vol. 13 (12) : 883 -887, 2022

Journal of Plant Production

Journal homepage & Available online at: www.jpp.journals.ekb.eg

Effect of Foliar Spraying with Different Concentrations of Chelated Boron on Humic and Fulvic Acids on Growth, Yield and Chemical Composition of Potato Grown in Sandy Soils

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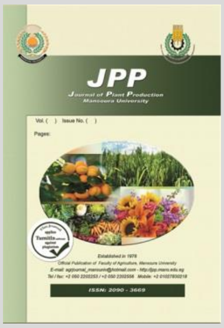

ABSTRACT

This investigation was carried out at the Agricultural Research Station, National Research Centre, El-Nubaria, Egypt, during the two successive seasons of 2020 and 2021. The layout of the study was complete randomized blocks in three replicates. The experiment aimed to compare the chelated boron on humic and fulvic acids, extracted in the laboratory from compost, with the commercial one, in addition to investigate their foliar spraying effects at different rates (2, 3 and 4 ml L^{-1}) on plant growth, productivity and quality of potato. Results showed that no significant differences were detected between chelated boron prepared in the laboratory and the commercial compound in their effects on the growth of potato plants as well as yield and its attributes however, the best results were obtained by 4 ml L^{-1}. Concerning starch, protein, nitrogen, phosphorous, potassium and boron contents, the highest values were recorded as a result of spraying the plants by 4 ml L^{-1} for all studied boron types. In contrast, boron had no effect on chlorophyll content in potato leaves for all used treatments. It could be concluded that chelated boron at 4 ml L^{-1} was effective for enhancing potato growth, production as well as improving its quality, regardless the source of used boron.

Keywords: Potato; Chelated boron; Foliar; Humic acid; Fulvic acid

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a highly economic vegetable for Egypt, as it generates income for the Egyptian economy by exporting fresh and processed potatoes. Moreover, potato is considered a financially economical and gainful crop for the farmers because of its remunerative yield within a short duration. In addition to being a favorite vegetable and stock feed, it is also an important source for manufacturing starch and other products. The total cultivated area in Egypt reached 560,000 feddan in 2021 with total production of 6.7 million tons meanwhile the exported amount was 862,000 ton in 2022.

Boron is an essential micronutrient for plant life, due to its role in cell wall synthesis, division and development of the cell, auxin metabolism, sugar transport, induction of amino acids and proteins as well as systemize of carbohydrate metabolism (Jafari-Jood *et al*., 2013).

Bari *et al*., (2001) on potato demonstrated that applying boron produced higher number of tubers per plant and total yield than control. Fertilization of boric acid caused an increment in cell diameter of medullary zone in the tuber leading to increments in tuber size and weight (Puzina, 2004).

Foliar spray of potato plants with B at different rates was studied by El-Banna and Abd El-Salam (2005), El-Dissoky and Abdel-Kadar (2013) and Alkharpotly *et al*. (2018). Their studies appeared the superiority effect of spraying boron at 75, 60 and 100 ppm in the three studies respectively. The effect of boron was conflicted in improving potato growth parameters and total yield as well as N, K, B, protein and starch percentages. Moreover, Kadam *et al*., (2010) demonstrated that chelating micronutrients on humic substances leads to prevent its deposition, leaching or oxidation.

The response of plant growth to humic and fulvic acids depends on their mode of application to the plant, content of bioactive molecules, source, dose and molecular weight of the humic fraction, and plant species (Nardi *et al*., 2021).

The study aimed to examine the chelation of boron on each of the humic and fulvic acids, extracted from compost, in addition to investigate their effects on the growth, yield and chemical composition of potato as compared with the commercial compound.

MATERIALS AND METHODS

The field trials were conducted at the Agricultural Research Station, National Research Centre, El-Nubaria District, Egypt (Latitude of 30º 30N and Longitude of 30º 20E) in the two successive seasons of 2020 and 2021. Potato tubers of Cara cultivar were planted in October 18th in the two tested seasons. Plot area was 11.25 m2; consisted of 3 ridges; 5 m long; 75 cm wide and 25 cm apart. The experimental layout was a randomized complete block design (RCBD) with three replicates. Drip irrigation was applied. The study included four treatments i.e. boron chelated on humic acid (B- humate), boron chelated on fulvic acid (B- fulvate), B – Commercial and control (tap water).

