RESPONSE OF OAT CULTIVARS TO ETHEPHON AND BORON

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ABSTRACT

The aim of this study was to reduce the lodging and improve grain yield by evaluation the performance of some oat cultivars introduced into Iraq. A field experiment was conducted during two seasons of 2017-2018 and 2018-2019, included four cultivars (Genzania, Shafa, Carrolup and Hamel) under the influence of foliar spraying of ethephon at concentrations of 0, 500 and 1000 ppm, and foliar application of boron with concentrations of 0, 50 and 100 ppm. Using RCBD within split–split arrangement and three replicates. The results were revealed that Genzania was recorded the highest number of grains head^{-1} and grain yield 6.512 and 5.565 t ha^{-1} in the two seasons respectively. Shafa had the highest number of active tillers m^{-2} in both seasons and the highest single grain weight in the second season. Carrolup was produced the highest single grain weight in the first season. Spraying ethephon with concentrations of 500 and 1000 ppm increased stem diameter and number of active tillers m^{-2} for both seasons. Spraying 500 ppm of ethephon increased grain yield in the first season and reduced lodging rate in the second season. Ethephon with 1000 ppm reduced lodging rate in both seasons. Foliar application of boron with concentrations of 50 and 100 ppm increased plant height and grain yield in both seasons.

Key words: lodging, active tillers, grain yield.
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إستجابة أصناف من الشوفان للأثيفون والبورون

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المستخلص

تهدف هذه الدراسة إلى الحد من الاضطجاع وتحسين حاصل الحبوب وتقييم أداء بعض أصناف الشوفان المدخلة إلى العراق. نُفذت تجربة حقلية خلال موسمي 2017–2018 و2018–2019 غرب العراق، تضمنت أربعة أصناف (Genzania وShafa وCarrolup وHamel) تحت تأثير رش الاثيفون على النباتات بالتراكيز 0 و500 و1000 ppm والبورون بالتراكيز 0 و50 و100 ppm. أظهرت النتائج تسجيل Genzania أعلى عدد حبوب بالدالية واعلى حاصل حبوب بلغ 6.512 و 5.565 طن هـ$^{-1}$ للموسمين بالتتابع. أعطى Shafa أعلى عدد أشطاء فعالة في المتر المربع للموسمين وأعلى قيمة لوزن الحبة المفردة في الموسم الثاني. سجل Carrolup أعلى قيمة لوزن الحبة المفردة في الموسم الأول. أدى رش الاثيفون بالتركيزين 500 و1000 ppm إلى زيادة قطر الساق وعدد الأشطاء الفعالة لكلا الموسمين. حقق رش الاثيفون بالتركيز 500 ppm زيادة حاصل الحبوب في الموسم الأول فقط، وانخفاض نسبة الاضطجاع في الموسم الثاني. أدى رش الاثيفون بالتركيز 1000 ppm إلى خفض نسبة الاضطجاع في كلا الموسمين. أدى رش البورون بالتركيزين 50 و100 ppm إلى زيادة ارتفاع النبات وحاصل الحبوب في كلا الموسمين.

كلمات مفتاحية: اضطجاع، أشطاء فعالة، حاصل الحبوب.
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INTRODUCTION

Oat (*Avena sativa* L.) is an important and multipurpose crop, with major use for food and feed. Despite the importance of oat in the world, it is not grown in Iraq at the level of economic production, so some oat cultivars was introduced for the cultivation of locally, but was observed that these cultivars have a lodging problem. Yield quantity and quality are negatively affected by lodging (6). Ethephon (2-chloroethyl phosphonic acid) is one of plant growth regulator that turns out to be beneficial for shorten the plants and control lodging of wheat (25), and other studies have indicated that ethephon decreases plant height and increases stem diameter of maize, and caused less lodging (21, 26). In addition to that, Taylor et al., (24) pointed out that ethephon increased the active tillers in barley. Boron is one of the important micronutrient elements for plants, performing functions related to carbohydrate metabolism, phenol metabolism, indole acetic acid metabolism, sugar transport, respiration, membrane transport, cell wall synthesis, cell wall lignification and cell wall structure (7). The functions of boron, especially related to the lignification, could be a role in strengthening the stem of plants, and reducing the lodging, along with other functions that contribute to enhanced the yield. This study was aimed to investigate the effect of ethephon and boron on the lodging and some other traits correlated with the grain yield of some oat cultivars, which introduced into Iraq.

