Response of Oil Lettuce to Bio-,mineral Phosphorus Fertilizers and Boron Foliar Application Under Calcareous Soil Conditions

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ABSTRACT: The main purpose of this investigation was to evaluate the growth, yield and quality of oil lettuce under calcareous soil conditions. Two field experiments were carried out at Mariut Experimental Station, Desert Research Center, Egypt, during two successive winter growing seasons 2015/2016 and 2016/2017 to study the effect of four concentrations of boron, control (without boron), 300, 500 and 700 mg/L borax applied as foliar spraying at two times during growth season and assigned in the vertical plots and six treatments of mineral phosphorus and biofertilization; control (without mineral and biofertilization), 15.5 kg P_2O_5/fed., 31 kg P_2O_5/fed., biofertilizer, 15.5 kg P_2O_5/fed. + biofertilizer and 31 kg P_2O_5/fed. + biofertilizer which occupied the horizontal plots. Obtained results revealed that, all studied characters i.e. plant height, leaf area/plant, leaf area index, 1000 seed weight, seed yield/plant, seed yield/fed., biological yield/fed., straw yield/fed., harvest index, oil percentage, oil yield and crud protein percentage were significantly affected by either boron or mineral phosphorus and biofertilization in the two experimental seasons, except harvest index and crude portion percentage in the first season which were not affected significantly by the two studded factors. The interaction between born concentrations and mineral phosphorus with biofertilization treatments had significant effects on all previous studied traits for both seasons except, harvest index in the first season and crude protein percentage in the two seasons, which were not significantly affected by this interaction in this study.

Key words: Oil lettuce, Growth, yield, Quality, Mineral phosphorus, biofertilizers, Boron foliar application.

INTRODUCTION

Oil lettuce (*Lactuca scariola* var. *oleifra*) is considered an important economical oil crop which was known from ancient Egyptian age (Veronique) as it was planted for its many benefits. In Upper Egypt, this crop is known as cow lettuce. Assoupia, Eretria and North Africa are the homeland for this crop. Also, planting is better in warm weather as in Europe, North India, America and Australia so it is considered one of the winter oil crops. This kind of lettuce which differs from the normal table lettuce (*Lactuca sativa* L.) has many benefits, and is planted in south Egypt, but in small areas in Kina and Aswan in 500–1000 feddans and it is planted either intercropped with bean and barley or alone. As this crop has a great importance, it may be good idea to increase its cultivated area at North Egypt especially in new regions. Micro and macro nutrients, also bio-fertilizer are most important for crop production as well as for seed quality. Boron is a micronutrient critical to growth and health of all crops and is present in soils in concentration between 2 and 100 mg/kg. It is not required by plants in high amounts, but can cause serious growth problems if it is not supplied at appropriate levels. It is different from other micronutrients in that, there is no chlorosis associated with its deficiency, however it does have similar toxicity symptoms as other micronutrients (Marschner, 1995). Boron deficiency can occur when the pH of the growing medium exceeds 6.5 because boron is tied up and unavailable for plant uptake. Deficiency can also occur from low fertilizer application rates, use of general purpose fertilizers (which typically have a reduced micronutrient content), and cool, cloudy weather that, limits the uptake of water and boron. Boron's role within the plant includes cell wall synthesis, sugar transport, cell division, differentiation, membrane functioning, root elongation, regulation of plant hormone levels and generative growth of plants (Marschner, 1995 and Anonymous, 2007). Lettuce shows a pronounced yield and quality response to boron fertilizer under most conditions (Alkhader *et al.,* 2013). Boron availability to plants is controlled by various soil parameters such as pH, structure, moisture, temperature, organic matter, clay minerals, and sesquioxides (Matula, 2009). Chemical fertilizer application is an effective method to increase yields, but is costly and may also lead to environmental problems. In particular, phosphorus fertilizers present a serious risk of cadmium accumulation in soil (Al-Fayiz *et al.,* 2007). Recently, there has been interest in more environmentally sustainable agricultural practices (Orson, 1996). A greater number of studies have investigated microorganisms and promising results were obtained from biofertilization studies (Elkoca *et al.,* 2008). The bacteria used as phosphorus biofertilizers could contribute to increase the availability of phosphates immobilized in soil and could enhance plant growth by increasing the efficiency of other nutrients (Kucey *et al.,* 1989). A significant decrease in nitrate accumulation was noticed when lettuce plants were treated with biofertilizers. The benefits of biofertilizer on grown lettuce plants were presented by many researchers such as Chabot *et al.* (1996), Noel *et al.* (1996) and Kenawey (2009). Microbiological fertilizers are important to environmental friendly stainable agricultural practices (Bloemberg *et al.,* 2000). For these reasons, there was great attention to reduce the high amounts of mineral fertilizers by using the biofertilizers in crops production.