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DOI: 10.21608/jpp.2022.175771.1189

Application of humic and fulvic acids, as natural resources, is promising to be utilized for sustainable development. They are organic compounds produced by the decay of organic materials and are found in compost (Sharif *et al*., 2002). Boron humate and fulvate were prepared in the laboratory and compared with a commercial boron compound with the same rates for the three types, where the concentrations were 2, 3 and 4 ml L-1. All treatments were sprayed at 30, 45, 60 days after planting. Standard practices of Egyptian Ministry of Agriculture were followed for potato production.

Preparation of B- Humate and B-Fulvate

Residues of medicinal and aromatic plants were used to make mature compost (Table 1) as the method outlined by Cottenie (1980). Extraction of humic and fulvic acids from compost was as the method of Aiken (1985). In this classical method, the compost is dried at 40°C, homogenized and mechanically ground using a ball mill.

Table 1. Some chemical analysis of the resulting compost.

Analysis	Unite	Compost
pH	-	8.14
EC	dS m^{-1}	4.20
Total Nitrogen	%	1.40
Organic matter	%	43.6
Organic carbon	%	25.3
Ash	%	56.4
C/N ratio	-	1:18.1
P	%	0.61
K	%	0.98
Fe	Ppm	320
Zn	Ppm	70.2
Mn	Ppm	90.2

Humic acid extraction is carried out using 0.2 *M* NaOH under N_2 conditions, then acidified by HCl and centrifuged to isolate fulvic acid. The precipitated humic acid fraction was re-dissolved using NaOH and centrifuged at under N_2. Humic acid was precipitated using HCl centrifuged under N_2 conditions. A quantity of boric acid was dissolved in both obtaining humic and fulvic acids (28.6 g^{-1}) to reach 0.5% chelated boron concentration, taking care that the pH of the two compounds is adjusted up to 6.0. In order to compare the efficiency of the two compounds that were manufactured in the laboratory, it was necessary to compare them with a commercial chelated boron compound having the same boron concentration.

Soil characteristics

Some physical and chemical characteristics of the experimental soil are shown in Table 2. The soil of the experimental field was sandy soil its physical and chemical properties are analyzed according to the methods described by Champman, and Pratt (1978).

At 70 days after planting, four plants were chosen randomly for each experimental plot to determine the growth parameters of potato plants, i.e. plant height (cm), number of leaves and leaves dry weight (g) in addition to chlorophyll content which was determined in representative fresh leaves samples for each experimental plot according to Moran (1982).

Table 2. Some physical and chemical analysis of the experimental soil.

Soil property	Value
Particle size distribution %	
Sand	92.65
Silt	5.07
Clay	2.28
Texture	Sandy
pH	7.70
EC (dS m-1)	1.60
Soluble ions (mmol L^{-1})	
Ca^{++}	8.02
Mg^{++}	3.23
Na^{+}	3.92
K^{+}	0.91
CO_3^{--}	nd
HCO_3^{-}	2.20
Cl^{-}	3.98
SO_4	9.90
$CaCO_3$ %	1.90
Saturation percent %	22.5
Organic matter%	0.15
Available N (mg kg-1)	24.5
Available P (mg kg-1)	2.90
Available K (mg kg-1)	56.4

After 115 days from planting, the total tuber yield was harvested and weighed then; its parameters were recorded as follow:

1- Total tuber yield per plot (kg/plot) then yield was calculated per fed (ton/fed).
2- Number of tubers per plant.
3- Average tubers weight (Kg/plant).

Ten healthy tubers were randomly chosen from each experimental plot to obtain the quality of tubers as follow:

1- Tuber length (cm). 2- Tuber diameter (cm).
3- N, P, K and starch percentages 4- B content (mg kg^{-1})
5- Crude protein percentage

Tuber samples were dried at 70°C and grounded using stainless steel equipment's to determine the following:

1- Soluble starch content following the method of Malik and Srivastava (1979).
2- Total nitrogen content using the method described by Koch and Mcmeek in (1924).
3- Phosphorus following calorimetrically method Troug and Meyer (1939).
4- Potassium was flame - photometrically estimated as described by Kalra (1998).
5- Boron was determined using atomic absorption spectrophotometer according to A. O. A. C. (2000).
6- Crude protein percentage "multiplying total nitrogen percentage by 6.25 to give the crude protein content"

RESULTS AND DISCUSSION

Data illustrated in Table 3 show the effect of chelated boron, whether on fulvic or humic acid, on growth parameters of potato plants and comparing that with commercial chelated boron and control (without boron). In general, the results indicate the importance of boron fertilization to potato plants grown in sandy soil, as fertilization with boron compounds all significantly improved plant height, number of leaves and leaves dry weight of potato plants compared to the control (without boron), however, the concentration of 4 ml per liter gave the highest values for all tested types. Also, the same data clear that spraying B-fulvate was more significantly effective than B-humate on number of leaves without significant difference with the commercial compound, whereas leaves dry weight was more responsive to B- commercial then B-humate. Response of potato growth to chelated boron could be due to its ability to attract positive ions, forms chelates with micronutrients and release them slowly, therefore, it could be available when required by plants (Kadam *et al.*, 2010 and Nardi *et al.*, 2021).