MATERIALS AND METHODS

A field experiment was conducted during two winter seasons of 2017-2018 and 2018-2019, in western of Iraq, 100 km from Baghdad, at the research station, College of Agriculture, University of Anbar. The Randomize Complete Block Design (RCBD) was used according to the split-split plot arrangement, with three replicates. Boron (B) concentrations (0, 50 and 100 ppm) was occupied the whole plots, while ethephon (E) concentrations (0, 500 and 1000 ppm) in the split plots, and four cultivars of oat (Genzania, Shafa, Carrolup and Hamel) in the split-split plots. Random soil samples were taken from the soil of experiment at the depth of 0-30 cm and analyzed, as shows in Table 1, the results of some chemical and physical properties.

Table 1. Results of soil analysis

analysis type	Results	
	2017-2018	2018-2019
EC	1.50 dS m^{-1}	1.60 dS m^{-1}
pH.	7.82	7.97
Sand	312 g kg^{-1}	
Clay	26 g kg^{-1}	
Silt	662 g kg^{-1}	
Texture	Silt loam	
Bulk density	1.3 g cm^{-3}	
B extracted by hot water	0.36 mg kg^{-1}	0.41 mg kg^{-1}
Total nitrogen	126.40 mg kg^{-1}	112.94 mg kg^{-1}
Available phosphor	7.05 mg kg^{-1}	6.74 mg kg^{-1}
Available Potassium	144 mg kg^{-1}	132 mg kg^{-1}
Organic matter	0.55%	0.53%0
CEC	19 $cmol_c$ kg^{-1}	17 $cmol_c$ kg^{-1}

The experimental field was plowed, disked, then was divided into units (plots) of 3×2.5 m, the seeds were planted in the late November, with 10 lines in each unit, with seeding rate of 100 kg ha^{-1}. Triple super phosphate (45% P_2O_5) as granular fertilizer was applied at rate of 100 kg P ha^{-1} with one dose prior to planting, and urea (46% N) as granular fertilizer was applied at rate of 150 kg N ha^{-1} with three doses at emergence, tillering and booting. Ethephon (48% 2-chloroethyl phosphonic acid) was sprayed on the plants at ZGS15 and ZGS20, as well foliar application of boron as boric acid (H_3BO_3, 17% B) was performed at ZGS41 and ZGS61, according to Zadoks et al., (28). Studied traits: Plant height (cm), from the main shoot of ten randomly selected plants was measured from the soil surface to the bottom of the panicle, at 100% flowering. Stem diameter (mm), at 100% flowering, ten plants were randomly selected to measure stem of main shoots at the bottom, middle and top. Lodging rate (%), it was assessed at maturity by measured the lodging area, with a rate calculated using the formula: lodging rate = (lodging area / plot area) × 100, described by Chen et al., (12). Number of active tillers m^{-2}, it is the number of heads in the central square meter. Number of grains $head^{-1}$, it was calculated in ten randomize heads from the central square meter. Single grain weight (mg), it is 1000 grain weight dried at 65° C for 72 hours, divided by 1000. Grain yield (t ha^{-1}), it is the weight of grain yield of central square meter, which was dried at 65° C for 72 hours, multiplied by 10000.

RESULTS AND DISCUSSION

Plant height (cm): Results in Table 2 shows that Genzania produced the highest plant

height, reached 90.4 and 100.5 cm significantly higher than the other cultivars except Hamel in the first season, while Shafa had the lowest plant height 85.8 and 89.4 cm in two seasons respectively. The differences among cultivars in the plant height could be due to the differences in genotype and the differences in the response to environmental conditions and how to take advantage of the available nutrients, which reflected the increase in plant height. This result is consistent with the results of Midha et al., (19) and Dabhi et al., (13) in oat. Results in Table 2 shows that the ethephon reduced plant height. The control (0 ppm ethephon) recorded the highest value 93.5 and 100.4 cm for the two seasons respectively. Ethephon spraying with concentrations of 500 and 1000 ppm caused significant decreases with 5.56 % and 12.19% in the first season, 11.35% and 10.85% respectively in the second season. The reason could be due to ethylene, which inhibits cell division in the stem. This result is similar to what found in wheat (27) and barley (24, 23). Boron increased plant height (Table 2), as the control (0 ppm boron) recorded the lowest value, reached 83.0 and 87.9 cm in the two season respectively, and the boron concentrations of 50 and 100 ppm increased plant height significantly with 8.0 and 7.0 cm in the first season, 6.3 and 8.9 cm in the second season, but concentrations of 50 and 100 ppm were not significantly different in the two seasons. The increased plant height was probably due to the positive role of boron in the plant's vital processes (7). Similar results found by Al-Naqeeb and Hashim (3) about increase plant height of wheat due to effect of boron. Table 2 shows significant effects of the interaction between the cultivars and the ethephon concentrations on the plant height in both seasons. The combination of Hamel with 0 ppm ethephon was highest plant height

Table 2. Effect of boron and ethephon on the plant height (cm) of four oat cultivars