Therefore, the present study aimed to know the suitable treatment of boron foliar application and bio-, mineral phosphorus fertilizers for growth, yield and quality of oil lettuce grown in calcareous soil under climate condition completely different from south Egypt.

MATERIALS AND METHODS

Two field experiments were conducted at Mariut Experimental Station, Desert Research Center, Egypt during the two successive growing seasons 2015/2016 and 2016/2017. The main objectives of this study were aimed to study the effect of foliar application with boron concentrations, mineral phosphorus and biofertilization with bio-phosphorus dissolving bacteria (*Bacillus megaterium phosphaticum bactiria)* on growth, yield and quality of oil lettuce (*Lactuca scariola* L., var. *oleifera*) under calcareous soil conditions**.** Two field experiments were laid out in strip plot design with three replications. The vertical plots were assigned to four foliar applications of boron in the form of borax which was sprayed on oil lettuce plants two times (60 and 90 days after planting). The foliar solutions volume was 80 L/fed. sprayed by hand sprayer. The horizontal plots were occupied by six treatments of mineral phosphorous and biofertlizer. Seeds were divided in two parts, one of the two parts was treated with phosphorus dissolving bacteria as a bioferilizatin and the other was not treated, then the seeds were mixed with sugar solution in a shaded place after that, bioferilizer was added and well stirred, then were left for a quarter hour after treating in a shaded place before sowing in the bed on November 29th and December 11th in the first and second seasons, respectively. Then, one month old seedlings were transplanted to the field. The chemical and physical properties of soil are presented in Table (1). Each plot consist of 5 ridges, each 60 cm apart and 3.5 m long, comprising an area of 10.5 m^2 (1/400 fed.). The preceding summer crop was sorghum in both seasons. The experimental soil was fertilized with 40 kg N/fed. as ammonium nitrate (33.5 % N) after 30 days from transplanting before the second irrigation and mineral potassium was added at the rate of 48 kg K_2O /fed. in the form of potassium sulphate (48% K_2O) after 50 days from transplanting before the third irrigation.

Studied treatments

Boron concentrations:

-without boron application (Control).
-300 mg/L. borax $Na_2B_4O_7.10H_2O$ (11% boron).
-500 mg/L. borax $Na_2B_4O_7.10H_2O$ (11% boron).
-700 mg/L. borax $Na_2B_4O_7.10H_2O$ (11% boron).

Mineral phosphorus and biofertilization:

-Without mineral phosphorus and inoculation (control).
-15.5 kg P_2O_5/fed. in the form of calcium super phosphate (15.5 % P_2O_5).
-31 kg P_2O_5/fed. in the form of calcium super phosphate (15.5 % P_2O_5).
-Biofertilization [phosphorus dissolving bacteria (*Bacillus megaterium phosphaticum bacteria*)].
-15.5 kg P_2O_5/fed. in the form of calcium super phosphate (15.5 % P_2O_5)+ biofertilization.
-31kg P_2O_5/fed. in the form of calcium super phosphate (15.5 % P_2O_5))+ biofertilization.

Studied characters

A representative samples were taken during the growth period (90 days from planting in the field), *i.e.* six guarded plants were chosen at random from second and fourth ridges of each plot to determinate the following traits:
-Plant height (cm).
- Leaf area/plant (cm^2): It was determined by using a digital planimeter.
- Leaf area index: (LAI) = $\frac{\text{Leaf area/plant}}{\text{Land area/plant}}$ according to (Watson, 1952).