In this concern, foliar spray of boron significantly increased growth attributes of potato plants (plant height, leaves per plant and shoot weight) as compared with non-treated plants as reported by Jafari-Jood *et al.* (2013). They added that this response could be related to its important role in cell wall synthesis, cell division, cell development and auxin metabolism. Obtained results agree with those of El-Banna and Abd El-Salam (2005), El-Dissoky and Abdel-Kadar (2013) and Alkharpotly *et al.* (2018).

Illustrated data in Table 4 indicate the effect of different rates of chelated boron on different chelating materials on yield and its attributes. These data show the improvement in yield and its parameters i.e., number of tubers, average tubers weight, tuber length and tuber diameter by increasing of boron concentration whereas the best significant results were obtained from plants applied with 4 ml per liter in the two tested seasons despite of the source of chelated boron as compared with non- treated plants in the two investigated seasons. Our results are similar with those of Bari *et al.*, (2001) and Puzina (2004).

Table 3. Effect of chelating boron compounds on plant height (cm), number of leaves and leaves dry weight (g) of potato during 2020 and 2021 seasons.

Treatments	Concentration ml L^{-1}	Plant height (cm)	No. leaves/ Plant	Leaves dry weight /plant (g)
First season				
B- Fulvate	2	71.1	57.3	9.08
	3	73.3	61.4	9.97
	4	78.2	67.2	11.8
B – Humate	2	73.1	55.2	10.3
	3	74.4	57.3	11.6
	4	79.3	60.3	14.4
B –Commercial	2	72.2	57.3	10.4
	3	74.2	60.4	14.6
	4	78.3	68.2	15.3
Control		65.0	55.2	9.01
$LSD_{0.05}$		3.90	4.02	0.51
Second season				
B- Fulvate	2	71.3	57.1	8.98
	3	73.2	60.4	9.91
	4	76.4	65.4	11.7
B – Humate	2	72.0	55.7	9.56
	3	73.1	58.1	14.4
	4	77.1	61.3	11.6
B – Commercial	2	71.2	57.3	10.4
	3	73.2	60.3	14.6
	4	76.1	67.2	15.3
Control		63.5	55.2	9.01
$LSD_{0.05}$		3.82	4.01	0.51

Table 4. Effect of chelating boron compounds on potato yield and its attributes during 2020 and 2021 seasons.

Treatments	Concentration ml L^{-1}	No. tubers/ Plant	Tubers weight (Kg/plant)	Tuber length (cm)	Tuber diameter (cm)	Total yield (ton fed^{-1})
First season						
B- Fulvate	2	9.20	0.91	6.40	5.90	16.6
	3	11.1	1.15	8.70	6.81	17.5
	4	13.3	1.54	10.7	7.55	17.7
B – Humate	2	9.20	0.92	5.50	5.91	16.4
	3	11.2	1.06	8.91	6.51	17.2
	4	13.3	1.48	10.6	7.46	17.4
B – Commercial	2	10.3	0.90	6.00	5.88	16.5
	3	12.4	1.16	9.22	6.83	17.6
	4	13.1	1.49	10.8	7.50	17.6
Control		8.20	0.66	6.02	5.11	15.8
$LSD_{0.05}$		1.11	0.14	0.51	0.62	0.60
Second season						
B- Fulvate	2	9.15	0.92	6.44	5.92	16.4
	3	11.2	1.20	8.72	6.82	17.3
	4	13.2	1.52	10.9	7.57	17.6
B – Humate	2	9.22	0.91	5.98	5.90	16.3
	3	11.6	1.11	8.88	6.61	17.1
	4	13.2	1.45	10.3	7.42	17.3
B – Commercial	2	10.3	0.94	6.08	5.91	16.5
	3	12.1	1.18	9.10	6.83	17.4
	4	13.0	1.50	10.7	7.54	17.6
Control		8.11	0.62	6.00	5.01	15.6
$LSD_{0.0}$		1.12	0.13	0.50	0.61	0.61