B ppm	E ppm	2017-2018 Cultivars				B × E	2018-2019 Cultivars				B × E
		Genzania	Shafa	Carrolup	Hamel		Genzania	Shafa	Carrolup	Hamel	
	0	98.0	92.0	93.7	94.7	94.6	96.3	91.0	95.7	103.0	96.5
0	500	83.3	77.7	82.7	81.7	81.3	96.7	84.3	85.0	73.0	84.8
	1000	76.3	71.3	69.3	75.0	73.0	93.3	75.3	82.0	79.3	82.5
	0	94.0	88.7	96.3	101.7	95.2	104.0	97.0	100.7	102.7	101.1
50	500	93.3	93.7	93.7	98.3	94.8	102.3	82.7	85.3	87.0	89.3
	1000	86.7	87.7	76.0	81.7	83.0	102.0	98.0	83.7	85.0	92.2
	0	94.7	89.7	86.3	92.0	90.7	106.3	87.7	103.3	117.3	103.7
100	500	95.0	78.0	91.7	91.0	88.9	104.3	93.7	88.7	85.0	92.9
	1000	92.0	93.3	86.0	90.0	90.3	99.3	94.7	88.3	92.7	93.7
L.S.D 5%			N.S.			6.29		N.S.			N.S.
						B means					B means
B	0	85.9	80.3	81.9	83.8	83.0	95.4	83.6	87.6	85.1	87.9
×	50	91.3	90.0	88.7	93.9	91.0	102.8	92.6	89.9	91.6	94.2
Cultivars	100	93.9	87.0	88.0	91.0	90.0	103.3	92.0	93.4	98.3	96.8
L.S.D 5%			N.S.			3.51		N.S.			6.58
						E means					E means
E	0	95.6	90.1	92.1	96.1	93.5	102.2	91.9	99.9	107.7	100.4
×	500	90.6	83.1	89.3	90.3	88.3	101.1	86.9	86.3	81.7	89.0
Cultivars	1000	85.0	84.1	77.1	82.2	82.1	98.2	89.3	84.7	85.7	89.5
L.S.D 5%			5.84			4.12		7.52			2.94
Cultivars means		90.4	85.8	86.2	89.6		100.5	89.4	90.3	91.7	
L.S.D 5%			2.95					4.70			

reached 96.1 and 107.7 cm in the two seasons respectively, while Carrolup with 1000 ppm ethephon recorded the lowest value (77.1 cm) in the first season, Hamel with 500 ppm ethephon recorded the lowest value (81.7 cm) in the second season. The effect of interaction between the concentrations of boron and ethephon on plant height was significant in the first season only (Table 2). The combination of 0 ppm ethephon with 50 ppm boron recorded the highest mean, reached 95.2 cm, and the combination of 1000 ppm ethephon with 0 ppm boron recorded the lowest mean, reached 73.0 cm.

Stem diameter (mm): The results in Table 3 indicates that Hamel has greatest value of stem

diameter 6.28 and 5.97 mm, significantly higher than the other cultivars, while Shafa recorded the lowest value 3.80 and 3.56 mm in the two seasons respectively. The difference of stem diameter could be due to different of genotype. Sampson (20) obtained similar results, as stem diameter of oat genotypes was different: Attia et al., (5) found similar results in wheat genotypes. The results in the Table 3 shows that the ethephon was increased the stem diameter. The highest value of stem diameter was recorded at the concentration of 500 ppm ethephon were 4.89 and 4.84 mm for the two seasons respectively, which did not significantly different from the concentration of 1000 ppm ethephon, but both concentrations differed significantly with control (0 ppm ethephon) that has the lowest value of stem diameter of 4.22 and 4.49 mm in the two seasons respectively. This result is consistent with the results of Chandiposha and Chivende (10) in maize, and Abood (1) in sorghum, about increase stem diameter by ethephon effect. Boron application increased stem diameter significantly in the first season (Table 3). The concentration of 100 ppm of boron recorded the highest mean, reached 4.89 mm and did not differ significantly from the concentration 50 ppm boron (4.79 mm), but the two concentrations differed significantly from the 0 ppm boron, which recorded the lowest mean (4.28 mm). The increase of stem diameter could be due to the role of boron in the lignification (7).