At maturity (120 days from planting in the field) six guarded plants were chosen at random from the second and fourth ridges of each plot to determine yield, yield components and quality characters as follows:

- 1000-seed weight (g).
- Seed yield/plant (g).
- Seed yield (kg/fed.).
- Biological yield (kg/fed.).
- Straw yield (kg/fed.).

Seed, biological and straw yield were determined for each sub plot.

- Harvest index = $\frac{\text{Seed yield kg/fed.}}{\text{Biological yield kg/fed.}}$
- Oil percentage: Oil percentage in seeds was determined according to the method described in (AOCS, 1964) by using a soxhlt apparatus.
- Oil yield kg/fed: it was calculated by multiplying seed yield kg/fed by seed oil percentage.
- Crude protein percentage: Total nitrogen percentage was determined by using the modified micro-Kjeldahl method as described by Peach and Tracey (1956). The protein content was calculated by multiplying the total nitrogen % by 6.25 (Tripath *et al.,* 1971).

Statistical analyses

Data were arranged and analyzed as a strip plots design according to (Cochran and Cox, 1963) with three replicates. New L.S.D. test at a level of 5 % of significance was used for the comparison between means according to (Waller and Duncan, 1969).

Table (1).Some physical and chemical properties of the experimental soil (averages of the two growing seasons)

Particle size distribution			**Texture class**	**C h e m I c a l**			**A n l y s I s**		
Sand	Silt	Clay		pH	EC ds/m	Ca Co_3 (%)	Available (mg /kg)		
(%)	(%)	(%)					N	P	K
54	21	25	Sandy clay loam	8.7	1.2	25.8	355.1	3.5	671.0

RESULTS AND DISCUSSION

Effect of boron concentrations:

Significant effects were detected due to boron application on plant height, leaf area/plant, leaf area index, 1000 seed weight, seed yield /plant, seed yield/fed. (Table 2), biological yield/fed., straw yield/fed., oil percentage and oil yield (Table 3) in both seasons, except harvest index and crude protein percentage which were affected significantly by boron concentrations application in the second season only. Increasing boron concentrations up to 500 mg/L significantly increased the previous studied traits. While, application of boron at 700 mg/L came second with respect to these characters.

Foliar spraying of boron at 500 mg/L increased plant height, leaf area/plant, leaf area index, 1000 seed weight, seed yield /plant, seed yield /fed., biological yield/fed., straw yield/fed. and oil yield/fed. by 0.31, 0.74, 0.74, 0.54, 5.07, 5.11, 4.96, 4.93 and 11.78 % respectively, as an average of both seasons compared with control treatment. Also, oil percentage was affected significantly by boron concentrations application in both seasons, but the maximum value was detected by 700 mg/L while, application of boron at 500 mg/L came second with respect for this character, it was increased by 7.02 % as an average of both seasons compared with control treatment. The presented results revealed that, boron application could activate lettuce growth which reflects on yield and its compounds. This corresponds with the results of Dong *et al.* (2009) who reported that, application of boron could significantly influence an increase in the number and size of plant cells. Shkolnik and Kopmane (1970) also, cited that, the functions of boron have been associated with several plant physiologies, such as water relations, sugar translocation, cation and anion absorption and the metabolism of N, P, carbohydrates and fats. These results also, are consistent with Wojcik and Klamkowski (2008) they reported that, plant growth was incremental after applying boron. Also, it may be that, boron activated the high amount of assimilates transported into leaf tissues and led to an increase in cell expansion (Marschner, 1995). These results showed that, boron applications can stimulate crop growth. Effect of boron foliar application was significant on plant height, application of boron increased plant growth and plant height, in other words, plant height increased by 8.35% compared with control treatment (Dell and Huang, 1997). Abdium *et al.* (1994) reported that, boron foliar application increased wheat yield by 31.6% compared with control treatment. Regarding oil content, Heydarian *et al.* (2012) found that, the effect of boron rates on the percentage of oil content of sunflower was highly significant in all the years of the trial, the highest percentage of oil content 85.00 and 66% was obtained at 8 kg B/ha. in the two seasons respectively, the increase of 8 kg B/ha. were 13.4 and 23.2% over control in the two seasons respectively. Herrera *et al.* (2015) pointed out that, boron foliar application had a significant effect on safflower seed yield, biological yield harvest index nonetheless there was no significant difference between two boron concentrations 0.5 and 1 %. They added that, boron foliar application had no significant effect on 1000-seed weight. The effects of boron may be due to that, boron has metabolic role in biochemical reactions and protects plant cell from stresses which reflect appositive effects on plants.