Enhancing the total yield and its components as response to foliar spray boron could be related improving photosynthesis which in turn increased production of carbohydrates in addition to enhance activity of enzymes, protein and nucleic acid metabolism (Bari *et al.*, 2001). Also, the role of boron is related to formation of cell wall and its lignification which in turn improve cell wall structural integrity of bio membranes (Tanaka and Fujiwara, 2008). In addition, Adiloglu and Adiloglu (2006) concluded that boron is playing a vital role in division of the cell and its differentiation especially in the meristem parts (the active division parts in the plant). Under drought conditions, the deficiency of boron observed due to the lower availability of boron in sub-soils (Prasad *et al.*, 2014).

As shown in Table 5, boron foliar spray had no effect on chlorophyll content in potato leaves for all used treatments. In contrast, application of chelated boron significantly affected starch and protein tuber contents as compared with non-treated plants (control). Although they were not significantly affected by the type of material chelated with boron, their values increased as the increment of boron rate. The best results were obtained at the highest concentration (4 ml L-1).

The effect of boron could be due to its improvement of the rate of photosynthesis (Lora Silva et al., 2008). Where potato is a tuber crop, it needs boron supply throughout its all growing period due to the role of boron in translocation of photosynthetic products from source to storage parts (Sarkar et al., 2007). Also, Malan (2015) stated that fulvic acid have a positive role in mineral transportation resulting in improving photosynthesis which in turn enhance proteins plant hormonal activity.

Table 5. Effect of chelating boron compounds on leaves chlorophyll content, tuber starch and protein percentages of potato during 2020 and 2021 seasons.

Treatments	Concentration ml L^{-1}	Total chlorophyll (100 mg g^{-1})	Starch (%)	Protein (%)
First season				
B- Fulvate	2	65.1	13.1	10.6
	3	66.3	13.3	10.9
	4	67.2	13.6	11.2
B – Humate	2	64.2	13.2	10.5
	3	66.0	13.3	10.8
	4	66.5	13.5	10.9
B – Commercial	2	65.1	13.3	10.8
	3	66.3	13.4	11.0
	4	67.1	13.5	11.2
Control		52.3	12.4	9.88
$LSD_{0.05}$		4.33	0.51	0.12
Second season				
B- Fulvate	2	64.5	13.2	10.5
	3	65.3	13.4	10.8
	4	67.1	13.6	11.1
B – Humate	2	64.1	13.1	10.4
	3	65.6	13.3	10.7
	4	66.5	13.5	10.9
B – Commercial	2	65.2	13.3	10.7
	3	66.3	13.4	10.8
	4	67.1	13.6	11.0
Control		52.0	12.3	9.79
$LSD_{0.05}$		4.32	0.50	0.13

Data in Table 6 show the influence of different concentrations and several sources of chelated boron on the content of potato tubers from nitrogen, phosphorus, potassium and boron. Spraying chelated boron prepared in the laboratory on both humic and fulvic acids proved its effectiveness in improving the content of those nutrients, whether nitrogen, phosphorous, potassium and boron, compared to (control). Also, the results obtained as spraying B-fulvate and B- humate are similar with those of the commercial fertilizers. Improving N content in tuber with B fertilization may be related to the role of B in formation of amino acids which in turn enhance proteins (El-Dissoky and Abdel- Kadar, 2013). Bocanegra *et al*., (2006) concluded that chelating boron on fulvic acid could help in regulation of mobility and transmission of boron which in turn increase its availability duration and maximize benefits of boron fertilization. The transmission of sugars, starch, nitrogen and phosphorus, positively affected by application of boron (Puzina, 2004). He added that boron is an essential microelement for synthesis of amino acids and formation of proteins, in addition to its role in regulation carbohydrates metabolism and stabilize the oxidative system in plants.

Pettit (2004) stated that fulvic acid is created in minute amount by the action of beneficial microbes on the analysis of plant matter in soils having sufficient oxygen. It is biologically very active and because of its low molecular weight has the potential to readily bond minerals and elements (up to 70 or more) into its molecular structure which dissolve and become mobilized fulvic complexes.

Table 6. Effect of chelating boron compounds on N P K persentages and B content in potato tubers during 2020 and 2021 seasons.