Table 3. Effect of boron and ethephon on the stem diameter (mm) of four oat cultivars

B ppm	E ppm	2017-2018 Cultivars				B × E	2018-2019 Cultivars				B × E
		Genzania	Shafa	Carrolup	Hamel		Genzania	Shafa	Carrolup	Hamel	
	0	4.53	3.04	3.83	6.05	4.36	4.60	3.27	3.08	5.18	4.03
0	500	4.51	3.30	3.67	6.61	4.52	4.57	4.45	4.20	6.25	4.87
	1000	3.18	3.25	3.25	6.18	3.96	5.48	3.25	4.73	5.25	4.68
	0	4.93	2.98	2.76	5.87	4.14	5.80	3.28	4.20	6.37	4.91
50	500	5.64	3.75	4.43	6.63	5.11	4.92	3.75	4.67	5.95	4.82
	1000	3.90	4.45	4.45	7.65	5.12	5.50	3.67	4.83	5.67	4.92
	0	4.49	3.44	3.26	5.43	4.16	5.02	3.43	4.02	5.63	4.52
100	500	5.84	4.20	4.28	5.78	5.02	4.82	3.43	3.48	7.57	4.82
	1000	5.09	5.82	4.78	6.27	5.49	4.48	3.52	4.82	5.90	4.68
L.S.D 5%			N.S.			0.540		0.895			N.S.
						B means					B means
B	0	4.07	3.19	3.58	6.28	4.28	4.88	3.66	4.01	5.56	4.53
×	50	4.82	3.73	3.88	6.72	4.79	5.41	3.57	4.57	5.99	4.88
Cultivars	100	5.14	4.49	4.11	5.83	4.89	4.77	3.46	4.11	6.37	4.68
L.S.D 5%			N.S.			0.277		0.564			N.S.
						E means					E means
E	0	4.65	3.15	3.28	5.79	4.22	5.14	3.33	3.77	5.73	4.49
×	500	5.33	3.75	4.13	6.34	4.89	4.77	3.88	4.12	6.59	4.84
Cultivars	1000	4.06	4.51	4.16	6.70	4.86	5.16	3.48	4.79	5.61	4.76
L.S.D 5%			0.872			0.359		0.501			0.273
Cultivars means		4.68	3.80	3.86	6.28		5.02	3.56	4.23	5.97	
L.S.D 5%			0.541					0.290			

The interaction of cultivars and ethephon concentrations showed a significant effect on stem diameter for both seasons (Table 3). Hamel recorded the highest value of stem diameter (6.70 mm) when sprayed with 1000 ppm of ethephon in the first season, and the same cultivar recorded the highest value (6.59 mm) when sprayed with the concentration of 500 ppm of ethephon in the second season, while Shafa sprayed with a concentration of 0 ppm of ethephon recorded the lowest value 3.15 and 3.33 mm in the two season respectively.Table 3 shows that the triple interaction of the factors (Boron × Ethephon × Cultivars) had a significant effect on stem diameter for the second season only, as Hamel with 500 ppm of ethephon and 100 ppm of boron has the highest value (7.57 mm), while Carrolup with 0 ppm of ethephon and 0 ppm of boron has the lowest value (3.08 mm).

Lodging rate (%)

The data of lodging rate in the Table 4 indicates that the cultivars were differed significantly in the first season only. Shafa recorded the lowest lodging rate (7.70%), did not different significantly from Hamel, while

Genzania recorded the highest lodging rate (9.59%) and did not differed significantly from Carrolup. This difference is due to the different traits associated with lodging resistance, such as plant height, Shafa was lowest plant height (Table 2) and with lowest lodging, but Genzania was highest plant height and highest lodging. This is consistent with Kelbert et al., (17) who revealed that the short wheat plants were more resistant to lodging. The results were consistent with the results obtained by Ali et al., (2) and Arenhardt et al., (4) about the different lodging of oat genotypes. The results in Table 4 show that the ethephon spraying led to significant decreases lodging rate in both seasons. The control (0 ppm ethephon) recorded the highest average of lodging rate, reached 9.48% and 13.45% for the two seasons respectively, and lodging rate decreased significantly in the first season, by spraying ethephon with concentration of 1000 ppm was recorded the lowest average (7.53%). In the second season, lodging rate decreased significantly by spraying ethephon with concentrations of 500 and 1000 ppm, which recorded the lowest average, reached 9.75% and 9.98% for the two concentrations respectively. These decreases could be occurred due to reduction in plant height by ethephon (Table 2). This is consistent with the findings of Shekoofa and Emam (21) and Wei et al., (26), as well the result is consistent with results obtained in wheat (25, 27) and barley (24). There were significant effects of the interaction between the cultivars and ethephon concentrations on lodging rate in both seasons (Table 4). In the first season, Genzania with concentration of 1000 ppm ethephon had the lowest value of lodging rate (5.95%), and the same cultivar without ethephon recorded the highest value (13.49%). In the second season, Hamel with 500 ppm ethephon had the lowest value of lodging rate (7.33%), and Genzania without ethephon had the highest value (14.71%). The data of lodging rate in the Table 4 shows that there is a significant effect of the triple interaction of the study factors in the second season only. Shafa sprayed with ethephon at 1000 ppm and boron at 50 ppm recorded the lowest lodging rate, reached 6.42%, While Hamel with 0 ppm of ethephon and 50 ppm of boron recorded the highest lodging rate, reached 20%.