Table (2). Averages of plant height, leaf area/plant, leaf area index, 1000 seed weight, seed yield/plant and seed yield /fed. as affected by boron concentrations, mineral, biofertilization and their interaction in 2015/2016 and 2016/2017 seasons

Treatments	Plant height (cm)		Leaf area /plant (cm2)		Leaf area index		1000 seed weight (g)		Seed yield/plant (g)		Seed yield/fed. (kg)	
	15/16	**16/17**	**15/16**	**16/17**	**15/16**	**16/17**	**15/16**	**16/17**	**15/16**	**16/17**	**15/16**	**16/17**
Boron concentrations (A):												
Without boron (control)	100.25	100.22	3008	3013	3.008	3.013	0.95	0.96	9.21	9.29	364.91	367.87
300 mg/L. borax	100.31	100.62	3019	3035	3.019	3.035	0.97	0.98	9.42	9.55	373.17	378.18
500 mg/L. borax	100.38	100.71	3026	3039	3.026	3.040	1.00	1.02	9.63	9.86	381.57	390.71
700 mg/L. borax	100.34	100.65	3023	3027	3.023	3.027	0.99	1.00	9.56	9.67	378.61	385.72
New L.S.D. (0.05)	0.0043	0.0039	0.181	0.200	0.0017	0.0014	0.0021	0.0018	0.0021	0.0023	0.0497	0.0505
Mineral and biofertilization (B):												
Without mineral and biofertilizer	97.22	97.47	2926	2929	2.93	2.93	0.92	0.92	8.86	8.98	350.72	356.41
15.5 kg P2O5/fed.	100.05	100.25	3011	3018	3.01	3.02	0.98	0.99	9.45	9.59	374.66	380.71
30 Kg P2O5/fed.	102.08	102.29	3072	3085	3.07	3.09	1.00	1.01	9.70	9.84	384.32	390.52
Biofertilization	98.61	98.89	2968	2987	2.97	2.99	0.95	0.96	9.22	9.36	365.42	371.33
15.5Kg P2O5/fed+ biofertilization	101.06	101.28	3041	3048	3.04	3.05	1.00	1.01	9.62	9.76	381.38	387.53
30Kg P2O5/fed+ biofertilization	102.92	103.13	3097	3105	3.10	3.10	1.02	1.03	9.88	10.01	390.90	397.20
New L.S.D. (0.05)	0.0052	0.0048	0.222	0.238	0.0021	0.0017	0.0026	0.0022	0.0026	0.0028	0.0609	0.0618
Interaction: AXB	*	*	*	*	*	*	*	*	*	*	*	*

Effect of mineral phosphorus and biofertilization:

Data in Table (2) showed that, the effect of mineral phosphorus and biofertilization were significant on all studied characters i.e. plant height, leaf area/plant, leaf area index, 1000 seed weight, seed yield/plant, seed yield/fed. (Table 2), biological yield/fed., straw yield/fed., oil percentage and oil yield/fed. in both seasons, except harvest index and crude protein percentage which were significantly affected by mineral and bio fertilizer in the second season only (Table 3). Highest values of plant height (102.92 and 103.13 cm), leaf area/plant (3097 and 3104 cm^2), leaf area index (3.10 and 3.10), 1000 seed weight (1.02 and 1.03 g), seed yield /plant (9.88 and 10.01 g), seed yield/fed. (390.90 and 397.20 kg), biological yield/fed. (3074 and 3125 kg), straw yield/fed. (2684 and 2727 kg), oil percentage (36.58 and 36.93 %) and oil yield/fed. (143.08 and 146.77 kg) during first and second season respectively, and crude protein percentage (10.02 %) in second season were obtained as oil lettuce plants were fertilized by the combination treatment of (31 kg P_2O_5/fed. with biofertilization) while, harvest index recorded the highest value (12.83 %) in the second season by applying 15.5 kg P_2O_5/fed. Without biofertilization. Such increase in growth characters, yield and its compounds may be due to abundance of phosphorus with *bacillus* which would encourage roots development and this lead to increase the absorption of water and elements from soil, consequently this effect increased the growth characters as the plant height and leave area/plant which finely, led to positive effects on oil lettuce yield and its compounds also on oil percentage and yield. These findings were conferred with Sajjan *et al.* (1992) on legume lettuce (*Lactuca scariola*, L.) and Kenawey (2009) on oil lettuce (*Lactuca scariola* var. *oleifra*). Farnia and Moayedi (2014) reported that, phosphorus biofertilizer had a significant effect on sunflower yield and all yield components, seed oil content and protein percentage. Positive effect of biofertilizer may resulted from its ability to increase the availability of phosphorus and other nutrients especially under the calcareous nature of the soil which cause decreasing on the nutrients availability. Regarding to biological and straw yield, such increase in these traits may be due to the increase in the leaf area which consequently increased the amount of light energy intercepted by leaves and increased the dry matter accumulation and the dry weight of the different parts. Similar results were obtained by Stefan (2006) on sunflower and Kenawey (2009) on oil lettuce who pointed out that, fertilizing oil lettuce plants with mineral and bio phosphorus had appositive effects on growth, yield, yield compounds, oil percentage and yield and crude protein percentage in the two seasons of study. Such results reflect the importance of phosphorus as an essential element of enzymes activity and the role of biofertilizer in encouraging roots development and this lead to increasing water absorption and elements from soil which effects positively oil lettuce growth, yield and quality.

Table (3). Averages of biological yield/fed., straw yield/fed., harvest index, oil percentage, oil yield/ fed. and crude protein percentage as affected by boron concentrations, mineral, biofertilization and their interaction in 2015/2016 and 2016/2017 seasons

Treatments	Biological yield /fed (kg)		Straw yield/fed (kg)		Harvest index (%)		Oil (%)		Oil yield/fed (kg)		Crude protein (%)	
	15/16	16/17	15/16	16/17	15/16	16/17	15/16	16/17	15/16	16/17	15/16	16/17
Boron concentrations (A):												
Without boron (control)	2880	2899	2515	2532	12.67	12.69	33.41	33.61	122.07	123.81	9.98	9.99
300 mg/L. borax	2950	2972	2577	2594	12.65	12.73	34.84	35.23	130.17	133.38	9.98	9.98
500 mg/L. borax	3015	3066	2633	2676	12.66	12.74	35.95	36.13	137.36	141.39	10.00	10.00
700 mg/L. borax	2984	3035	2605	2650	12.69	12.71	36.07	36.77	136.72	141.99	9.98	10.00
New L.S.D. (0.05)	0.36	0.38	0.32	0.34	N.S	0.002	0.005	0.005	0.068	0.070	N.S	0.0008
Mineral and biofertilization (B):												
Without mineral and biofertilizer	2787	2844	2436	2488	12.59	12.54	32.90	33.22	115.45	118.48	9.92	9.95
15.5 kg P2O5/fed.	2954	2967	2580	2586	12.68	12.83	35.05	35.46	131.40	135.10	9.97	9.98
30 Kg P2O5/fed.	3043	3067	2659	2677	12.63	12.73	36.01	36.37	138.47	142.14	10.00	10.00
Biofertilization	2878	2914	2512	2542	12.70	12.74	34.16	34.58	124.90	128.50	9.99	9.99
15.5Kg P2O5/fed+ biofertilization	3006	3043	2624	2656	12.69	12.73	35.69	36.07	136.19	139.87	10.01	10.00
30Kg P2O5/fed+ biofertilization	3074	3125	2684	2727	12.71	12.71	36.58	36.93	143.08	146.77	10.02	10.02
New L.S.D. (0.05)	0.45	0.47	0.39	0.41	N.S	0.0021	0.0061	0.0066	0.084	0.086	N.S	0.001
Interaction: AXB	*	*	*	*	N.S	*	*	*	*	*.	N.S	N.S