Treatments	Concentration ml L^{-1}	N (%)	P (%)	K (%)	B (mg kg^{-1})
First season					
B- Fulvate	2	1.22	0.29	2.62	30.4
	3	1.24	0.29	2.63	35.5
	4	1.27	0.31	2.63	38.3
B – Humate	2	1.23	0.27	2.63	30.5
	3	1.24	0.28	2.64	36.3
	4	1.26	0.30	2.65	38.3
B – Commercial	2	1.24	0.29	2.62	31.2
	3	1.25	0.29	2.65	36.1
	4	1.28	0.31	2.64	38.4
Control		1.23	0.26	2.60	18.5
$LSD_{0.05}$		0.11	0.02	0.12	4.21
Second season					
B- Fulvate	2	1.23	0.28	2.62	30.4
	3	1.24	0.29	2.63	35.6
	4	1.27	0.31	2.63	38.2
B – Humate	2	1.23	0.28	2.63	30.4
	3	1.25	0.29	2.64	36.5
	4	1.26	0.30	2.64	38.4
B – Commercial	2	1.24	0.29	2.62	31.3
	3	1.25	0.29	2.65	36.4
	4	1.27	0.31	2.65	38.3
Control		1.23	0.26	2.60	18.5
$LSD_{0.05}$		0.11	0.02	0.12	4.20

This special bonding feature of fulvic acid brings nutrient elements in ideal natural form to be readily absorbed by plant roots and interact with living cells and helps plants to retain nutrients in their structure for use in maintaining good plant health. On the other hand, Mengel and Kirkby (1978) stated that the increment of potassium content as a response to boron fertilization may be due to the combined effect of both potassium and boron in transportation of sugars and carbohydrates in the plant. They added that for tuber crops, which need a lot of K, need high boron value (>20 ppm) in plant tissues where at tuberization stage, high boron rates in their tissues are required for taking up the needed amount of potassium (El-Dissoky and Abdel Kadar, 2013). Meanwhile, Canada (2002) cleared that high phosphorus values are related to the effect of boron on membrane-bound ATPase activity.

CONCLUSION

The humic materials resulting from the extraction of compost (made from the residues of medicinal and aromatic plants) can be used as strong chelating materials with the boron, and the production of chelating materials, whether on humic or fulvic acid, improved growth and yield of potato plants. The use of chelated boron at 4 ml per liter was the best treatment despite of the source of chelated. It is inferred from the previous results that it can easily produce locally chelating materials with high efficiency and low cost, to chelate the boron and give good results on the potato plants, where it can be used instead of the high-cost commercial compounds which imported using hard currency.

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تأثير الرش الورقى بتركيزات مختلفة من البورون المخلب على حمض الهيوميك والفولفيك على النمو والمحصول والمكونات الكيميائية للبطاطس المنزرعة فى الأراضى الرملية

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الملخص

اجريت الدراسة في محطة البحوث الزراعية بالمركز القومي للبحوث بمصر خلال موسمى 2020 و 2021 وكان تصميم التجربة قطاعات كاملة العشوائية لدراسة تأثير الرش بالبورون المخلب على أي من حمض الهيوميك او الفولفيك (واللذين تم استخلاصهما معمليا من الكومبوست) مع البورون المخلبى التجارى بتركيزات (2 ، 3 ، 4 ميللى مول/ لتر) على نمو وانتاج وجودة محصول البطاطس. اوضحت النتائج عدم وجود فرق معنوي بين البوون المخلبى الذي تم تحضيره معمليا وبين البورون التجاري فى تأثيرهم على النمو الخضري للبطاطس والمحصول وجودته وكانت أفضل النتائج المتحصل عليها عند 4 ميللى مول/لتر. كما سجلت نفس المعاملة (من كل صور البورون محل الدراسة) اعلى القيم لمحتوى الدرنات من النشا والبروتين و النيروجين والفوسفور والبوتاسيوم والبورون مقارنة بالكنترول (لم تعامل بالبورون). وعلى العكس ، لم يكن للبورون تأثير على محتوى الأوراق من الكلوروفيل. كما كان الرش بالبورون المخلب معمليا على كلا من حمض الهيوميك أو الفولفيك مشابها للبورون المخلبى التجاري من حيث تأثيرهم على تحسين محتوى الدرنات من النيتروجين والفوسفور والبوتاسيوم والبورون مقارنة بالكنترول (لم تعامل بالبورون). الخلاصة: يستخلص من هذه الدراسة ان معاملة نباتات البطاطس بالبورون المخلبي المحضر معمليا يمكن ان يحل محل البورون التجاري وبنفس الكفاءة. كما ان الرش بتركيز 4 ميللى مول/لتر اعطى أفضل نمو وكذا المحصول وجودته بغض النظر عن مصدر البورون المستخدم.