Table 4. Effect of boron and ethephon on the lodging rate (%) of four oat cultivars

B ppm	E ppm	2017-2018 Cultivars				B × E	2018-2019 Cultivars				B × E
		Genzania	Shafa	Carrolup	Hamel		Genzania	Shafa	Carrolup	Hamel	
	0	12.62	6.97	10.17	5.74	8.87	10.56	18.49	7.69	12.14	12.22
0	500	11.44	9.80	9.94	7.72	9.73	13.78	10.27	14.31	6.49	11.21
	1000	6.68	7.37	10.21	9.79	8.51	10.32	8.93	11.78	12.41	10.86
	0	14.21	6.40	11.20	7.66	9.87	14.04	10.36	12.96	20.00	14.34
50	500	7.72	8.90	6.70	8.41	7.93	11.56	10.31	8.76	7.80	9.61
	1000	3.35	6.91	5.17	8.53	5.99	10.33	6.42	11.27	11.53	9.89
	0	13.65	7.27	11.59	6.34	9.71	19.53	13.88	11.72	11.09	14.05
100	500	8.84	5.95	9.35	6.77	7.73	8.98	8.47	8.53	7.70	8.42
	1000	7.82	9.73	6.28	8.55	8.09	7.65	11.04	10.47	7.65	9.20
L.S.D 5%			N.S			N.S.		7.195			N.S.
						B means					B means
B	0	10.24	8.05	10.10	7.75	9.04	11.55	12.56	11.26	10.35	11.43
×	50	8.43	7.40	7.69	8.20	7.93	11.97	9.03	10.99	13.11	11.28
Cultivars	100	10.10	7.65	9.07	7.22	8.51	12.05	11.13	10.24	8.81	10.56
L.S.D 5%			N.S.			N.S.		N.S.			N.S.
						E means					E means
E	0	13.49	6.88	10.99	6.58	9.48	14.71	14.24	10.79	14.41	13.54
×	500	9.33	8.22	8.66	7.63	8.46	11.44	9.68	10.53	7.33	9.75
Cultivars	1000	5.95	8.00	7.22	8.96	7.53	9.43	8.80	11.18	10.53	9.98
L.S.D 5%			1.933			1.162		3.982			3.211
Cultivars means		9.59	7.70	8.96	7.72		11.86	10.91	10.83	10.76	
L.S.D 5%			1.077					N.S.			

Number of active tillers m^{-2}

The results in the Table 5 shows that Shafa was produced the highest number of active tillers m^{-2}, reached 434 and 346 tillers m^{-2}, significantly higher than Genzania and Hamel, while Hamel had the lowest average, reached

338 and 302 in the two seasons respectively. This result corresponds to the results of Maral et al., (18) in relation to the different oat genotypes in the number of active tillers per unit area. The data shows that the number of active tillers m^{-2} was increased significantly over the control at ethephon concentrations 500 and 1000 ppm with 8.80% and 6.93% in the first season, 14.91% and 16.61% in the second season (Table 5). This could be because promote tillering due to inhibition the growth in the main stem of plant (16). Similar results was found by Taylor et al., (24) that number of active tillers of barley increased by ethephon effect. The effect of interaction between cultivars and ethephon concentrations was significant on the number of active tillers m^{-2} in both seasons (Table 5). Shafa with ethephon at concentration of 1000 ppm recorded the highest number of active tillers m^{-2}, reached 456 and 380 tillers m^{-2}, while Hamel without ethephon (0 ppm) recorded the lowest number, reached 318 and 264 tillers m^{-2} for the two seasons respectively. The results in the Table 5 indicates that there was a significant effect of the interaction between the ethephon and boron concentrations on the number of active tillers m^{-2} in the first season only, as combination of 500 ppm of ethephon with 0 ppm of boron produced the highest average (412 tillers m^{-2}), while the combination of 0 ppm of ethephon with 100 ppm of boron had the lowest average (371 tillers m^{-2}).