Effect of the Interaction:

Regarding the interaction between both studied factors, boron concentrations and (mineral phosphorus and biofertilization), analyses of variance showed a significant effect on all studied characters i.e. plant height, leaf area/plant, leaf area index, 1000 seed weight, seed yield /plant, seed yield/fed., biological yield/fed., straw yield/fed., oil percentage and oil yield/fed. due to the interaction between mineral phosphorus, biofertilization and boron concentrations whereas, highest values were obtained by using the interaction treatment (500 mg/L borax and 31 kg P_2O_5/fed. with biofertilizer) for two seasons. On the other side, harvest index in the first season and crude protein percentage in the two seasons were not affected significantly by the interaction between the two studded factors as shown in Tables (2 and 3).

CONCLUSIONS

It could be recommended that, to maximize oil lettuce yield and quality achieved by foliar spraying 500 mg/L borax and applying 31 kg P_2O_5/fed. with inoculating seeds by phosphorus dissolving bacteria (*Bacillus megaterium phosphaticum bacteria*) as a source of biofertilizer.

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الملخص العربى

استجابة خس الزيت للتسميد الحيوى والمعدنى بالفوسفور والرش الورقى بالبورون تحت ظروف الأرض الجيرية

محمد قناوى محمد قناوى

قسم الإنتاج النباتى – شعبة البيئة وزراعات المناطق الجافة – مركز بحوث الصحراء – مصر

أجريت تجربتان حقليتان خلال الموسمين الشتويين ٢٠١٦/٢٠١٥ و٢٠١٧/٢٠١٦ بمحطة بحوث مريوط التابعه لمركز بحوث الصحراء لدراسة إستجابة خس الزيت لثلاثة مستويات من البورون رشا على الأوراق (٣٠٠ – ٥٠٠ – ٧٠٠ ملليجم/لتر بوراكس) بالإضافة الى معاملة المقارنة (بدون الرش الورقى بالبورون) وستة مستويات من التسميد الفوسفاتى المعدنى والتسميد الحيوى: [بدون تسميد (مقارنة)، ٥, ١٥ كجم فو٢ أ٥ /فدان ، ٣١ كجم فو٢ أ٥ /فدان ، التسميد الحيوى بالبكتريا المذيبة للفوسفور ، ٥, ١٥ كجم فو٢ أ٥ /فدان مع التسميد الحيوى و ٣١ كجم فو٢ أ٥ /فدان مع التسميد الحيوى]. صممت التجربة فى نظام الشرائح المتعامدة حيث شغلت معاملات الرش الورقى بالبورون الشرائح الرأسية بينما وزعت معاملات التسميد المعدنى والحيوي فى الشرائح الأفقية فى ثلاث مكررات. أوضحت النتائج حدوث تأثير معنوى لمعاملات الرش الورقى بالبورون ومعاملات التسميد المعدنى والحيوي على جميع الصفات التى تم دراستها (ارتفاع النبات، مساحة سطح أوراق النبات، دليل المساحة الورقية، وزن ال١٠٠٠ بذرة، محصول البذور للنبات، محصول البذور للفدان، المحصول البيولوجى، محصول القش، النسبة المئوية للزيت بالبذور ومحصول الزيت للفدان) فى كلا الموسمين عدا خاصيتى دليل الحصاد والنسبة المئوية للبروتين الخام بالبذور والتى تأثرت معنويا بكلا عاملى الدراسة فى الموسم الثانى فقط. أيضا كان للتفاعل بين االعوامل التى تم دراستها تأثير معنوى على كل الصفات السابقة عدا صفتى دليل الحصاد فى الموسم الأول ونسبة البروتين الخام فى كلا الموسمين حيث لم تتأثرا معنويا بالتداخل بين عاملى الدراسة.