Table 5. Effect of boron and ethephon on the Number of active tillers m^{-2} of four oat cultivars

B ppm	E ppm	2017-2018 Cultivars				B × E	2018-2019 Cultivars				B × E
		Genzania	Shafa	Carrolup	Hamel		Genzania	Shafa	Carrolup	Hamel	
	0	362	393	425	326	376	327	283	352	274	309
0	500	381	455	462	350	412	328	364	315	315	331
	1000	378	464	374	342	390	306	367	340	332	336
	0	365	395	426	321	377	318	323	269	265	294
50	500	390	455	424	344	403	351	361	384	315	353
	1000	396	446	406	358	401	291	391	363	314	340
	0	358	393	425	308	371	268	281	327	253	282
100	500	392	445	460	344	410	348	366.	316	303	333
	1000	383	457	450	353	411	314	381	374	350	355
L.S.D 5%			N.S.			12.1		N.S.			N.S.
						B means					B means
B	0	374	437	420	339	393	320	338	336	307	325
×	50	384	432	419	341	394	320	358	339	298	329
Cultivars	100	378	432	445	335	397	310	343	339	302	323
L.S.D 5%			N.S.			N.S.		N.S.			N.S.
						E means					E means
E	0	362	394	425	318	375	304	296	316	264	295
×	500	388	452	448	346	408	342	364	338	311	339
Cultivars	1000	386	456	410	351	401	304	380	359	332	344
L.S.D 5%			19.6			5.8		37.5			25.7
Cultivars means		378	434	428	338		317	346	338	302	
L.S.D 5%			12.6					19.4			

Number of grains $head^{-1}$

Significant differences were found among cultivars in the number of grains $head^{-1}$ (Table 6). Genzania had the highest average, reached 69.6 and 76.0 grains $head^{-1}$, significantly higher than all other cultivars in the first season, and higher than Shafa and Carrolup in the second season, while Carrolup had the lowest average, reached 39.0 and 43.4 grains $head^{-1}$ for the two seasons respectively. This finding agree with the results found by Siloriya et al., (22), and Dumlupinar et al., (14) about the different of grains $head^{-1}$ in oat genotypes. Foliar application of boron in the first season with concentrations of 50 and 100 ppm resulted in significant increases number of grains $head^{-1}$ than in control with 15.08% and 16.52% respectively, but the concentrations 50 and 100 ppm did not differed significantly (Table 6). The results in Table 6 indicated there were significant effects of the interaction between ethephon and boron on the number of grains $head^{-1}$ in both seasons. In the first season, the combination of 500

ppm ethephon with 50 ppm boron produced the highest value (58.3 grains head^{-1}), while the combination of 1000 ppm ethephon with 0 ppm boron had the lowest value (46.8 grains head^{-1}). In the second season, the combination of 0 ppm ethephon with 100 ppm boron produced the highest value (64.6 grains head^{-1}), while the combination 500 ppm ethephon with 0 ppm boron had the lowest value (56.2 grains head^{-1}).

Table 6. Effect of boron and ethephon on the Number of grains head $^{-1}$ of four oat cultivars

B ppm	E ppm	2017-2018 Cultivars				B × E	2018-2019 Cultivars				B × E
		Genzania	Shafa	Carrolup	Hamel		Genzania	Shafa	Carrolup	Hamel	
	0	69.1	34.8	32.4	64.3	50.2	72.9	44.6	37.4	79.8	58.6
0	500	61.8	35.9	32.0	63.3	48.3	77.0	42.2	40.3	65.4	56.2
	1000	60.9	32.4	31.1	62.9	46.8	78.7	39.4	39.1	68.2	56.4
	0	65.4	38.5	41.4	61.1	51.6	79.3	42.5	47.4	62.9	58.0
50	500	73.5	42.1	48.4	69.5	58.3	78.7	52.2	44.9	81.3	64.3
	1000	76.9	42.0	41.2	69.1	57.3	78.4	48.7	43.2	71.8	60.6
	0	72.4	44.7	44.6	69.6	57.9	78.3	52.1	43.4	84.4	64.6
100	500	77.8	41.1	43.7	66.8	57.3	70.5	45.2	45.6	67.3	57.2
	1000	69.0	42.3	35.9	68.8	54.0	70.2	45.2	49.7	75.6	60.2
L.S.D 5%			N.S.			6.03		N.S.			9.47
						B means					B means
B	0	63.9	34.4	31.9	63.5	48.4	76.2	42.1	38.9	71.1	57.1
×	50	71.9	40.8	43.7	66.6	55.7	78.8	47.8	45.2	72.0	60.9
Cultivars	100	73.1	42.7	41.4	68.4	56.4	73.0	47.5	46.3	75.8	60.6
L.S.D 5%			N.S.			5.81		N.S.			N.S.
						E means					E means
E	0	69.0	39.3	39.5	65.0	53.2	76.8	46.4	42.8	75.7	60.4
×	500	71.0	39.7	41.4	66.5	54.6	75.4	46.5	43.6	71.3	59.2
Cultivars	1000	68.9	38.9	36.1	67.0	52.7	75.8	44.5	44.0	71.9	59.0
L.S.D 5%			N.S.			N.S.		N.S.			N.S.
Cultivars means		69.6	39.3	39.0	66.2		76.0	45.8	43.4	73.0	
L.S.D 5%			2.73					5.26			

Single grain weight (mg)

The results in the Table 7 showed that Carrolup produced the highest mean of the Single grain weight (35.7 mg) in the first season, significantly higher than Hamel and Genzania which had the lowest mean (28.0 mg). In the second season, Shafa produced the highest mean of the Single grain weight (36.4 mg) superior to the other cultivars, while Genzania had the lowest mean (26.4 mg). These differences could be due to the differences genotype of cultivars that led to the different efficiency of metabolism and transport of storage materials during the grain filling period. Dumlupinar et al., (14) and Chappell et al., (11) found that oat genotypes differed in grain weight. The data shows that there were negative effects of ethephon on the Single grain weight (Table 7). There were significant decreases less than control with 8.2% at the concentration 1000 ppm ethephon in the first season, with 8.2% and 8.5% at concentrations 500 and 1000 ppm of ethephon in the second season. The decreases could be attributed to the increases in the number of the active tillers m^{-2} caused by ethephon (Table 5), which increased competition for energy and nutrients, so that reduced the amount of storage materials that reaches the grain during grain filling period. The results indicated that single grain weight significantly increased with effect of boron in the second season with 50 ppm concentration with 8.4% compared to the control treatment (Table 7). This increase could be due to the important role of boron in carbohydrate metabolism and transport through cellular membranes (8). Data in Table 7 show significant effects of the interaction between the cultivars and boron concentrations on single grain weight in both seasons. In the first season, Carrolup with 100 ppm of boron was recorded the highest value of single grain weight (38.7 mg), while Hamel with 0 ppm of boron recorded the lowest value (25.4 mg). In the second season, Carrolup with 50 ppm of boron recorded the highest value of single grain weight (38.9 mg), while Genzania with 0 ppm recorded the lowest (24.8 mg). Significant effects were found in the interaction between the ethephon and boron

concentrations on the single grain weight in the first season only (Table 7). The treatment of 0 ppm ethephon with 100 ppm boron recorded the highest value (35.2 mg) while the treatment of 1000 ppm ethephon with 0 ppm boron recorded the lowest value (27.0 mg).

Table 7. Effect of boron and ethephon on the Single grain weight (mg) of four oat cultivars

B ppm	E ppm	2017-2018 Cultivars				B × E	2018-2019 Cultivars				B × E
		Genzania	Shafa	Carrolup	Hamel		Genzania	Shafa	Carrolup	Hamel	
	0	27.7	29.7	32.5	24.9	28.7	28.6	36.5	31.8	29.9	31.7
0	500	28.1	34.3	36.7	28.6	31.9	24.8	35.0	28.4	29.0	29.3
	1000	23.5	30.1	31.8	22.6	27.0	21.1	34.1	32.3	24.5	28.0
	0	31.1	39.4	35.4	29.9	34.0	27.6	37.9	40.0	30.9	34.1
50	500	27.1	35.6	34.1	28.4	31.3	27.4	32.0	37.2	26.7	30.8
	1000	25.7	38.4	34.8	26.8	31.4	24.6	35.7	39.4	26.3	31.5
	0	34.1	36.4	38.2	32.1	35.2	26.8	38.9	35.2	29.1	32.5
100	500	29.0	29.8	39.4	31.2	32.4	28.9	37.1	30.6	24.3	30.2
	1000	25.5	31.8	38.5	29.8	31.4	28.1	39.9	28.3	25.6	30.5
L.S.D 5%			N.S.			3.51		N.S.			N.S.
						B means					B means
B	0	26.5	31.4	33.7	25.4	29.2	24.8	35.2	30.8	27.8	29.7
×	50	28.0	37.8	34.8	28.3	32.2	26.5	35.2	38.9	28.0	32.2
Cultivars	100	29.5	32.7	38.7	31.0	33.0	27.9	38.6	31.4	26.3	31.1
L.S.D 5%			4.09			N.S.		3.22			1.73
						E means					E means
E	0	31.0	35.2	35.4	29.0	32.6	27.7	37.8	35.7	30.0	32.8
×	500	28.1	33.3	36.7	29.4	31.9	27.0	34.7	32.1	26.7	30.1
Cultivars	1000	24.9	33.4	35.0	26.4	29.9	24.6	36.6	33.3	25.5	30.0
L.S.D 5%			N.S.			1.45		N.S.			2.13
Cultivars means		28.0	34.0	35.7	28.2		26.4	36.4	33.7	27.4	
L.S.D 5%			2.06					2.74			

Grain yield (t ha^{-1})

The results in Table 8 shows that Genzania recorded the highest average grain yield (6.512 and 5.565 t ha^{-1}) in the two seasons respectively, significantly highest than other cultivars in the first season, highest than Shafa and Carrolup in the second season, while Shafa recorded the lowest average (5.011 t ha^{-1}) in the first season, Carrolup recorded the lowest average (4.113 t ha^{-1}) in the second season. Genzania's superiority could be attributed to its superiority in the number of grains head^{-1} (Table 6). The results were consistent with the findings by Elsahookie et al., (15) about the differences among oat cultivars in the grain yield and Genzania superiority. The ethephon spraying had a significant effect on the grain yield for the first season only (Table 8). Grain yield increased with 9.15% more than control, at 50 ppm ethephon. This increase could be due to the increase number of active tillers m^{-2} (Table 5). At concentration of 1000 ppm ethephon, grain yield decreased significantly lower than grain yield at 50 ppm ethephon, and non-significant decrease lower than grain yield at control. These results agreement with the results of Taylor et al., (24) who showed an increase grain yield of barley for one season from several seasons, when the low level of ethephon was used, and a decrease grain yield when using the high level of ethephon. Data in Table 8 indicates significant positive effects of boron on the grain yield in both seasons. Boron spraying was led to significantly increases over the control with 27.81% and 33.75% at boron concentrations 50 and 100 ppm respectively, in the first season, as well in the second season, the increase was20.17 and 12.45% at the two concentrations respectively, but there was no significant difference between 50 and 100 ppm boron. The increases of grain yield in the first season could be due to an increase of the number of grains head^{-1} (Table 6), as well the increases in the second season could be due to the increase of single grain weight (Table 7). These results were consistent with Castagnara et al., (9) with regard to the increase grain yield of oat by boron effect. There were significant effects of interaction between the ethephon and boron concentrations on the grain yield in the two seasons (Table 8). In the first season, the combination of 500 ppm ethephon with 100

ppm boron had the highest grain yield (6.425 t ha^{-1}). In the second season, the combination of 500 ppm ethephon with 50 ppm boron had the highest grain yield (5.982 t ha^{-1}). The combination of 1000 ppm ethephon with 0 ppm boron had the lowest grain yield, reached 3.955 and 4.255 t ha^{-1} in the two seasons respectively.

Table 8. Effect of boron and ethephon on the grain yield (t ha^{-1}) of four oat cultivars

B ppm	E ppm	2017-2018 Cultivars				B × E	2018-2019 Cultivars				B × E
		Genzania	Shafa	Carrolup	Hamel		Genzania	Shafa	Carrolup	Hamel	
	0	6.140	3.454	4.030	4.666	4.572	6.032	3.780	3.420	5.664	4.724
0	500	5.934	4.928	4.779	5.595	5.309	5.458	4.168	2.789	5.076	4.373
	1000	4.738	3.911	3.049	4.121	3.955	4.509	4.212	3.431	4.750	4.225
	0	6.548	5.161	5.361	4.945	5.504	6.159	4.359	4.233	4.379	4.782
50	500	7.030	5.931	6.085	5.987	6.258	6.764	5.209	5.863	6.093	5.982
	1000	6.875	6.278	4.893	5.653	5.925	4.828	5.944	5.310	4.908	5.248
	0	7.783	5.567	6.288	5.985	6.406	4.686	4.800	4.052	5.322	4.715
100	500	7.718	4.654	7.043	6.286	6.425	6.306	5.366	3.453	4.183	4.827
	1000	5.838	5.215	5.353	6.326	5.683	5.340	6.014	4.466	5.940	5.440
L.S.D 5%			N.S.			0.8834		N.S.			0.6753
						B means					B means
B	0	5.604	4.098	3.953	4.794	4.612	5.333	4.053	3.214	5.163	4.441
×	50	6.817	5.790	5.446	5.528	5.895	5.917	5.171	5.135	5.127	5.337
Cultivars	100	7.113	5.145	6.228	6.199	6.171	5.444	5.393	3.990	5.148	4.994
L.S.D 5%			N.S.			0.8853		N.S.			0.4706
						E means					E means
E	0	6.824	4.727	5.226	5.198	5.494	5.626	4.313	3.902	5.122	4.740
×	500	6.894	5.171	5.969	5.956	5.997	6.176	4.914	4.035	5.117	5.061
Cultivars	1000	5.817	5.135	4.432	5.367	5.188	4.892	5.390	4.402	5.200	4.971
L.S.D 5%			N.S.			0.3167		N.S.			N.S.
Cultivars means		6.512	5.011	5.209	5.507		5.565	4.872	4.113	5.146	
L.S.D 5%			0.4600					0.5605			

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